The Application of Palynology in Archaeology

A Case Study of Badalpur Site in Taxila

By

Attiya Malik

Taxila Institute of Asian Civilizations

Quaid-I-Azam University

Islamabad

2015

Acknowledgements

Firstly, special thanks to Allah Almighty, the benevolent, the merciful for giving me the strength, help and courage that enabled me to complete this task.

I would like to express thanks from the core of my heart for my supervisor, **Dr. Ghani-ur-Rahman,** Associate professor, Taxila Institute of Asian Civilization, Quaid-i-Azam University Islamabad. I have no words to admire for his able guidance, valuable advices, professional support, needed encouragement and intellectual stimulation, which I received throughout the duration of my research.

I am extremely thankful to Dr. M. Ashraf Khan, Dr. Rafiullah Khan, Dr. Sadeed Arif, my senior Abdul Basit and my friend Mehwish Bashir for encouragement and guidance during the research work.

I wish to thank all those, whom I cannot mention individually but their direct or indirect help during my research work is highly appreciated.

Thanks are also offered to assistant of the Palynology Laboratory for his immeasurable guidance in the development of new and more efficient methods of pollen extraction from archaeological sediments.

Last but not the least I would like to express my gratitude to my parents and other family members for their love, prayers, well wishes and complete support that motivated me to go my work in a best way.

May Allah shower His blessings upon everyone who assisted me at any stage during my work (Āmīn).

Attiya Malik

'To Be Yourself in a World That Is Constantly Trying To Make You Something Else Is the Greatest Accomplishment'

Ralph Waldo Emerson

My This Humble Effort Is Dedicated To My Beloved Family

&

Respected Teacher

Dr. Ghani-ur-Rahman

List of Figures

Fig 1.1: A Plate representing Natural Sciences 26

Fig 1.2: The orbitals of the hydrogen atom showing distributions of an electronic bond to a proton 28

Fig 1.3: Space Missions have been used to image distant locations within the solar system 29

Fig 1.4: Structuralal formula of the molecule of coffeine 30

Fig 1.5: Structure of a typical animal cell showing the various organelles 31

Fig 1.6: A fragment of DNA showing the chemical sequence of genetic instructions for the development and functioning of living organisms 32

Fig 1.7: Reconstruction of Cultural History 40

Fig 1.8: Reconstruction of Past life ways 41

Fig 1.9: The use and abuse of ethnographic analogy 41

Fig 1.10a, 1.10b: Modern or ancient, people have to dispose of their garbage 42

Fig 1.11: Flotation system used to recover ancient plant remains 48

Fig 1.12: Pollen grain of Morina persica of the teasel family 50

Fig 2.1: Frontispiece to a version of the expanded and illustrated Historia Plantarivm 60

Fig 2.2: A biomedical work by Ibn al-Nafis, an early adherent of experimental dissection who discovered the pulmonary circulation and coronary circulation 61

Fig 2.3: De arte venandi, by Frederick II, Holy Roman Emperor, was an influential medieval natural history text that explored bird morphology 62

Fig 2.4: The fruit of Myristica fragrans, a species native to Indonesia 70

Fig 2.5: A Sumerian harvester's sickle dated to 3000 BC 72

Fig 2.6: General structure of flowering plant 82

Fig 2.7: Plant Cell Structure 83

Fig 2.8: Chlorophyll 84

Fig 2.9: Chloroplasts 84

Fig 2.10: Process of Photosynthesis 85

Fig 2.11: Structure of flower buds 86

Fig 2.12: Plant species diversity 86

Fig 2.13: A poster with flowers or clusters of flowers 87

Fig 2.14: Diagram showing the parts of the flower 87

Fig 2.15a, 2.15b: The development sequence of a typical drupe 88

Fig 2.16a: Pollen of Lilium auratum showing single sulcus (monosulcate) 89

Fig 2.16b: Arabis pollen has three colpi and prominent surface structure 89

Fig 2.17a: Brown flax seeds 90

Fig 2.17b: Bean seed 90

Fig 2.18: Spores produced in a spore’s life cycle 90

Fig 2.19: Fossilized plants of the Pennsylvanian sub period of the Carboniferous period 93

Fig 2.20: Scanning electron microscope image of pollen grains 94

Fig 2.21: Drawings of Linear B tablets from Knossos showing saffron 101

Fig 2.22: Kamares Ware ceramic vessel from Knossos 102

Fig 2.23: Section of the Birds and Monkeys fresco 102

Fig 2.24: Late Bronze Age wine pressing assemblage at Vathypetro 103

Fig 2.25: Late Bronze Age stone mortar for pounding cereals at Gournia 103

Fig 2.26: Base Ring Ware juglet from Enkomi 104

Fig 3.1: Pollen under Microscope 114

Fig 3.2: Tip of a tulip stamen with many grains of pollen 119

Fig 3.3a, 3.3b: Structure of Pollen Grain 120

Fig 3.4: Cell wall of Pollen grain 121

Fig 3.5: Various types of microscopically of pollen grains 122

Fig 3.6: Spectrum of possible pollen types 123

Fig 3.7a, 3.7b and 3.7c: Vesiculate pollens 124

Fig 3.8a, 3.8b: Trilete 125

Fig 3.9a, 3.9b, 3.9c and 3.9d: Inaperturate pollens 125

Fig 3.10a, 3.10b and 3.10c: Monolete 126

Fig 3.11a, 3.11b and 3.11c: Monocolpate pollens 126

Fig 3.12a, 3.12b and 3.12c: Monocolpate pollens 126

Fig 3.13: Tricolpate Pollens 127

Fig 3.14a, 3.14b, 3.14c and 3.14d: Stephanocolpate Pollens 127

Fig 3.15a, 3.15b and 3.15c: Heterocolpate: Pollens 127

Fig 3.16a, 3.16b, 3.16c and 3.16d: Syncolpate pollens 128

Fig 3.17a, 3.17b, 3.17c, 3.17d and 3.17e: Syncolpate pollens 128

Fig 3.18a, 3.18b and 3.18c: Syncolpate pollens 128

Fig 3.19a, 3.19b, 3.19c: Triporate, psilate (smooth) pollens 129

Fig 3.20a, 3.20b, 3.20c, 3.20d and 3.20e: Triporate, with Vetibulum pollens 129

Fig 3.21a, 3.21b: Triporate, baculate and clavate, them forming reticulum pollens 129

Fig 3.22a, 3.22b: Stephanoporate pollens 130

Fig 3.23: Periporate pollens 130

Fig 3.24a, 3.24b and 3.24c: Periporate, scabrate (scab-like) pollens 130

Fig 3.25a and3.25b: Periporate, echinate pollens 131

Fig 3.26a, 3.26b and 3.26c: Periporate, echinate pollens 131

Fig 3.27a and 3.27b: Tricolporate Pollen 131

Fig 3.28a and 3.28b: (Spikes) Trizonocolporate 131

Fig 3.29a, 3.29b and 3.29c: RETICULATE (Cavities) Trizonocolporate 132

Fig 3.30a, 3.30b and 3.30c: SCABRATE Trizonocolporate 132

Fig 3.31a, 3.31b and 3.31c: Striate (Roughly Parallel Elongation) Trizonocolporate 132

Fig 3.32a and 3.32b: Stephanocolporate Pollens 133

Fig 3.33a, 3.33b, 3.33c and 3.33d: Fenestrate pollens 133

Fig 3.34a and 3.34b: Polyad: Pollen 133

Fig 3.35: Cleaning the trowel between samples 151

Fig 3.36: Preparing to the samples; note and labeled whirl packs 151

Fig 3.37: Collection of soil sample from Archaeological site 152

Fig 3.38a and 3.38b: Palynological Laboratory 153

Fig 3.39: Chemicals for Extraction of Pollens 153

Fig 3.40a and 3.40b: Microscopic Pollen by extraction techniques 154

Fig 3.41: Sodium Hexametaphosphate and Ethylenediaminetetraacetic acid (EDTA) 155

Fig 3.42a and 3.42b: Sodium polytungstate and acetylated used for the flotation process 155

Fig 3.43a and 3.43b: Different Pollen Species under Microscope 156

Fig, 3.44a and 3.44b: Microscopic analysis of Pollen slides 157

Fig 3.45: Counting technique 157

Fig 3.46a, 3.46b and 3.46c: Different Genus size of Pollen within the same family 158

Fig 4.1: Recent Excavation in Badalpur Site 168

Fig 4.2a, 4.2b: Recent Excavation in Badalpur Monastery (Different Trenches) 169

Fig 4.3a, 4.3b: Researcher collecting pollen sample 171

Fig 4.4: Sealed and labeled whirlpak bag 172

Fig 4.5a, 4.5b: Two samples from BP -15, T.No.Y- 15, and Layer- 1 173

Fig 4.6a, 4.6b: Two samples from BP -15, T.No.Y- 16, and Layer- 1 173

Fig 4.7a: Three samples from BP -15, T.No. Z-15, Layer- 1 174

Fig 4.7b: Three samples from BP -15, T.No.Z- 15, Layer- 2 174

Fig 4.8a, 4.8b: One sample from BP -15, T.No.Z- 16, Layer- 1 174

Fig 4.9a, 4.9b: Two samples from BP -15, T.No.Y- 14, Layer- 2 175

Fig 4.10a, 4.10b: One sample from BP -15, T.No.X- 15, Layer-1 and One from Layer-2 175

Fig 4.11a, 4.11b: Pollen Analysis in Laboratory 178

Fig 4.12a, 4.12b: Chemicals like hydrofluoric acid and hydrochloric acid 179

Fig 4.13a, 4.13b: Researcher used chemicals and water to neutral the sample 179

Fig 4.14: Laboratory Chemicals 180

Fig 4.15: Steps of Slide Preparation 181

Fig 4.16a, 4.16b: Slide Preparation for Observation 182

Fig 4.17: Scanned pollen slides 182

Fig 4.18: Scanned pollen grains under microscope 182

Fig 4.19a, 4.19b: Amaranthaceae (Achyranthus aspera L) 185

Fig 4.20: Achyranthus aspera L Linn pollen under Electron Microscope 185

Fig 4.21a, 4.21b: Caesalpiniaceae (Cassia fistula Linn) 186

Fig 4.22a, 4.22b: Cassia fistula Linn pollen under Electron Microscope 186

Fig 4.23a, 4.23b: Combretaceae (Quisqualis indica Linn) 187

Fig 4.24a, 4.24b, 4.24c, 4.24d, 4.24e and 4.24f:

Quisqualis indica Linn pollen under Electron Microscope (Family Combretaceae) 187-188

Fig 4.25a, 4.25b, 4.25c: Euphorbiaceae (Jatropha curcas Linn) 188

Fig 4.26a, 4.26b, 4.26c and 4.26d: Jatropha curcas Linn pollen under Electron Microscope (Family Euphorbiaceae) 189

Fig 4.27a, 4.27b: Lythraceae (Lagerstroemia indica Linn) 189

Fig 4.28a, 4.28b, 4.28c and 4.28d: Lagerstroemia indica Linn pollen under Electron Microscope (Family Lythraceae) 190

Fig 4.29a, 4.29b: Malvaceae (Hibiscus rosa-sinensis Linn) 190

Fig 4.30a, 4.30b, 4.30c, and 4.30d: Hibiscus rosa-sinensis Linn pollen under Electron Microscope (Family Malvaceae) 191

Fig 4.31a, 4.31b: Mimosaceae (Acacia nilotica (Linn.)Delile) 192

Fig 4.32a, 4.32b, 4.32c: Acacia nilotica (Linn.)Delile pollen (Family Mimosaceae) 192-193

Fig 4.33a, 4.33b: Poaceae (Imperata cylindrica (Linn.)) 193

Fig 4.34a, 4.34b, 4.34c, and 4.34d: Imperata cylindrica (Linn.) pollen under Electron Microscope (Family Poaceae) 193-194

Fig 4.35a, 4.35b: Plantaginaceae (Plantago lenceolata L) 194

Fig 4.36a, 4.36b: Plantago lenceolata L pollen under Electron Microscope 195

Fig 4.37a, 4.37b: Rosacea (Rosa indica Linn) 195

Fig 4.38 a, 4.38b: Rosa indica Linn pollen under Electron Microscope (Family Rosaceae) 196

Fig 4.39a, 4.39b: Rubiaceae (Ixora coccinea Linn) 196

Fig 4.40a, 4.40b: Ixora coccinea Linn pollen under Electron Microscope 197

Fig 4.41a, 4.41b: Rutaceae (Murraya koenigii (Linn.) 197

Fig 4.42a, 4.42b: Murraya koenigii (Linn.) pollen under Electron Microscope 197

Fig 4.43a, 4.43b: Solanaceae (Solanum americanum Mill) 198

Fig 4.44: Solanum americanum Mill pollen under Electron Microscope 198

Fig 4.45: Violaceae (Viola canescens Wall) 199

Fig 4.46: Viola canescens Wall pollen under Electron Microscope (Family Violaceae) 199

Fig 4.47: Zygophyllaceae (Tribulus terrestris L. (Bhakra) 200

Fig 4.48: Tribulus terrestris L. (Bhakra) pollen under Electron Microscope 200

Fig 4.49a, 4.49b, 4.49c, 4.49d, 4.49e, 4.49f: A- *Ageratum conyzoides* (Polar view -1000x), B- *Convolvulus arvensis* (Polar view - 400x), C-*Parthenium hysterophorus* (Polar view – 1000x), D- *Saussuria heteromala* (Equatorial view – 400x), E- *Boerhaavia procumbens* (Polar view – 400x), F- *Tribulus terrestris* (Polar view – 400x) 211

List of Tables

Table 0.1: Different Terminologies of Palynology as an archaeological tool 3

Table 0.2: Flow Chart showing the journey of research 13

Table 1.1: Flow List representing different types of Archaeology 17

Table 1.2: Flow Chart of the Branches of Natural Science 25

Table 1.3: Flow Chart showing the relation of Archaeology with Social Sciences 33

Table 1.4: Flow Chart showing the relation of Archaeology with Natural Sciences 35

Table 2.1: Flow Chart showing the sub branches of Natural Science 53

Table 2.2: A Flow Chart that illustrates scientific investigation 56

Table 2.3: Showing the relationship of Biology with other disciplines 63

Table 2.4: Show the relation between Biology with other branches of science 64

Table 2.5: Showing the three main branches of Biological Sciences 66

Table 2.6: Circle Chart showing the sub branches of Biology 66

Table 2.7: Flow Chart showing branches of archaeology with special focus on sub-branches of Environmental Archaeology 69

Table 2.8: Flow Chart showing the branches of Botany 78

Table 2.9: Flow Chart of biological classification 81

Table 3.1: Flow Chart of Pollen Analysis 153

Table 4.1: Chart show the Soil Samples from Different Trenches of Badalpur site 176

Table 4.2: List of Pollen Morphology of the Identified Species from a Gandharan Archaeological Site (Badalpur) 201

Table 4.3: Flow Chart of Pollen Morphology (Shapes and Class) of Plants Species 202

Abstract

The main objective and aim of this research under the title 'The Application of Palynology in Archaeology: A Case Study of Badalpur Site in Taxila', is to establish the relationship and bond between Botany and Archaeology by using analytical, quantitative, qualitative and experimental methods. It will explain from the detailed introduction of Archaeology and Botany till developing the relationship between them then discuss about ancient pollens, ancient DNA, Dendrocronology and finally termed as palynological archaeology. It will also investigate the features of pollen grains from ancient Gandhara sites through excavation and evaluate the significance of this investigation in systematic and perspective. This scientific research includes its characteristics and experimental techniques in Palynological Laboratory that applied on the pollens from an archaeological site. The researcher used soil sample from archaeological site for pollen analysIs. Soil samples were collected from an archaeological site (Badalpur, Taxila) to evaluate pollen morphology and types of pollen presence in soil. Strandard methods were used for the treatment of soil samples and slides were prepared. The result indicated total 47 pollen taxa in the soil sample belonging to 15 families and 12 genera. The purpose of this research is thus to investigate the features of pollen grains from the ancient Gandhara site (Badalpur) and the comparison of Gandhara period plants with the existing plants and investigate the agriculture evolution in Gandhara. The change of climate patterns can be determined by pollen analyses of the soil. The investigational palynological research will contribute in the meadow of archaeology and towards the conversion of traditional archaeology into "Experimental Archaeology".

CONTENTS

Acknowledgments ii

List of Figures v

List of Tables xii

Abstract xiii

Introduction ` 1

Review of Literature 5

Statement of the Problem 8

Hypothesis 9

Aims and Objectives of the Study 9

Significance of Study 10

Methodology 11

CHAPTER: 1. Bond between Archaeology and Natural Sciences 14

Types of Archaeology 15

Archaeology as a Science 23

Archaeology and the Other Sciences 24

Bond between Archaeology and Natural Sciences 25

Relationship between Archaeology with Social and Natural Sciences 32

The Basic Goals of Archaeology in Natural Sciences 39

Role of Natural Sciences in Archaeology 43

CHAPTER: 2. Application of Botany in Archaeology 53

Biological Science 54

History of Biological Sciences 56

Relation of Biology with other Sciences 63
Branches of Biological Sciences 65
Botany 70
History of Botany 71
The Leading Branches of botany 76
Taxonomy 80
Core concepts of botany 81
Kinds of plants 91
Application of Botany in Archaeology 92
Archaeobotany or Palaeobotany 106
Aims and Objectives of Archaeobotany 111
CHAPTER: 3. Palynological Archaeology **113**
Introduction 113
Palynology 114
A Brief History 116
Define Pollen 119
Spectrum of possible pollen types 123
Applications and uses of Palynology 134
Palynological Archaeology 135
The Role of Palynology in Archaeology 138
History of Palynological Applications to Archaeology 138
Pattern of Pollen Analysis 147
Sampling Methods 149
Data Analysis 152
Observation under Microscope 156

Previous Studies about Archaeological Palynology 158

CHAPTER: 4. Pollen Analysis from Archaeological Perspective 165

Researcher Field Work 165

Overview of Gandhara Regions 165

Badalpur Site in Taxila 166

Recent Excavation in Badalpur Site 168

Stratigraphy 170

Chronology 170

After Excavation: Pollen Analysis 171

Some Precautions during Sampling 171

Collection of soil sample from different Trenches across the Badalpur site 173

Table of the Soil Samples from Different Trenches of Badalpur site 176

Palynological Laboratory 177

Experimental Techniques for the Pollen Analysis from the Archaeological Soil 177

Materials and Methods 178

Chemical Extraction of pollen samples 178

Preservation of pollen sample 181

Microscopic analysis 181

Experimental Results 183

CHAPTER: 5. Discussion 203

Present existing cultivated plants in Taxila, Punjab 203

Palynomorph and Morphology of the recent cultivated plants in Taxila valley 204

Conclusion 212

Bibliography 214

Introduction

Archaeology is a study of past civilizations, primarily through the recovery and analysis of the material culture and environmental data left behind that includes artifacts, architecture, biofacts (animal bones, plant remains) and cultural landscapes. Archaeology studies human history from the development of the first stone tools in eastern Africa 3.4 million years ago uptil recent decades. Archaeology has various goals, which range from studying human evolution to cultural evolution and understanding cultural history. The purpose of Archaeology is to learn more about past societies and the development of the human race. Over 99% of the history of humanity has occurred within the prehistoric cultures, which did not make use of writing, thereby not leaving written records about themselves that we can study today. Without such written sources, the only way to learn about prehistoric societies is to use Archaeology. Archaeology is basically about three things: objects, landscapes and what we make of them. It is merely the study through material remains (Gamble 2001: 15). The word Archaeology comes from the Greek word ‘arkhaiologia’ which means “discourse about ancient things”, but presently it has come to mean the study of the human past through the material traces of it that have survived (Bahn 1996: 2).

Archaeology as a scientific discipline came into existence in the last part of the 20th century that is broadly defined as the application of scientific principles and methods to the characterization of materials that are related to cultural heritage. As with most academic disciplines, there are a number of Archaeological sub-disciplines typically characterized by emphasis on a specific method or type of material, geographical or chronological focus, or other thematic concern. Social Anthropology, History and Science are the disciplines which are strongly allied to the practice of archaeology such as: Anthropology focuses on culture and ethnic data (how people interact everyday); History focuses on past context; Zoo archaeology, study of animal remains; while Archaeobotany focuses on plant fossils such as pollens and spores (Schiffer and Brian 2013).

Historically, all living things were classified as either animals or plants, where Zoology covers animal kingdom and Botany covers the study of all organisms not considered animals. Botanists examine both the internal functions and processes within plant organelles, cells, tissues, whole plants, plant populations and plant communities. At each of these levels, a botanist may be concerned with the classification (Taxonomy), phylogeny and evolution, structure (Anatomy and Morphology), or function (Physiology) of plant life. Botany is a natural science concerned with the study of plants. It is the branch of Biology, also called Plant Sciences or Plant Biology. The term “Botany” comes from the Ancient Greek word βοτάνη (*botanē*) meaning “pasture”, “grass**”** or **“**fodder. Nowadays, Botanists study approximately 400,000 species of living organisms of which some 260,000 species are vascular plants and about 248,000 are flowering plants. Botany originated as Herbalism, the study and use of plants for their medicinal possessions. The early recorded history of Botany includes many ancient writings and plant classifications. Examples of early Botanical works have been found in ancient texts from India dating back to a period before 1100 BC, in Archaic Avestan writings and in works from China before it was unified in 221 BC. Botany originated in pre-history as Herbalism with the efforts of early humans to identify – and later cultivate – edible, medicinal and poisonous plants, making it one of the oldest branches of science. Medieval physic gardens (herb garden with medicinal plants), Botanical gardens developed from them. Often attached to the monasteries are plants of medical importance (Stopes 1912: 54).

Modern Botany is a broad, multidisciplinary subject with inputs from most other areas of science and technology. Research topics include the study of plant structure, growth and differentiation, Reproduction, Palynology, Dendrochronology, Biochemistry and primary metabolism, chemical products, development, diseases, evolutionary relationships, systematic, and plant taxonomy. Dominant themes in 21st century Plant Science are molecular genetics and epigenetic, which are the mechanisms and control of gene expression during differentiation of plant cells and tissues (Smith 1978:16). Botanical research has diverse applications in providing staple foods and textiles, in modern horticulture, agriculture and forestry, plant propagation, breeding and genetic modification, in the synthesis of chemicals and raw materials for construction and energy production, in environmental management, and the maintenance of biodiversity.

The leading branches of Botany (also referred to as "Plant science") are commonly divided into three groups:

- The first group includes core topics, concerned with the study of the fundamental natural phenomena and processes of plant life, the classification and description of plant diversity, such as Paleobotany, Palynology etc.
- The second group covers applied topics which study the methods in which plants may be used for economic benefit in horticulture, agriculture and forestry.
- The third group includes topics about organism which focus on plant groups such as algae, mosses or flowering plants.

In the group of Core topics we study several features of the natural phenomena and processes of plant life such as, Paleobotany, Palynology etc. Plant responses to climate and other environmental changes can inform our understanding of how these changes affect ecosystem function and productivity. For example, plant phonology can be a useful proxy for temperature in historical climatology, and the biological impact of climate change and global warming. Palynology is the analysis of fossilized pollen deposits in sediments from thousands or millions of years ago (Martin 1919: 97).

Palynology is an independent science that studies polymorphs such as pollen acritarchs, spores, din flagellate cysts, scolecodons and chitinozoans, along with POM (Particulate Organic Matter) found in different archaeological sites. Palynology is the science that studies fossil pollen and other palynomorphs (tiny organic-walled micro-fossils). Palynology has its origin from Greek word “Palynein” meaning “to scatter” like flour or dust, as pollen does. The pollen and spore is the single cell and carried within it a minute quantity of protoplasm, Pollen grains are the minute male reproductive organs of flowering plants. Pollen is defined as the multinucleate reproductive micro-gametophyte of seed vegetation. They are enclosed in a microscope wall. The pollen of each species has a distinct and unique microscopic structure. Archaeologist fined fossilized pollen, generally indentified by its shape and apertures. This characteristic enables palynologists (scientists that study and analyze pollen and spores) to identify the various plants that occur on archaeological sites. Palynology entails a set of techniques for the extraction of pollen and spores. These techniques enable us to identify to which family, genus or species levels the pollen or spores belong. The plant must produce a huge amount of extra pollen, called pollen rain, is eventually deposited on the ground where, if conditions are favorable, it may persist for thousands of years (Bhutta 1968:30-36).

Palynology, is a type of environmental archaeology in which microscopes are used to analyze the range of plant pollens present in archaeological layers: these can tell us what crops, vegetation or ground cover were likely to have been present when a layer was deposited. Archaeological palynology is the study of pollen, the virtually indestructible, microscopic, but easily identifiable plant parts in archaeological sites. Pollen is one of several types of plant residues which have been retrieved from archaeological sites, either clinging to the inside of pots, on stone tools or within archaeological features such as storage pits or living floors. When identified to species, archaeological pollen can be used to identify clues to prehistoric climate (what kind of plants grew in the neighborhood of a given site) and diet (what kind of plants were consumed at a given site).

The focus of this study is to use Palynology as an archaeological tool. Archaeological Palynology has developed somewhat independently in different nations during the mid- twentieth century, so terminologies and emphases vary. Its various aspects are summarized below as:

Diagram by the researcher

Table 0.1: Different Terminologies of Palynology as an archaeological tool

- **Quaternary Palynology**

This branch of archaeological palynology focuses on the influence of vegetation and climate change on human behavior and demographic patterns in addition to the effect of humans on the environment.

- **Archaeopalynology**

This term, primarily refers to the palynological study of human impact on the environment. Pollen analysis of lakes and bogs may be used to study humans as agents of vegetation change rather than causes such as climate.

- **Environmental Archaeology**

As used here, this term refers to the study of sediments of archeological sites, particularly soils. In Britain, it is a general term for the application of Palynology and other geological methods to archaeological settings.

- **Archaeological Palynology**

Archaeological Palynology is a branch of Archaeobotany - applying Botanical and Paleo-botanical techniques to archaeological investigations. It is characterized by the analysis of artifacts, features, and coprolites from archeological sites as well as stratigraphic study of its sediments (Bryant, JR and Holloway 1983:191).

Palynology has its application in Archaeology in the analysis of spores, pollen and other palynomorphs from archaeological sites is an attempt to reconstruct ancient diets, funeral practices, the function and use of discovered artifacts, the source of raw materials for tools or food consumption, the use of natural topography and artificial landscape changes, the domestication and cultivation of food plants, and the study of human impact on the ancient environment. Pollen grains are distinctive to each plant species and sub-species, and their tiny and dense structure mean that they survive well in many soil types for thousands of years. Pollen analysts (palynologists) extract pollen from soil that has been excavated or removed from the ground in auger-cores. Each layer of soil is analyzed separately. Radiocarbon dating is commonly used to date these layers so that the changing pollen presence over time can be measured. Pollen collected from an archeological site can provide insights into what the overall environment was like at the time the site was occupied and how area vegetation changed through time. Samples can be derived both from cultural and non-cultural settings when reconstructing plant communities. However, pollen outside the wet bogs is generally poorly preserved.

The soil is mixed with water and placed in a centrifuge (a machine that spins it very fast). This separates the lighter pollen from the heavier soil. Individual grains are then identified and counted. Grass, wood, cereal and weed pollens all have a story to tell about past land use-forest clearances, cultivation and abandonment can all be identified in this way. When combined with other types of archaeological evidence such as settlements or field systems, pollen evidence can be extremely informative.

Usually, the goal of Palynology is to reconstruct the probable character of local plant communities in the historical past, as inferred from the abundance of plant species in dated potions of the pollen record. Palynology is a very important tool for interpreting historical plant communities, and the speed and character of their response to changes in environmental conditions, especially climate change. Pollen analysis is also useful in archaeological and ecological reconstructions of the probable habitats of ancient humans and wild animals, and in determining what they might have eaten. Pollen analysis is also sometimes useful in exploration for resources of fossil fuels.

The present researcher used chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is lower than in peat. Techniques to evaluate microfossils have been applied to bulk samples of soil, sediment and also to residues extracted from wooden, stone or ceramic artifacts and teeth among others (Denham 2009: 2-3). The discipline of Archaeobotany requires a serious take on the duration and collection of samples, both macro-botanical assemblages and microfossils (Jansonius and McGregor 1996:23-25).

Review of Literature

The study of plant remains was started three decades ago. There are much observation and interpretation about them written by different natural and social scientists. A lot of literature as a secondary source is given below which are related to the research:

The article "*Palynological study of soil sample*" written by G.Khola and U.Hanif deals with the types of pollen present in soil or either they belong to vegetation of the same area or somewhat migrated. This article played a vital role in the identification and delimitation of various taxa. This variation would prove as taxonomic criteria in the classification of plant species (Khola and Hanif 2012).

The Role of Palynology in Archaeology is written by Vaughn M. Bryant and Richard G. Holloway describes the primary objective of archaeological investigation is to reconstruct and explain as fully as possible mechanisms and directions of prehistoric culture change. The introductive chapter discusses the careful analysis of other sources of information-such as plant macro-fossils (seeds, leaves, bark, flowers, and wood), animal remains (bones, hair, tooth, and shells), soil chemistry, charcoal identification, and pollen-the archaeologist is able to speak more confidently about many aspects of past cultures. Pollen analysts working primarily in the field of Archaeology collect pollen samples and the various ways that pollen data are useful in archaeology (Bryant, and Holloway 1983).

Archaeology: written by Paul Bahn is a short introductory book of archaeological basic concepts that is very useful for this research (Bahn 1996).

'*Archaeology:* The Basics' is written by Clive Gamble. In this book the writer has described basic concepts of Archaeology (Gamble 2001).

The Report *"Pollen and Macro floral Analysis of Bulk soil samples*" written by Kathryn Puseman and Linda Scott Cummings, discusses the methods of Pollen chemical extraction technique based on flotation is the standard preparation technique used in this laboratory for the removal of pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils (Puseman and Cummings 2009).

Archaeological Palynology written by Vaughn M. Bryant, and Stephen A. Hall describes sampling, processing, counting, preservation and interpretation. In this report, the authors present guidelines for researchers seeking pollen analyses, recommend the kinds of observations palynologists should make on their samples and suggest ways of determining when samples should be considered invalid for paleoethnobotanical interpretations or paleoenvironmental reconstructions (Bryant and Hall1993).

'*A History of Archaeological Thought*' written by Bruce G. Trigger. This book was the first ever to examine the history of archaeological thought from medieval times to the present in world-wide perspective. This book discusses the original work and introduces new archaeological perspectives and concerns (Trigger 2006).

The Palynology of Archaeology sites is written by G.W. Dimbleby. This book is based on the use of palynology in archaeological investigations (Dimbleby 1985).

Palynology: written by Kashinath Bhattacharya deals with all the aspects of palynology encompassing most recent information and highlighting the organizational development of palynology (Bhattacharya 2011).

Palynology, principles and applications written by J. Jansonius and Duncan Colin McGregor deals with the introduction and basic principles of palynology (Jansonius and McGregor 1996).

An International Journal*: Review of Palaeobotany and Palynology* written by H. Kerp, M. Stephenson deals with all groups, ranging from marine palynomorphs to higher land plants. The journal especially encourages the publication of articles in which Palaeobotany and Palynology are applied for solving fundamental geological and biological problems as well as innovative and interdisciplinary approaches (Kerp and Stephenson 2014-2015).

Archaeobotany of the Late Woodland is written by Kathleen A. Furgerson. This Archaeobotanical analysis provided a wealth of information concerning the dietary patterns practiced by the Late Woodland and Contact Period inhabitants of the site. While interpretations of the data were limited by sampling issues, the assemblage indicates the site's inhabitants practiced a diverse subsistence economy based on gathering of wild plants and cultivation of domesticated plants (Furgerson 2007).

'Field Archaeology: an introduction' writtenby Peter L. Drewett, discusses about different tyes of field methods which are used in archaeology (Drewett 1999).

'Field Archaeology: An Introduction' is written by William S. Dancey. It is about some basic field methods in archaeology (Dancey 1981).

The article *"Recent Research in Paleoethnobotany*" written by Christine A. Hastorf1, discusses paleoethnobotanical research and results presented in the recent literature. Although Archaeobotany is a fairly recent addition to the study of the past, it now encompasses a diverse range of techniques, analysis, and new results. In this article, the study of microbotanical remains has expanded greatly and includes pollen, phytolith, chemical, and molecular analyses (Hastorf1 1999).

In a paper"The study of Archaeobotanical remains written by Anwar A-Magid, a modest attempt is made to initiate a debate on the current theory, methodology and objectives of the study of archaeological plant remains with special emphasis on issues relevant to Archaeology and archaeological research on ancient plant remains. The paper also includes some suggestions (that are open to discussion) on prospective contribution of archaeobotanical research to applied science, and hence the needs of the contemporary world (Magid 1989).

Ethnopalynological Application in land and water based Archaeology written by Dawn Marie Marshall. Palynological applications to Archaeology are myriad depending on the research question(s), the context of the samples and the research methodologies employed (Mashall 2007).

Botany for agriculture students, written by John Nathan Martin deals the fundamental principles of Botany with emphasis upon the practical application of these principles. The subject matter is presented in two parts, part I being devoted to the study of the structures and functions chiefly of Flowering Plants, and Part II, to the study of the kinds of plants, relationships, Evolution, Heredity, and Plant Breeding (Martin 1919).

Botany: the Modern Study of Plants **is written by** Marie Stopes. This textbook is a short introduction to the fundamental principles of modern botany (1912 edition). From the contents: Morphology, Anatomy, Cytology, Physiology, Ecology, Paleontology, Plant Breeding, Pathology, and Systematic Botany (Stopes 1912).

The Molecular Biology of Plant Cells **written by** H. Smith, covers the basic cellular physiology, biochemistry and genetics of plant cells, but does not deal with metabolic pathways, or with the physiology and biochemistry of the intact plant (Smith 1978).

The Archaeology of Science written by **Schiffer,** Michael Brian discusses the scope of the archaeology of science and furnishes a conceptual foundation and research strategies that contribute to the archaeology of science (Schiffer and Brian 2013).

Bioarchaeology: written by **Martin**, Debra L., **Harrod,** Ryan P., **Pérez** and Ventura R. Bioarchaeology is the analysis of human remains within an interpretative framework that includes contextual information. This comprehensive and much-needed manual provides both a starting point and a reference for archaeologists, bioarchaeologists and others working in this integrative field. The authors cover a range of bioarchaeological methods and theory. This book integrate theoretical and methodological discussion with a wide range of field studies from different geographic areas, time periods, and data types, to demonstrate the full scope of this important field of study (Martin,RyanP,Perez and Ventura 2013).

Introduction to Environmental Archaeology written by Elizabeth J. Reitz, Myra Shackley is concerned with the applications of scientific methods to support broad interpretations of long-term changes in both human behaviors and the environments within which they occur (Reitz and Shackley 2012).

Statement of the Problem

Archaeology yields information and develops theories about past human activity by means of a study of ancient materials remains. Important archaeological information can be obtained by the investigations of botanical material (plant remains). In this way Botany skills are essential to archaeological investigations. Archaeobotany investigates the relationship between humans and the plant world in the past by analyzing plant remains recovered from archaeological contexts. It is a field of environmental archaeology which studies the relationship between the natural environment and human culture development in the past using input from archaeology, natural sciences, ethnography and history.

Archaeological evidence indicates that the entire domestication syndrome did not suddenly appear when people began to cultivate plants. Rather, different aspects of the syndrome evolved in response to the new ecological conditions of early cultivation. But there is no such surprising combination of Botany and Archaeology to reduce the traditional way of human past study. There are lots of weaknesses in traditional process of human past study and due to which numerous significant archaeological information could not be obtained. Published work about application of palynology in archaeology is scattered in nature or not enough therefore much more work remains to be done. The proper research has not yet been done on the agriculture evolution of Gandhara due to lack of researchers and laboratories in Pakistan. In Pakistan there are no laboratories associated with museums and archaeological institutions. During the early developmental phase, it suffered because of:

(1) Inadequate communication between botanically-oriented palynologists and field archaeologists.

(2) Differences in conceptual orientation between archaeologists and archaeological palynologists and archaeology is more often associated with the discovery of tombs, temples, and palaces than with plants.

(3) The study of fossilized pollen from archaeological sites often had been incorporated into final reports only as appendices.

(4) A growing number of studies on the fossilized pollen remains of archaeological sites were published almost exclusively in "contract type" reports where the number of printed copies was limited and distribution is restricted.

(5) Sophisticated, statistical techniques had not been applied to fossilized pollen data from archaeological sites.

Hypothesis

The comparative study of Gandhara period plants with present existing plants will reveal the agriculture evolution in Gandhara. The investigational palynology will contribute in the meadow of archaeology and towards the conversion of traditional archaeology into “Experimental Archaeology”.

Aims and Objectives of the Study

As no Palynological research work has been done for domesticated plants and agriculture of Gandhara civilization in Pakistan, so in view of this fact the present researcher decided to study palynologically, the ancient plants occurring of Gandhara region in Pakistan with the following aims and objectives:

1. To investigate the features of pollen grains from ancient Gandhara sites through excavation and evaluate the significance of this investigation in systematic and perspective.
2. Statistical analysis of different morphometric features of ancient pollens and its application for circumscription of taxa at different levels of taxonomic hierarchy.
3. Some of the specimen were tried to investigate under Scanning Electron Microscope (SEM).
4. Comparison of Gandhara period plants with present existing plant and to investigate the agriculture evolution in Gandhara

Significance of Study

The research focus on the interdisciplinary collaboration between Botany and Archaeology. It forms a more coherent bond between these two disciplines. This disciplinary research places Asrchaeology in the modern sciences. Additionally the Significance and scope of this research is:

- Palynology has its application in archaeology in the analysis of spores, pollen, and other palynomorphs from archaeological sites in an attempt to reconstruct ancient diets, funeral practices, the functions and use of discovered artifacts, the source of raw materials for tools or food consumption, the use of natural topography and artificial landscape changes, the domestication and cultivation of food plants. And the study of human impact on the ancient environment.
- In palynology, the analysis of artifacts, coprolites, soil and rock on archaeological sites, in search of microfossils of pollen and other palynomorphs, is helping archaeologists to investigate the intimate inter-relationship between humans and their ancient environments that may be helpful for modern societies that are rapidly outgrowing their own environments.
- The researcher used soil sample from archaeological sites for the pollen analyses. The change of climate patterns often can be determined by pollen analyses of the soil, especially the soil of Badalpur Gandhara sites.
- As the vegetation changes, so does the pollen that is deposited. Thus, the vegetation changes are recorded in the different layers. By analyzing different layers, different pollens will be found. Any climate change can be determined by comparing the pollen found in the layers to the climate in which those plants occur.
- Archaeological palynology provided data concerning what plant species were introduced and how prehistoric groups altered the equilibrium of the natural vegetation by clearing the forest.
- Before considering the archaeobotanical data, we must have in mind a framework for assessing changes. The ‘domestication syndrome’ provides such a framework by highlighting a set of characters that differ between domesticated crops and their wild

ancestors These characters can be related to different aspects of cultivation in terms of what causes them to evolve.

- With the use of biochemical and genetic tests to identify wild plant species and domesticated species ancestral to the early and the now existing cultivars; by using of these tests, reconstruction of different forms of economic activity (construction, commerce, seasonality of occupation and some of the economic activities, healing, in worship; how the plant foods were obtained and consumed, methods of animal husbandry) and studies made of the impact of taphonomic processes and methods of sample-taking on interpretation possibilities

Methodology

The research is cross-disciplinary with comparative investigation of Botany and Archaeology. In this research primary and secondary sources have been used.

Primary Sources:

The researcher has applied experimental palynological archaeology. Pollen analysis methods has been used and also an electronic pollen detection method using Coulter counting principle for experiment as a primary source. Primary sources include field work, observations, interpretations and photography.

Secondary Sources:

Secondary resources have been acquired from articles, seminars, online database, relevant books, journals and other relevant theses.The researcher has used the following different experimental methods for the analysis of ancient pollen samples.

- **Quantitative method**

Quantitative methods place greatest reliance on representing developments numerically. Numerical data, of many types, are useful in thinking about longer-term developments, and this type of research methods requires quantifiable data involving numerical and statistical explanations.

- **Qualitative method**

This type of research methods involves describing in details specific situation using research tools like interviews, surveys and Observations.

1. Predictive methods

Predictive methods are primarily those that envisage a single future considered most likely, whether this future is desirable or not on the basis of hypothesis. To this extend, a deterministic method may or may not be normative. The methods stemming from the forecasting and from the planning schools of thought are mostly predictive.

2. Meta-Analysis

This research method is useful for finding out the average impact of several different studies on a hypothesis.

3. Experimental Method

Experimental research is conducted mostly in laboratories in the context of basic research. The principle advantage of experimental designs is that it provides the opportunity to identify unknown specimen and sample. The researcher having following experiments in its own research:

➢ Collection of sample

The first step in quantitative analysis is to acquire the sample. The researcher has acquired number of soil sample from the archaeological sites for the extraction of ancient pollens. These samples were labeled and placed in sample bags.

➢ Procedure for isolation of pollen

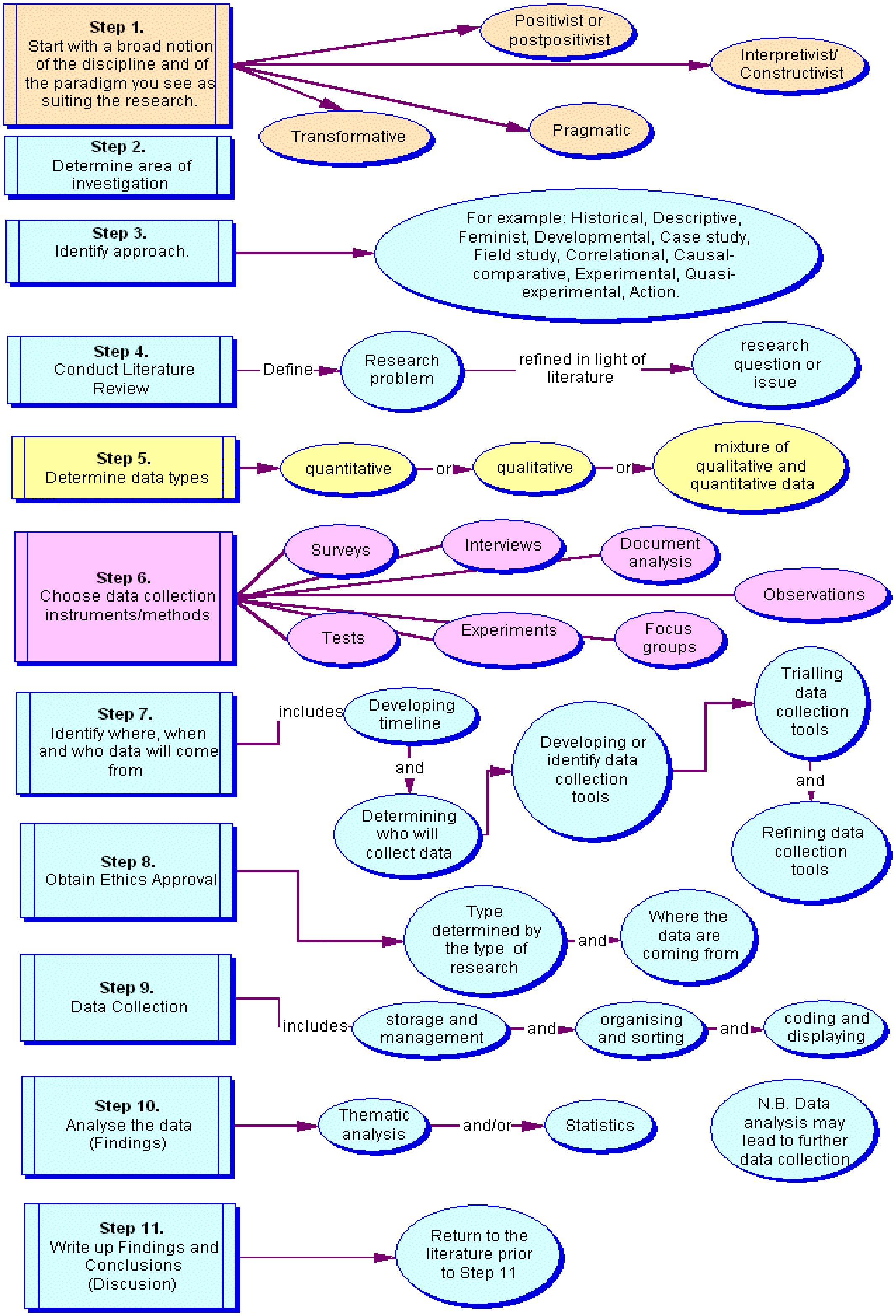
Samples were extracted from archaeological sites of taxila and then pollen separated from soil and other organic matter with slight modification of some chemicals such as HF or HCl and KOH. A method for detecting and counting pollen particles based on Coulter counting principle is presented. This approach also provides information on the size and surface charges of the micro particles, allowing for preliminary differentiation of pollens from other micro particles. Chemical extraction of pollen samples was conducted at the Palynology Laboratory.

➢ Preparation of slide

The researcher has eliminated all impurities from the unknown sample and prepared a slide by using Glycerin jelly and Safranine.

➢ Microscopic Observation

Prepared slides were observed under research microscope at different modifications. The ancient pollens which were clear and fully enough to distinguish their types and characteristics.



By the Present Researcher

Table 0.2: Flow chart showing the journey of research

CHAPTER: 1

Bond between Archaeology and Natural Sciences

Archaeology is about excitement. It is a magical gateway of the past. It is about intellectual curiosity and finding ways to turn that curiosity into knowledge about people in the past. It is an excitement that comes when we use what Julian Thomas (1996: 63) calls, in a borrowed phase, ‘our archaeological imagination. This allows us to go where we can never travel, to the past, and to think about time and objects in very different ways to our everyday experience (Clive Gamble 2001).

Archaeology is like a Jigsaw Puzzle, except that you cannot cheat and look at the box, and not all the pieces are there (Stephen Dean). According to Oxford dictionary:

“It is the study of human history and prehistory through the excavation of the site and the analysis of the artifacts and other physical remains” (Oxford Dictionary 1985:81). The word Archaeology comes from the Greek (arkhaiologia,”discourse about ancient things”), but in present it has come to mean the study of the human past through the material traces of it that have survived (Bahn 1996: 2).

There are numerous definitions of archaeology: so many that some people talk about archaeologies in the plural and some argue that archaeology is a way of thinking a creative process, others says it is a set of questions about the past, while some define it as the study of human experience how people have lived in the past and responded to their environments. According to different aspects and interests, as defined below:

Archaeology

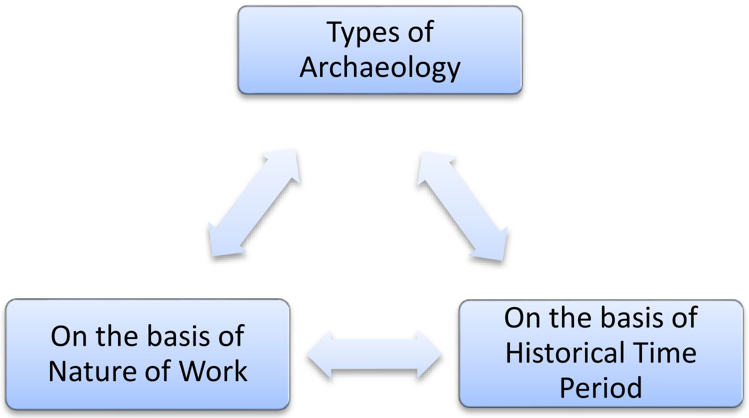
The study of past civilizations, primarily through the recovery and analysis of the material culture and environmental data which they have left behind (Gamble 2001: 15).
The study of human through their material remains (Muckle 2006:3).
The discipline with the theory and practice for the recovery of unobservable hominid behavior patterns from indirect traces in bad samples (Clarke. d.).

The study of the social and cultural past through material remains with the aim of ordering and describing the events of the past and explaining the meaning of those events (Sharer and Ashmore 2003).
The only branch of anthropology where we kill our informant in the process of studying them (Kent V. Flannery).
The scientific study of human past (Sutton and Yohe 2003).
The science of digging in the earth to try and find a civilization worse than ours (Anonymous 1968, 1995:40).
The study of the material remains of human behavior (Feder 2004).
The study of the past through the systematic recovery and analysis of material remains (Thomas and Kelly 2006).
The study of physical remains to help understand the behavior of people in the past (Grant, Gorin, and Fleming 2002).
The study of the human past using the surviving material remains of human behavior (Fagan 2004).
Dead Archaeology is the driest dust that blows (Wheeler 1957).

There are also many different kinds of Archaeologist and Historians also study the past, but they do so by using written and oral records. Archaeologist can also supplement history by looking for material evidence that doesn’t appear in historical record.

Types of Archaeology

Archaeology involves reconstructing history with the help of material remains. It is a stimulating job of interpreting material culture in human terms. It involves both, toiling hard in the field as well as formulating hypotheses in the laboratory/study. An archaeologist has to be, therefore, extremely well-versed in other disciplines which archaeology encompasses, that include history, anthropology, and other social and general sciences. It is thus a subject having a multidisciplinary approach, wherein every small thing matters. With most academic disciplines, there are a very large number of archaeological disciplines characterized by a specific method or type of material, as it helps to study about culture which is the source and our sense of identity. Its draws together and enables us to understand, to give value to the traditions and to articulate our experience. It helps to make life worth living (Chris 1998). Archaeology studies about a way of living within the cultures. There are many different types of archaeology which are basically divided into two categories i.e. on the basis of the historic time period and on the basis of the nature of work.



Types of Archaeology on the basis of Nature of Work

- Environmental Archaeology
- Ethnoarchaeology
- Historical Archaeology
- Forensic Archaeology
- Experimental Archaeology
- Landscape Archaeology
- Archaeometry
- Household Archaeology
- Cultural resources management
- Underwater Archaeology
- Public Archaeology
- Industrial Archaeology
- Pseudoarchaeology
- Aerial Archaeology
- Commercial Archaeology
- Aviation Archaeology
- Virtual Archaeology
- Battlefield Archaeology

Types of Archaeology on the basis of Historical Time Period

- Prehistoric Archaeology
- Protohistoric Archaeology
- Historical Archaeology
- Classical Archaeology
- Medieval and Modern Archaeology

Table 1.1: Flow List representing different types of Archaeology.
By the present Researcher

Types of Archaeology on the basis of Nature of

1. **Environmental Archaeology:** Environmental archaeology deals with the study of interrelationship between the ancient people and their natural environment. It involves three sub-disciplines in it, zooarchaeology that deals with the study of ancient animal remains, geoarchaeology that deals with the study of soil, sediments, rocks, natural deposits, etc., and archaeobotany that studies ancient plant remains. Environmental archaeology encompasses field studies along with laboratory experiments (http://en.wikipedia.org/2015).

2. **Ethnoarchaeology:** Ethnoarchaeology is the archaeological study of living people. The approach gained notoriety during the emphasis on middle range theory that was a feature of the processual movement of the 1960s. Ethnoarchaeology is the science that deals with the ethnographic investigation of living communities in order to acquire knowledge of the past. It involves the application of anthropological methods to a large extent. Early ethnoarchaeological research focused on hunting and gathering on foraging societies. Ethnoarchaeology continues to be a vibrant component of post-processual and other current archaeological approaches. Ethnoarchaeology is the use of ethnography to increase and improve analogs. Which are then used as analogies to interpret the archaeological record? In short, ethnoarchaeology is the application of ethnography to

archaeology. By using ethnoarchaeological techniques archaeologists in a way attempt to land the past with the present. They try to understand how the ancient people in a given region may have lived kipping as their basis, the tangible and intangible culture of the modern communities (Ibid).

3. **Historical Archaeology:** Historical archaeology is the study of cultures with some form of writing. In England, archaeologists have uncovered the long-lost layouts of medieval villages abandoned after the crises of the 14th century and the equally lost layouts of 17th century parterre gardens swept away by a change in fashion. In downtown New York City archaeologists have exhumed the 18th century remains of the African burial ground. Historical archaeology is the study of the past using both material evidence (i.e. artifacts and their contexts) and documentary evidence (including maps, photographs and film). Usually this is associated with the Americas (Atkinson 1953).

4. **Forensic Archaeology:** Forensic archaeology - the application of archaeological techniques to criminal investigations. It has become particularly prominent in the investigation of mass-killings associated with war crimes. Forensic archaeology is a newly developed stream and a very interesting one. It pertains to the use of archaeological techniques in finding evidences on crime scenes. Duties of archaeologists in this field of archaeology include collecting evidences like human burials, artifacts, footprints, tool-marks, etc., and trying to figure out the situation in which a particular crime might have happened; and to ascertain the influences on the remains of external factors that may have disturbed the crime scene. The findings of forensic archaeologists prove to be very effective in the court of law, and help the police to a great extent in the investigation of the occurred crime (http://en.wikipedia.org/2015).

5. **Experimental Archaeology:** Experimental archaeology represents the application of the experimental method to develop more highly controlled observations of processes that create and impact the archaeological record. It is a kind of archaeological study in which archaeologists try to figure out how the archaeological deposits were formed. In the course of this quest. They experiment with various processes which they think people might have applied in order to make or manufacture all those things which make the archaeological deposit. This experimentation of remaking or replicating things using the methods of the past is the core of the entire concept of experimental archaeology. In the context of the logical positivism of processualism with its goals of improving the scientific rigor of archaeological epistemologies the experimental method gained importance. Experimental techniques remain a crucial component to improving the inferential frameworks for interpreting the archaeological record. It has to be noticed, however, that experimental archaeology is related to a large extent to the imaginations of the archaeologists, with regards to the period in question. Because most of the things,

especially structures are seldom found intact; the replication mostly depends on the perception of the archaeologist. Experimental archaeology involves attempting to re-enact past processes to test theories about ancient manufacturing, engineering and the effects of time on sites and objects (for example: flint knapping) (Coles 1979).

6. **Landscape Archaeology:** Landscape Archaeology is a broad division in archaeology that deals with the study of the various changes that take place in different landscapes, both natural as well as due to human intervention. On the basis of this, landscapes have been classified into natural and cultural landscapes, for archaeological purposes. There are a variety of changes that landscapes may undergo over a period of time. These include natural changes with respect to topography, climate, soil, natural calamities such as floods, landslides, tsunamis, rivers changing their courses and so on, and human induced changes such as agriculture, industrial and construction activities, clearing of forest areas, etc (Ibid).

7. **Archaeometry:** Archaeometry is a field of study that aims to systematize archaeological measurement. It emphasizes the application of analytical techniques from physics, chemistry, and engineering. It is a field of research that frequently focuses on the definition of the chemical composition of archaeological remains for source analysis. Archaeometry also investigates different spatial characteristics of features, employing methods such as space syntax techniques and geodesy as well as computer-based tools such as geographic information system technology. Rare earth elements patterns may also be used. A relatively nascent subfield is that of archaeological materials, designed to enhance understanding of prehistoric and non-industrial culture through scientific analysis of the structure properties of materials associated with human activity (Atkinson 1953).

8. **Household Archaeology:** It involves a small-scale excavation within a given area on an archeological site. It considers every single household as a unit that not only portrays the social, cultural, economic, and political sensibilities of the people of a particular household but also throws light on the affiliations of the society on the whole. Household archaeology is also helpful in studying aspects of secular art and architecture, food habits of the people, their religious beliefs, and so on (Ibid).

9. **Cultural resources management:** While archaeology can be done as a pure science, it can also be an applied science, namely the study of archaeological sites that are threatened by development. In such cases, archaeology is a subsidiary activity within Cultural resources management (CRM), also called heritage management in the United Kingdom (Coles 1979).

10. **Underwater Archaeology:** This is also known as marine archaeology or maritime archaeology. It is associated with the study of underwater evidences such as shipwrecks, water-buried cities, and other inundated archaeological sites. It is an expensive branch of archaeology and incurs a much higher cost than any terrestrial archaeological excavation. Archaeologists who work under water rely on sophisticated and excavating equipment and special methods to preserve perishable materials that have been waterlogged for long periods. (Ibid).

11. **Public Archaeology:** Motivated by a desire to halt looting, curb pseudoarchaeology, and to help preserve archaeological sites through education and fostering public appreciation for the importance of archaeological heritage, archaeologists are mounting public-outreach campaigns. They seek to stop looting by combating people who illegally take artifacts from protected sites. Common methods of public outreach press releases, and the encouragement of school field trips to sites under excavation by professional archaeologists. Public appreciation of the significance of archaeology and archaeological sites often leads to improved protection from encroaching development or other threats (Atkinson 1953).

12. **Industrial Archaeology:** Industrial archaeology is another kind of archaeology which studies the material remains of industrial by-products and artifacts. It does not deal with the movement of goods from one place to another. On the contrary, it deals with the production of goods and the various processes involved in the same. Evidences from industrial sites tell us about the industries that existed during a given period in history, things that were manufactured then, the tools that were used at that time, and attempt to answer queries like what people did other their agriculture. Evidences recovered from such sites generally include those related to activities such as manufacturing, mining, quarrying, milling, building roads and other infrastructure, etc (Ibid).

13. **Pseudoarchaeology:** Pseudoarchaeology is an umbrella term for all activities that claim to be archaeological but in fact violate commonly accepted and scientific archaeological practices. It includes much fictional archaeological work, as well as some actual activity. Many non-fiction authors have ignored the scientific methods of processual archaeology, or the specific critiques of it contained in post-processualism (Trigger 1994).

14. **Aerial Archaeology:** Aerial archaeology, as the name suggests, is the investigation of archaeological remains from the air. This is a concept that gained impetus after aerial survey and photography were considered to be important during the two world wars. Archaeologist thought of applying the technique to record the bird’s-eye view of archaeological sites so that they could get a better perspective of the same. Nowadays, the technique of satellite imagery also forms part of aerial archaeology (Ibid).

15. **Commercial Archaeology:** Commercial archaeology is actually a sub-discipline of archaeology which deals with everything that is related to commerce and trade. This includes evidences with respect to the commodities that were traded and bartered, numismatic finds, and ancient forms of transportation that were used for commercial purposes and so on. Many a times at commercial sites, ancient inscriptions are found which are obviously very valuable resources that are used for recording economic histories (Ibid).

16. **Aviation Archaeology:** Aviation archaeology deals with finding the historical remains of aircraft, airborne weaponry, abandoned air basis or runways, and the like. It deals with everything that has to do with the history of aviation. Sometimes, remains from aircraft crashes are found under the sea, which are eventually recovered, recorded and studied (Ibid).

17. **Virtual Archaeology**: Sometime around 1995 archaeologists started using computer graphics to build virtual 3D models of sites as the throne room of an ancient Assyrian palace or ancient Rome. This is done by collecting normal photographs and using computer graphics to build the virtual 3 d model. Computer-built topographical models have been combined with astronomical calculations to verify whether or not certain structures (such as pillars) were aligned with astronomical events such as the sun’s position at a solstice (Dorrell 1989).

18. **Battlefield Archaeology:** Battlefield archaeology, also known as military archaeology, is one of the most intriguing types of archaeologies. It deals with digging up battlefields of the past and recovering evidences relating to military activities, which may have been responsible for subsequent changes in the social, political and economic spheres of the society. Archaeological evidences recovered from battlefields have the capability to alter those historical viewpoints which have been widely accepted and acknowledged. Evidences on such sites include remains of implements of war, skeletal remains, and various artifacts related to military history. These so-called war sites give valuable evidences to events, which took place not only during a given war, but also before and after it, because not only actual battlefields but even military camp sites provide valuable evidences. Also, just as all other sites tell us about how and when people lived, war sites tell us how and when they died. All in all, battlefield archaeology is an engrossing case-study of how written historical accounts can undergo changes when actual material remains relating to the recorded events are uncovered (http://www.buzzle.com/articles/different-types-of-archaeology).

Types of Archaeology on the basis of Historic Time

1. **Prehistoric Archaeology:** Prehistory is the name assigned to the period before the invention of writing. Obviously, there are no written records or historical accounts from the prehistoric age, and so, whatever we know about prehistory is simply through physical archaeological finds. Prehistory has been classified into Palaeolithic, Mesolithic, Neolithic, and Chalcolithic periods, on the basis of the developments that took place over a period of time in the human lifestyles. Prehistory also includes periods before the lithic age (Stone Age), which preceded the existence of humans (Ibid).

2. **Protohistoric Archaeology:** Protohistory is the period that lies in between prehistory and history. Though this is a period that came after the invention of writing, many of the evidences have not been deciphered yet. Protohistory encompasses the Bronze Age and Iron Age, and sometimes even the copper age, but this differs from region to region. Dating of this period is a difficult task for an archaeologist, as this again depends on regional and cultural aspects. But, we know from the data available that it was during the protohistoric period that great ancient civilizations of the world sprang up, and the world took its first and prominent steps towards urbanization. Thus, it is an important transitional phase, and sites are loaded with surprising artifacts, which makes protohistoric archaeology an interesting option (Ibid).

3. **Historical Archaeology:** Historical archaeology studies that period of the history of mankind from which we have ample written sources that tell us a huge variety of things. So, historical archaeology involves the study of not only the artifacts recovered from the archaeological sites but also of the documented evidences that have been left behind. Sites relating to historical archaeology are spread across the world in large numbers, and each of these help reconstruct different kinds of aspects of human past, such as industries, trade, art and architecture, social and cultural history, military history, and so on. However, it should be noted that historical records are not always correct, and hence, it should be supplemented with other evidences (Ibid).

4. **Classical Archaeology:** Classical archaeology is a special branch of archaeology which pertains only to Greece and Rome. It deals with a detailed study of the ancient Greek and Roman civilizations. Classical archaeology not only studies these two civilizations

individually, but also in relation to other contemporary civilizations of that period. It also studies the influences of and on other civilizations of the ancient Greeks and Romans. It is a very interesting field of study, but because it pertains to specific regions, is limited in scope (Ibid).

5. **Medieval and Modern Archaeology:** Medieval archaeology deals with the study of material remains of human culture belonging to the Middle Ages. Similarly, modern archaeology pertains to the study of the colonial and post-colonial periods in history. Material remains of these periods aid, in most cases, only to establish firmly the facts from the written records of these periods, which are available in the large numbers (Ibid).

   There are a large number of people who want to practice archaeology, but are not quite exposed to the field. On the other hand, there are also a large number of people who do not practice it properly and tend to completely ignore or oppose the established hypotheses and theories of archaeologists and historians. This kind of non-scientific and baseless approach to archaeology is known as pseudoarchaeology or cult archaeology, which is sometimes a result of religious fundamentalism. Moreover, a fantastical form of archaeological study related to the physical remains of aliens, known as xenoarchaeology, has also been conceptually put forth by some. However, this cannot be an established mainstream discipline. Nevertheless, archaeology, with its numerous types, becomes an absolutely amazing package (Ibid).

Archaeology as a Science

Archaeology emerged gradually during the past two centuries as a systematic study of the past. According to the Webster dictionary Archaeology is:

“The scientific study of extinct peoples or of past phases of the historic peoples through skeletal remains and objects of human workmanship found in the earth” (Webster International Dictionary 1986:64).

So Archaeology is the scientific and systematic study about the culture of prehistory and history through their artifacts, skeletal remains and other physical remains excavated from archaeological sites. Archaeology is concerned with the full range of past human experience how people organized themselves into social groups and why their societies changed (Pollard 2007:3).

Archaeology is partly the discovery of the treasures of the past, partly the meticulous work of the scientific analyst, partly the exercise of the creative imagination. It is toiling in the sun on an excavation in the deserts of Central Asia; it is working with living Inuit in the snows of Alaska. It is diving down to Spanish wrecks off the coast of Florida, and it is investigating the sewers of Roman York. But it is also the painstaking task of interpretation so that we come to understand what these things mean for the human story. And it is the conservation of the world's cultural heritage against looting and against careless destruction. Archaeology, then, is both a physical activity out in the field, and an intellectual pursuit in the study or laboratory. That is the part of its great attraction.

Since the aim of archaeology is the understanding of humankind. It is a humanistic discipline, a humane study. And since it deals with the human past it is a historical discipline. The scientist collects data (evidence), conducts experiments, formulates a hypothesis (a proposition to account for the data), tests the hypothesis against more data, and then in conclusion devises a model (a description that seems best to summarize the pattern observed in the data). The Archaeologist has to develop a coherent view of the natural world. It is not found readymade.

Archaeology, in short, is a Science as well as Humanities. That is one of its fascinations as a discipline: it reflects the ingenuity of the modern scientist as well as the modern historian. The technical methods of archaeological science are the most obvious, from radiocarbon dating to studies of food residues in pots. Equally important are scientific methods of analysis, of inference. Some writers have spoken of the need to define a separate "Middle Range Theory," referring to a distinct body of ideas to bridge the gap between raw archaeological evidence and the general observations and conclusions to be derived from it. That is one way of looking at the matter. But we see no need to make a sharp distinction between theory and method. Our aim is to describe clearly the methods and techniques used by archaeologists in investigating the past. The analytical concepts of the archaeologist are as much a part of that battery of approaches as are the instruments in the laboratory (Thames and Hudson 1991).

As Archaeology has many different types that are related to different fields and discipline and has their own prominent importance so it acts as a multidisciplinary field.

Archaeology and the Other Sciences

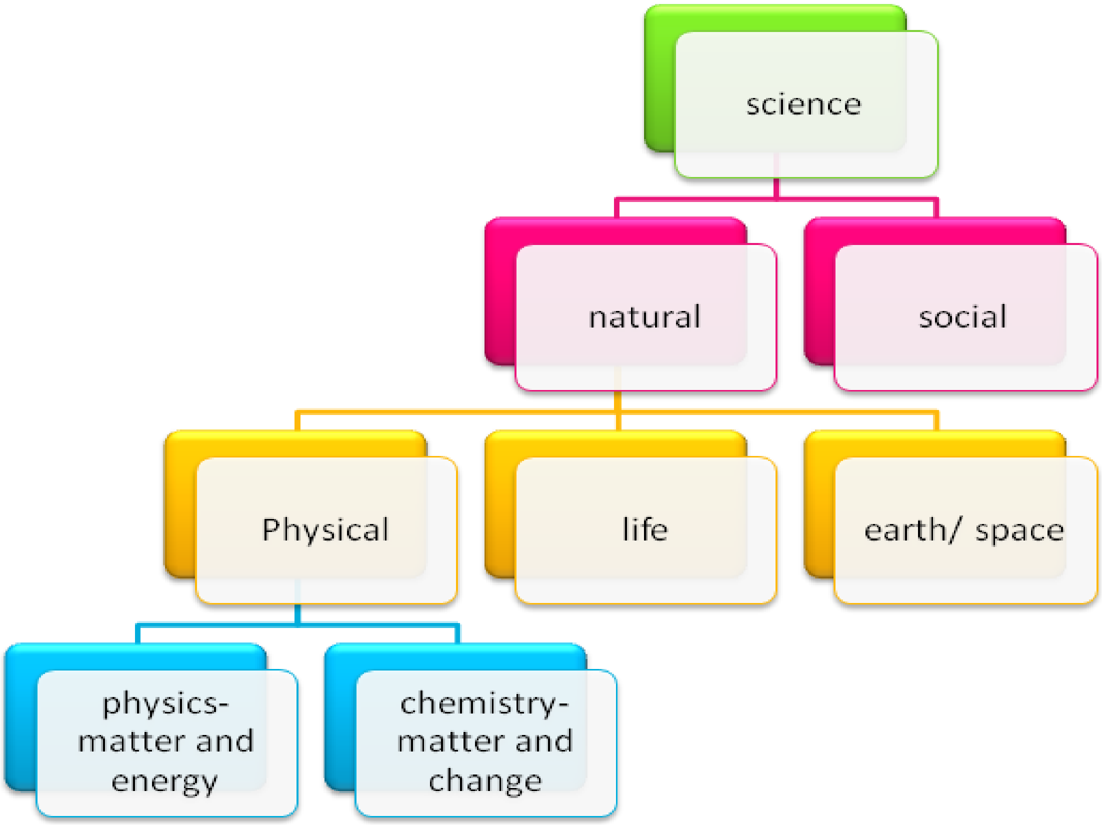
The field of archaeology is very broad, dealing with humans, their activities, and their environment over long periods of time. To understand all this complexity, archaeologists must seek help from other disciplines. In addition to cultural anthropology, archaeologists draw from a number of other social sciences, such as history, psychology, and sociology, to help provide a context in which to understand the cultural and social aspects of past human behaviors. As examples, studies of conditions in contemporary urban settings can be used to help understand the social situations of early cities, and a general understanding of the human mind can shed light on the thinking processes of early humans. Other fields, too, provide information to archaeologists about things related to human activities. Botanists assist archaeologists in the identification of plants to help understand their evolution and use. Zoologists do the same thing with animals.

Geologists study sites and their surroundings and provide information regarding erosion, deposition, age of deposits, and the like.

Finally, archaeologists rely on various specialists to help analyze what is found. Physicists and chemists actually perform most of the techniques used to date materials. Chemists also conduct other studies, such as residue analyses and geochemical sourcing. Mathematicians and computer scientists help in statistical analyses, mapping, and model building. Thus archaeology is truly an interdisciplinary science.

Bond between Archaeology and Natural Sciences:

Archaeology as a scientific discipline came into existence in the last part of the 20th century that is broadly defined as the application of scientific principles and methods to the characterization of materials that are related to cultural heritage. As with most academic disciplines, there are a number of Archaeological sub-disciplines typically characterized by emphasis on a specific method or type of material, geographical or chronological focus, or other thematic concern. Archaeology is a wide field that relates to every discipline of natural and social sciences because it depends upon the nature of the artifacts.



By the Present Researcher

Table 1.2: Flow chart of the Branches of Natural Science

Social science

Social science is the study of the social world constructed between humans. The Social sciences usually limits itself to an anthropomorphic centric view of these interactions with minimal emphasis on the inadvertent impact of social human behavior on the external environment (physical, biological, ecological, etc.). 'Social' is the concept of exchange/influence of ideas, thoughts, and relationship interactions (resulting in harmony, peace, self-enrichment, favoritism, maliciousness, justice seeking, etc.) between humans. The scientific method is utilized in many social sciences, albeit adapted to the needs of the social construct being studied.

Natural science

Natural science is a branch of science concerned with the description, prediction, and understanding of natural phenomena, based on observational and empirical evidence. Validity, accuracy, and social mechanisms ensuring quality control, such as peer review and repeatability of findings, are amongst the criteria and methods used for this purpose. In natural science, hypotheses must be verified scientifically to be regarded as scientific theory. Validity, accuracy, and social mechanisms ensuring quality control, such as peer review and repeatability of findings, are amongst the criteria and methods used for this purpose. Natural sciences play a massive role in archaeological research evolving it into the interdisciplinary research field. Natural science can be broken into 2 main branches: Biology, and Physical Science. Each of these branches, and all of their sub-branches, are referred to as natural sciences (Becker 1982: 1-2).

Fig 1.1: A Plate representing Natural Sciences (Lagemaat 2006:283)

Branches of Natural Science

In Western society's analytic tradition, the empirical and especially natural sciences use tools from formal sciences, such as mathematics and logic, converting information about nature into measurements which can be explained as clear statements about the "laws of nature". The social sciences also use such methods, but rely more on qualitative research, so that they are sometimes called "soft science", whereas natural sciences, insofar as emphasizing quantifiable data produced, tested, and confirmed through the scientific method are sometimes called "hard science".

Modern natural science succeeded more classical approaches to natural philosophy, usually traced to ancient Greece. Galileo, Descartes, Francis Bacon, and Newton debated the benefits of using approaches which were more mathematical and more experimental in a methodical way. Still, philosophical perspectives, conjectures, and presuppositions, often overlooked, remain requisite in natural science. Systematic data collection, including discovery science, succeed natural history, which emerged in the 16th century by describing and classifying plants, animals, minerals, and so on. Yet today, natural history suggests observational descriptions aimed at popular audiences.

Natural science can be broken into two main branches: **Life Science** (or Biological Science) and **Physical Science**. Physical science is further broken down into several branches, including Physics, Astronomy, Chemistry, and Earth Science. All of these branches of natural science are divided into many further specialized branches (also known as fields), and each of these is known as a "natural science" (Lagemaat 2006: 283).

1. **Physical Science:** Branch of natural science that studies non-living systems, in contrast to the Biological Sciences. It in turn has many branches, each referred to as a "Physical Science", together called the "Physical Sciences". However, the term "physical" creates an unintended, somewhat arbitrary distinction, since many branches of physical science also study Biological Phenomena and Organic Chemistry.

- **Physics:** Physical science that studies matter and its motion through space-time, and related concepts such as energy and force. Physics embodies the study of the fundamental constituents of the universe, the forces and interactions they exert on one another, and the results produced by these interactions. In general, physics is regarded as the fundamental science, because all other natural sciences use and obey the principles and laws set down by the field. Physics relies heavily on Mathematics as the logical framework for formulation and quantification of principles.

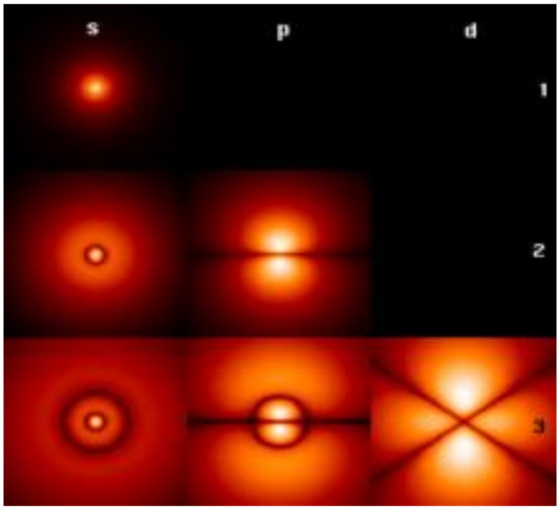


Fig 1.2: The orbitals of the hydrogen atomare descriptions of the probability distributions of an electron bound to a proton. Their Mathematical descriptions are standard problems in Quantum Mechanics, an important branch of Physics (Lagemaat 2006:283).

The study of the principles of the universe has a long history and largely derives from direct observation and experimentation. The formulation of theories about the governing laws of the universe has been central to the study of physics from very early on, with philosophy gradually yielding to systematic, quantitative experimental testing and observation as the source of verification. Key historical developments in physics include Isaac Newton's theory of universal gravitation and classical mechanics, an understanding of electricity and its relation to Magnetism, Einstein's theories of special and general relativity, the development of Thermodynamics, and the Quantum Mechanical Model of Atomic and Subatomic Physics. The field of Physics is extremely broad, and can include such diverse studies as Quantum Mechanics and Theoretical Physics, Applied Physics and Optics. Modern Physics is becoming increasingly specialized, where researchers tend to focus on a particular area rather than being "universalists" like Isaac Newton, Albert Einstein and Lev Landau, who worked in multiple areas (Lagemaat 2006).

- **Astronomy:** Studies the universe beyond Earth, including its formation and development and the Evolution, Physics, Chemistry, Meteorology, and Motion of Celestial objects (such as Galaxies, Planets, etc.) and phenomena that originate outside the atmosphere of Earth (such as the Cosmic Background Radiation).

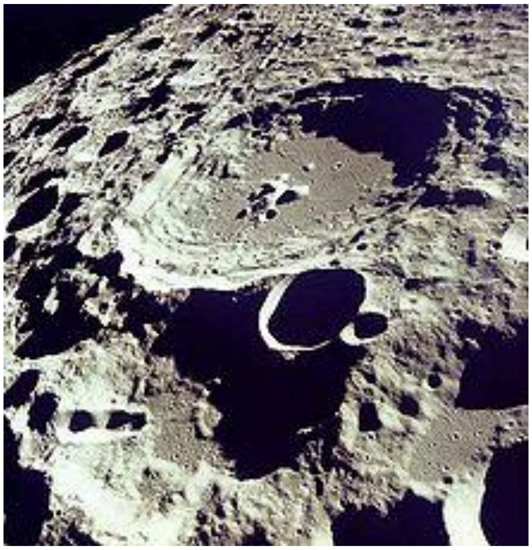


Fig: 1.3: Space Missions have been used to image distant locations within the Solar System, such as this *Apollo 11* view of Daedal us crater on the far side of the Moon (Hugh and Gauch 2003: 71–73).

This discipline is the science of celestial objects and phenomena that originate outside the Earth's atmosphere. It is concerned with the evolution, Physics, Chemistry, Meteorology, and Motion of Celestial objects, as well as the formation and development of the universe.

Astronomy includes the examination, study and modeling of Stars, Planets, Comets, Galaxies and the Cosmos. Most of the information used by Astronomers is gathered by remote observation, although some laboratory reproduction of celestial phenomena has been performed (such as the Molecular Chemistry of the interstellar medium).

While the origins of the study of celestial features and phenomena can be traced back to antiquity, the scientific methodology of this field began to develop in the middle of the 17th century. A key factor was Galileo's introduction of the telescope to examine the night sky in more detail.

The mathematical treatment of astronomy began with Newton's development of celestial mechanics and the laws of gravitation, although it was triggered by earlier work of astronomers. By the 19th century, astronomy had developed into a formal science, with the introduction of instruments such as the spectroscope and photography, along with much-improved telescopes and the creation of professional observatories (Hugh and Gauch 2003: 71–73).

- **Chemistry:** Physical science of atomic matter (matter that is composed of chemical elements), especially its chemical reactions, but also including its properties, structure, composition, behavior, and changes as they relate the chemical reactions.

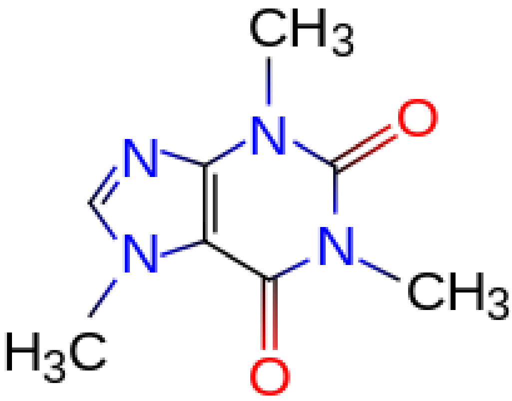


Fig 1.4: This structural formula for molecule caffeine shows a graphical representation of how the atoms are arranged (Hugh and Gauch 2003: 71–73).

Constituting the scientific study of matter at the atomic and molecular scale, chemistry deals primarily with collections of atoms, such as gases, molecules, crystals, and metals. The composition, statistical properties, transformations and reactions of these materials are studied. Chemistry also involves understanding the properties and interactions of individual atoms and molecules for use in larger-scale applications.

Most chemical processes can be studied directly in a laboratory, using a series of (often well-tested) techniques for manipulating materials, as well as an understanding of the underlying processes. Chemistry is often called "the central science" because of its role in connecting the other natural sciences.

Early experiments in chemistry had their roots in the system of Alchemy, a set of beliefs combining mysticism with physical experiments. The science of chemistry began to develop with the work of Robert Boyle, the discoverer of gas, and Antoine Lavoisier, who developed the theory of the Conservation of mass.

The discovery of the chemical elements and atomic theory began to systematize this science, and researchers developed a fundamental understanding of states of matter, ions, chemical bonds and chemical reactions. The success of this science led to a complementary chemical industry that now plays a significant role in the world economy (Hugh and Gauch 2003: 71–73).

- **Earth Science:** All-embracing term for the sciences related to the planet Earth. Earth Science, and all of its branches, is branches of Physical Science. Earth science (also known as Geo Science), is an all-embracing term for the sciences related to the planet Earth, including Geology, Geophysics, Hydrology, Meteorology, Physical Geography, Oceanography, and Soil Science.

Although mining and precious stones have been human interests throughout the history of civilization, the development of the related sciences of geology and mineralogy did not occur until the 18th century. The study of the earth, particularly Paleontology, blossomed in the 19th century. The growth of other disciplines, such as Geophysics, in the 20th century led to the development of the theory of plate tectonics in the 1960s, which has had a similar effect on the Earth sciences as the theory of evolution had on Biology. Earth Sciences today are closely linked to petroleum and mineral resources, climate research and to environmental assessment and remediation (Magner 2002: 3–4).

2. Biological Science:

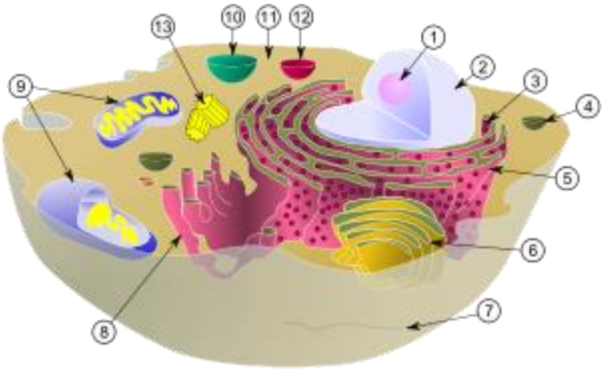


Fig 1.5: Structure of a typical animal cell showing the various organelles (Hartl D, Jones E (2005).

Biology is a natural science concerned with the study of life and living organisms, including their structure, function, growth, evolution, distribution, and Taxonomy. Modern Biology is a vast and eclectic field, composed of many branches and sub disciplines. However, despite the broad scope of Biology, there are certain general and unifying concepts within it that govern all study and research, consolidating it into single, coherent fields. In general, Biology recognizes the cell as the basic unit of life, genes as the basic unit of heredity, and evolution as the engine that propels the synthesis and creation of new species. It is also understood today that all organisms survive by consuming and transforming energy and by regulating their internal environment to maintain a stable and vital condition (Hartl and Jones 2005).

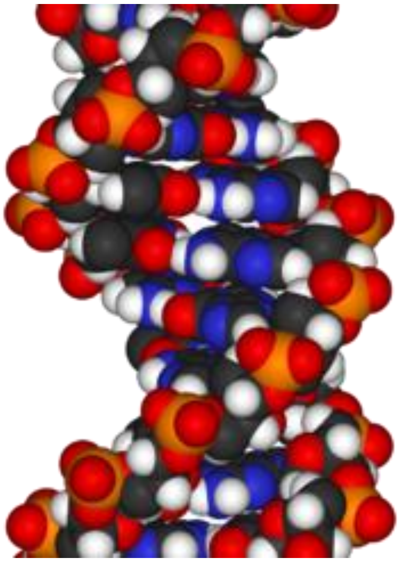


Fig 1.6**:** A fragment of DNA showing the chemical sequence that of genetic instructions for the development and functioning of living organisms (Grant 2007:155).

This field encompasses a set of disciplines that examines phenomena related to living organisms. The scale of study can range from sub-component biophysics up to complex ecologies. Biology is concerned with the characteristics, classification and behaviors of organisms, as well as how species were formed and their interactions with each other and the environment.

The Biological fields of Botany, Zoology, and Medicine date back to early periods of civilization, while Microbiology was introduced in the 17th century with the invention of the Microscope. However, it was not until the 19th century that Biology became a unified science. Once scientists discovered commonalities between all living things, it was decided they were best studied as a whole.

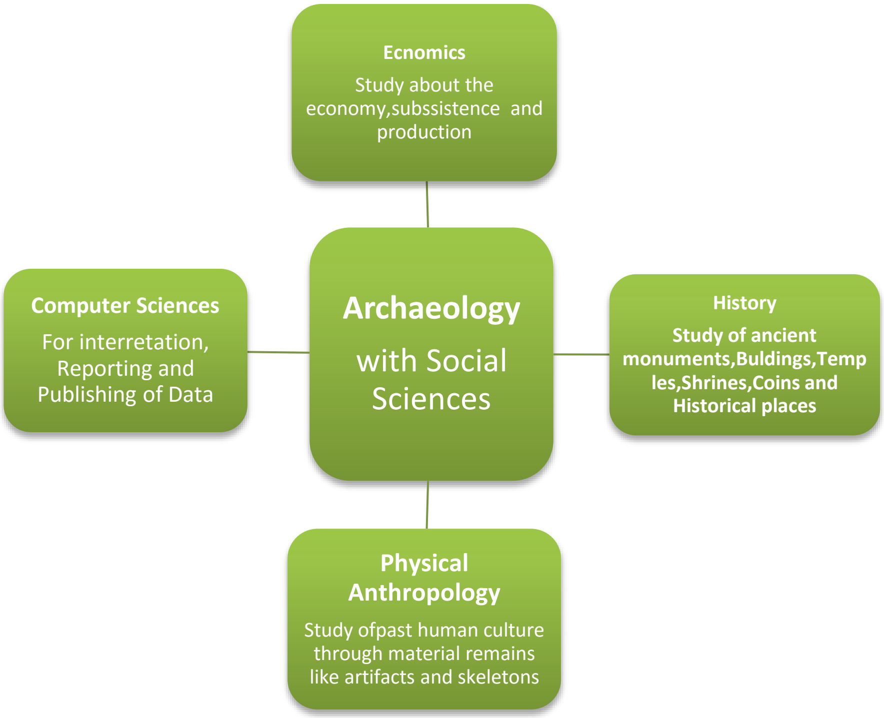
Some key developments in Biology were the discovery of Genetics; Darwin's theory of evolution through natural selection; the germ theory of disease and the application of the techniques of Chemistry and Physics at the level of the Cell or Organic Molecule.

Modern Biology is divided into sub disciplines by the type of organism and by the scale being studied. Molecular Biology is the study of the fundamental Chemistry of life, while Cellular Biology is the examination of the cell; the basic building block of all life. At a higher level, Physiology looks at the internal structure of organism, while Ecology looks at how various organisms interrelate (Grant 2007: 155).

Relationship between Archaeology with Social and Natural Sciences

Archaeology with Social Sciences

Archaeology is a broad discipline and therefore it provides basis for every aspect of other discipline from its roots. That’s why archaeologists have a challenge to develop roots of phenomena from simple materials. As Trigger said archaeologist study the past, they are able to observe and understand human behavior directly unlike historians. They work for the depth of artifacts to infer human behavior and beliefs from the remains of what people made and use and how they live they explain like other social scientists (Trigger 1988: 1).



` By the Present Researcher

Table 1.3: Flow chart showing the relation of Archaeology with Social Sciences

1. Economics and Archaeology

Archaeology is also related to economics to know about the economy, subsistence, currency power, coins study, production, trade relations, exchange and distribution of goods.

2. History and Archaeology

Archaeology helps to understand history with evidences. It is related as to study historical events, monuments, buildings and other aspects related to history study under this field. History and archaeology has a strong relation they are like scattered pieces of past society and events.

3. Computer Sciences and Archaeology

Archaeology has a strong relation with computer sciences because it helps in locating sites, mapping of the sites, creating data sheets, analysis of documents, preserving photographs, 3D techniques and interpretation of data till the publication of the report. Now a day it is creating more place in the field of archaeology as it is time consuming and easy to understand.

4. Physical Anthropology and Archaeology

The study of human remains from archaeological contexts is one of the many research areas comprising Physical Anthropology. They are directed toward determining population origins and kinship, nutrition, disease status, and longevity of past populations (McGOVERN 1995: 127).

Natufian skeletal remains, re-covered from the sites of Shukbah, Kebara, El Wad, Eynan, Nahal Oren, Erq el Ahmar, and Hayonim in Israel and the West Bank has focused studies on population affinities, disease, and diet. Small sample sizes similarly limited the analyses of craniofacial parameters. Fortunately, mandibles are better preserved than other skeletal elements, and the number available for analysis is sufficient for basic inferences. The data show that a significant reduction in mandibular robusticity occurred during the Natufian period, thus corroborating the evidence for changing diets and reduced selective pressures on jaws based on patterns of dental disease (Ibid: 130).

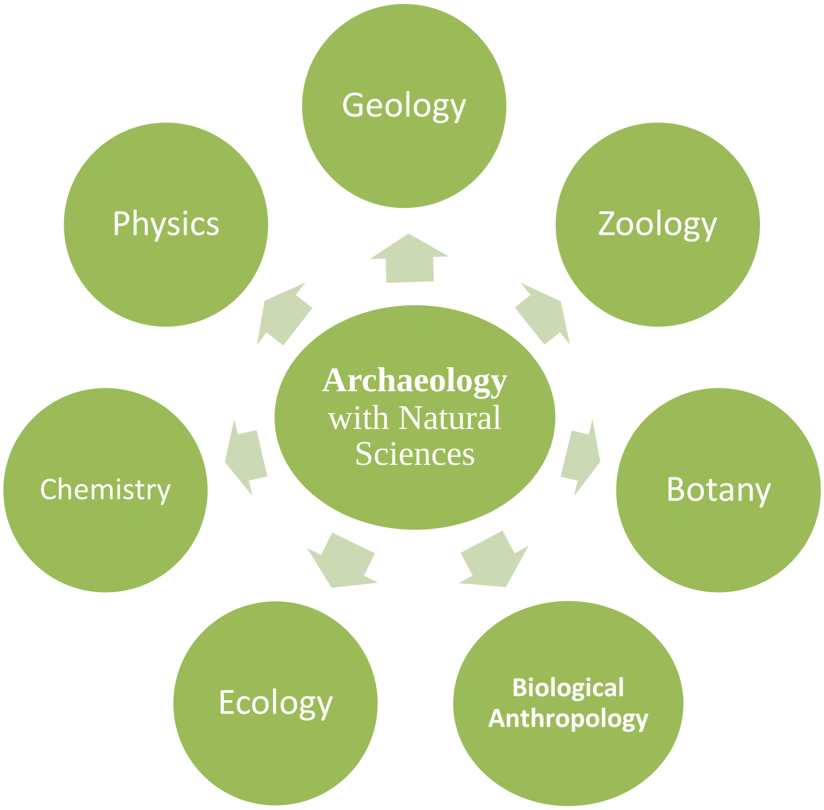
A supplementary approach to population studies has been the use of dental traits, which have been found to be extremely reliable in studies of the population affinities of modern and ancient societies. Dental disease patterns in Natufian populations indicate increased consumption of cooked carbohydrates over time. The dental disease patterns of the Natufians more nearly resemble those of early agriculturalists than those of hunter-gatherers in rates of attrition, caries, and periodontal disease Skeletal analyses offer unique perspectives on past societies and individuals, and can provide specific answers to questions that cannot be addressed by other means. The latest innovation is nuclear and mitochondrial DNA analysis of ancient skeletal remains and mummified tissues, which promises to be a very powerful technique with wide application (Ibid).

Archaeology with Natural Sciences

A longstanding debate, in the scientific community, investigates whether Archaeology should be regarded as a Science or not. Archaeology possesses both elements of “hard science” and field specific theories concerning human behavior. Latter of which advocates the general thought that Archaeology is integrally linked to Anthropology, being a humanistic science.

The last three decades have seen a steady growth of application of natural scientific methods to Archaeology. The interdisciplinary approach of Archaeometry has found increasing appreciation by the archaeologists and is now considered indispensable and an integral part of Archaeological studies. Interdisciplinary collaboration requires a multidisciplinary background. It is becoming increasingly difficult for the individual to grasp the whole field of Archaeometry with its rapid developments. The aim of the Natural Science in Archaeology is to bridge this information gap at the interface between Archaeology and Science (Wagner, Miller and Schutkowski).

Whatever the case, field specific Natural Sciences play a massive role in Archaeological research evolving it into an interdisciplinary research field. This research will show in what way some Natural Sciences carries direct relationship to Archaeology.



By the Present Researcher

Table 1.4: Flow chart showing the relation of Archaeology with Natural Sciences

5. Geology and Archaeology

The Geological layers formed at sites help us construct the climatic conditions prevalent at a certain time and environments in which ancient cultures existed. All objects made from metal and stone originally come from a geological source. This alone makes Geology an integral discipline within the field of Archaeology (UNISA 2012: 28).

Geological principles play a very big part in the indirect dating and relative age calculations of sites and artifacts. The principle of stratification is one of the basic principles in Archaeological dating, this states that the lower layers are usually the oldest (with some exceptions), this is a geological principle (UNISA 2012: 66). Also stratigraphic-geomorphological dating method plays a role. This form of dating is based on association of sites/artifacts with local geological phenomena, and the age and sequence of these phenomena in general terms. The study of ancient glacial deposits and changes it brought to the landscape is important for Archaeology; the whole chronology of the Pleistocene is based on the interpretation of natural and geological phenomena created by the glaciers. Also, further on, pedological investigations concerns itself with the study of the rate of the building up of certain soils as a means to deduce climatic conditions that cause that buildup of soil and the rate thereof.

Geophysical prospecting/surveying allows a pre-diction of the location of sites or the location of features within sites. Geophysical exploration can detect a feature at any depth and also is a relative cheap form of surveying. A well-known example of its application was at the site of ancient Sybaris, in Italy, where the Greeks established a colony renowned for its "sybaritic" lifestyle. Over the period from 1962 to 1967, she (Ralph) worked on site in Italy for a total of about two years. She made between 300,000 and 400,000 magnetic measurements, which enabled the archaic roof tiles of Sybaris to be located at a depth of 4 m beneath the alluvium that had accumulated over 2,500 years (McGOVERN 1995: 89-90).

6. Zoology and Archaeology

The assumption that the spread of animal species is determined by environmental conditions allows us to make inferences about the environment by studying faunal remains. This is particularly important to point out subsistence patterns (UNISA 2012: 28).

The Perception of what faunal analysts do and should do varies among archaeologists. At one end faunal analysis is a set of procedures to identify and record animal bone remains with a view toward documenting the history of human impact on animals, these are called Archaeozoologists. At the other end is analysis and interpretation of faunal remains in the context of particular archaeological problems with a focus on interactions between humans and animals within a specific social and cultural context. Both methods draw direct relationship to Archaeological research (UNISA 2012: 28).

An example of the application of Zoology has been that of Sebastian Payne in Anatolia and southeastern Europe. In a study of sampling methods, he demonstrated that bones of medium and small animals can be significantly underrepresented in a hand-picked faunal assemblage when compared to a sieved assemblage. For the material from Agvan Kale, he developed a technique for recording tooth wear in sheep and goats and, subsequently, studied tooth wear patterns in hundreds of living Angora goats in order to be better able to determine age at death of animals represented in the archaeological record. From aging data such as these, it is possible to describe a "kill-off pattern" that reflects hunting or husbandry practices employed in the past (Ibid).

7. Botany and Archaeology

No matter what the time period or geographical area, plants played an important role in human culture. As data about the natural environment, land-use practices, diet, architecture, and trade in exotic plant materials, plant remains also reflect many aspects of society, including social practices, such as eating, the organization of labor, and status differentiation. The three major categories of archaeobotanical materials are macro-remains, pollen, and phytoliths. Macro-remains are relatively large items that generally comprise the bulk of plant remains re-covered from archaeological sites. They include seeds and seed-like plant structures, fruits, wood, leaves, tubers, etc (McGOVERN 1995: 91).

Pollen analysis (also fossilized pollen analysis), the science concerned with the study of pollen spores, play an important role in the determination of climatic change and ecological conditions. Many micro-botanical remains such pollen and phytoliths are able to survive after the plant has died or burned. This quality makes it much useful in a lot of sites. Dendrochronology also forms part of this field. This dating technique determines dates and ages of artifacts and sites by the analysis of growth rings in trees associated to archaeological objects (UNISA 2012: 28-29). Pollen analysis also serves as an important form of indirect dating in Archaeology. Especially in arid, waterlogged or acidic deposits (that facilitates preservation of pollen) it has been used extensively to reconstruct the vegetation of a certain area and time frame (Ibid: 68).

Recent work at the Gordion site illustrates the kinds of questions one can ask of archaeobotanical data specifically regarding macro-remains. (McGOVERN 1995: 92) Gordion, located on the Sakarya River in central Turkey, was the capital of ancient Phrygia. Renewed excavations in 1988 and 1989 and archaeobotanical study have portrayed the picture of ancient plant and land-use practices at Gordion between the Late Bronze Age and Medieval times. Land clearance for fuel and agriculture, the grazing of domesticated animals, and, in the Phrygian period, construction seem to have had the cumulative but gradual effect of reducing natural tree cover there was. Since fuel is rarely transported from far away, fuel remains enable one to monitor the vegetation growing relatively close to a settlement. At Gordion, the analysis showed a decline in juniper relative to oak. The absence of juniper fuel in contemporary Phrygian deposits suggests that juniper timber had already become a fairly rare material, reserved for or limited to use in the royal tombs (Ibid).

The full potential of Archaeobotany for the investigation of ancient culture is yet to be realized. Plant remains enable us to assess human impact on the environment. As direct, site-specific evidence of agricultural and culinary activities, they enrich our understanding of how people lived. Archaeobotanical research at Gordion shows both skeptics and the converted how bits and fragments of charred remains help create a picture of the lives of ancient people and the landscape they shaped and inhabited (Ibid).

8. Ecology and Archaeology

As zoology and botany, ecology is a discipline of biology and for the purposes of this assignment ecology will be discussed as a natural science. Ecologists and conservation biologists have discovered the deep human past, long before that of archaeologists. Recent books and journals show growing number of studies that consider archaeological evidence to explain and manage current environments. This trend can be tied to (a) an increasing interest in how historical processes shape modern landscapes, (b) the recognition that humans are part of landscape history even in areas long thought of as pristine, and (c) the emergence of restoration ecology with its goal of aiding the recovery of degraded ecosystems using historical reference conditions. At the same time, archaeologists have begun to realize the potential application of their work to current environmental research, management, and policy. Archaeology can provide information on human actions and their environmental consequences over very long periods of time (HAYASHIDA 2005: 44).

There are numerous studies of prehistoric clearing and the overexploitation of plants that resulted in lasting changes in soils, vegetation, and wildlife, including the extirpation or extinction of species as habitats were altered or eliminated. A well-known example, based primarily on pollen evidence, is the loss of areas of upland forests in the British Isles. The process began in the later Mesolithic, as hunter gatherers maintained and created canopy openings within the forest and along forest edges to encourage the growth of favored species and to attract game. Increasing areas were cleared in later periods for farming, grazing, timber, and fuel, ultimately resulting in the creation of moors and heathlands characterized by poor soils and low biodiversity (HAYASHIDA 2005: 47).

As archaeologists take a larger role in research relevant to current environmental and land-use issues, the intersection of research and public policy debate is inevitable. Others will use archaeological findings in ways we had not anticipated, in many cases misinterpreting or deliberately misusing them. Only by taking active roles can we shape how our research results are interpreted in public discourse.

The time has come for archaeologists to take a more active role in designing and participating in research that addresses contemporary environmental concerns and contributes to public policy (Ibid).

9. Chemistry and Archaeology

Chemistry plays an important role in archaeology to know about the originality of artifacts and other materials. It has many useful applications like XRD, XRF, spectroscopy and X-rays through which archaeologists can bring useful information in a very clear manner.

Application of chemistry will provide archaeology with absolute measurement of the chemical composition of a variety of archaeological materials. The chemical composition will identify the archaeological material. Chemical composition of archaeological materials can be used for different purposes like authentication, conservation, and answering archaeological questions about the past.

It will help to study artifacts, provenance, and technology of past cultures more scientifically. SEM (Scanning Electron Microscope) can be used for the measurement of elemental composition of materials under analysis. Thus it is the most modern analytical technique applied in archaeology.

10. Physics and Archaeology

Archaeology relates to physics to study about ancient astronomical beliefs and other related aspects, the concept of time, space and astrology. It helps to study about ancient people beliefs about space and their myths about it with special reference to physics. The applications of physics to the solution of archaeological problems, the use of magnetic, resistivity and electromagnetic surveying techniques for the location of buried features is described. Various methods of age determination are outlined while the problems associated with radiocarbon dating of organic material and thermo luminescent dating of pottery are discussed in detail. The techniques, including petro logical examination, chemical analysis and isotopic analysis, employed in the physical examination of archaeological artifacts are described. Examples of the application of these techniques in establishing the source of the raw materials used in pottery, metal and stone implements and in elucidating the techniques of manufacture of pottery and metal objects are also given.

Conclusion

It is not difficult to understand why science should play an important role in archaeology. The general principles and empirical procedures of stratigraphic excavation and record-keeping, as well as site survey and landscape archaeology, themselves embody the empirical observation and systematization that characterize science (McGOVERN 1995: 81). As shown in the research Natural Science’s methods and principles play a big role in indirect and direct dating methods of sites and artifacts within archaeology.

Archaeology is still a humanistic science concerning it with cultural aspect of ancient civilizations, but consulting other fields is becoming more and more important.

The Basic Goals of Archaeology in Natural Sciences

The basic and primary purpose of archaeology is to help us understand humans. As in all science, archaeology begins with the discovery of new information, which then must be described. All are about reconstruction of the past, the term ‘reconstruction’ Archaeologists assumes that there was one past and that it is knowable. This is a flawed perspective: there are multiple pasts, or at least, multiple threads. Because we can’t witness these pasts, we are left with inference about them. Thus, archaeologists don’t really reconstruct the past. Rather, they construct it.

Archaeologists seek to reconstruct the life ways of past people, their daily lives, where they lived, what they ate, what their tools were, how they interacted, and how they adapted to their environment. Ultimately, archaeology seeks to contribute to the development of a comprehensive understanding of human behavior. At any step along the way, the information and understanding derived from archaeological work can be applied to the management and conservation of the past and to the education of the public about the past.

Whether archaeologists concentrate on the most ancient human societies or on more recent centuries they have four broad goals.

1. Reconstruction of Culture History

The first goal of archaeology is to generate basic information, the basic discovery, description, and classification of artifacts and sites. Reconstruction of Culture History is derived from studying sites and the artifacts and structure with them in a temporal and spatial context to reconstruct descriptions of long sequences of human culture. Reconstruction of Culture History requires consideration of archaeology's three dimensions: form, space and time. Once some basic idea of the prehistory of a region has been obtained, the information can be synthesized into definitions and a description "a culture history" of the past groups for that region. In conjunction, the delineation of cultural chronology, the description and sequences of groups through space and time, is also a major goal.

Fig 1.7: Reconstruction of Cultural History (Fagan 1999:26-30)

Cultural history is reconstructed by building up local sequences of archaeological sites into regional and even larger frameworks of changing human cultures. This descriptive activity reconstructs cultural history. It is an essential preliminary to any work on life ways or cultural process. These initial basic descriptions, often based on relatively little information, serve as foundations for future work. As more work is done, the chronologies and culture histories will be rejected or revised as necessary. The advent of more accurate dating techniques has permitted much greater precision, and basic cultural chronologies are now much better understood. In spite of all this work, the basic cultural chronologies of most regions remain poorly known, and obtaining baseline data still remains an important goal in much archaeological work today.

2. Reconstruction of Past Life ways

The study of past life ways in which people have made their livings in the past has developed into a major goal since the 1930s. This new purpose of archaeology is important as people realized that the prehistory played an important role in the ground of the changing environment. Prehistory is complex and complicated back for changing adaptations in environmental conditions.

The ethno historical method, as it has come to be known, involves developing histories informed by Ethnography, Linguistics, Archaeology, and Ecology.

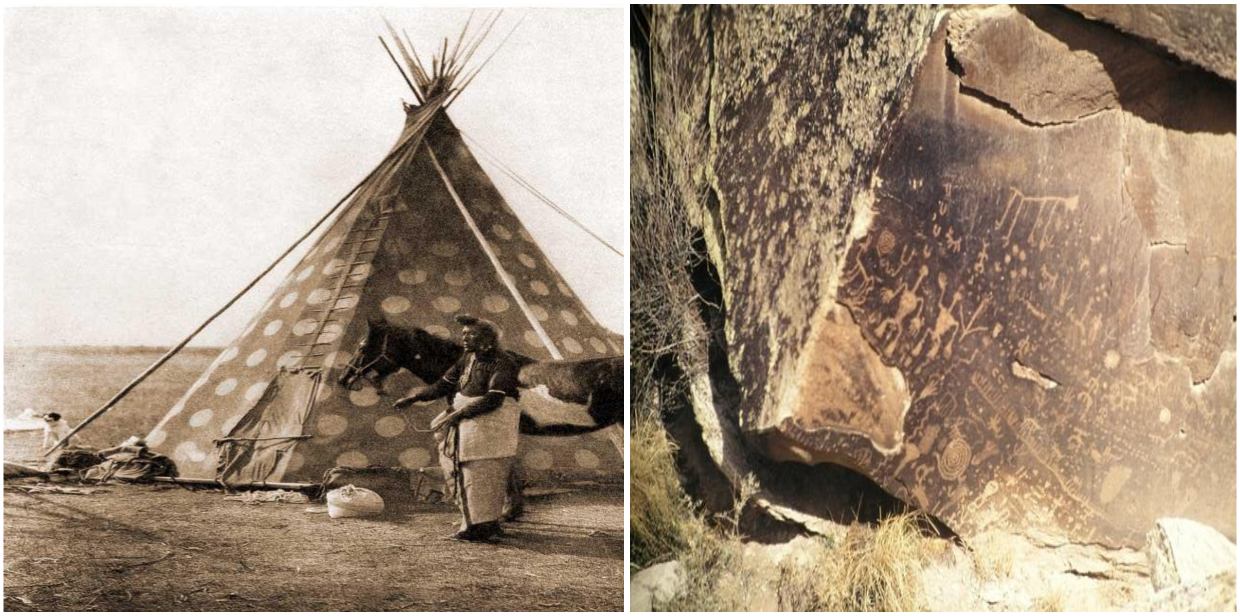


Fig 1.8, 1.9: Reconstruction of Past life ways Fig: The use and abuse of ethnographic analogy

Ethno archaeology often focuses particularly on the behavior patterns responsible for creating physical objects and their spatial distribution. The use and abuse of ethnographic analogy explaining the archaeological evidence in terms of behavior recorded in the historic and ethnographic record.

Archaeology seeks to contribute to the comprehensive understanding of human behavior. By understanding the past, we can better understand ourselves, and archaeology can help to foster an understanding of the global human experience over the span of human existence. While it is true that archaeology has yet to contribute significantly to the formulation of such knowledge, this is partly due to the difficulty in obtaining and analyzing appropriate information. As the discipline of archaeology matures, such contributions should increase.

3. Reconstruction of Cultural Process

This is the third goal from about twenty-five years that describes the past with cultural change in prehistory. Archaeologists with this goal explain cultural change, process and evolution in prehistory. The ultimate goal of these archaeologists that describe prehistory is to define evolution in culture from the ancient times. This goal leads to ‘new Archaeology’ which also called as ‘Processual Archaeology’ which describes that archaeology is more than a descriptive it is also related with science its scientific methods and designs which can explain cultural change in the past.

Fig 1.10 a,1.10 b: Modern or ancient, people have to dispose of their garbage (Fagan 1999:26-30)

4. Understanding the Archaeological record

This is about understanding sites, food remains, and other aspects of material remain as to relate to the contemporary world. As Lewis Binford writes “The archaeological record is here with is in the present”. This describes that the observation that made on artifacts and material remains with thoughts of today as they are part of present soil. The observations and translation about the past materials should be according to past conditions (Fagan 1999: 26-30).

Role of Natural Sciences in Archaeology

Late 20th-century science-here viewed in its more narrow sense as the natural sciences-is now making its share of discoveries in Old World archaeology, a field that some consider a rather esoteric pursuit, divorced from the modern world. A review of this kind might then simply be seen as a long-overdue response to our headlong plunge into a technological present and future. Computers and other "black boxes" are no longer just the province of a few scientific wizards, but are now part of everyone's life, including the archaeologist's, whether we like it or not and whether it produces worth-while results in our research or not. Since there is no turning back, we all need advice on how best to cope with this revolution and perhaps even come to enjoy it a little more.

The phrase "Archaeological Science" has fared somewhat better, but raises the hackles of both archaeologists (archaeology itself being viewed by many as a social science) and natural scientists, who do not view this as a well-developed discipline. Since "Science and Archaeology" is a similarly infelicitous just a position, I have settled on "Science in Archaeology" as the title for this research. This phrase implies that science of whatever variety (Social, Biological, Physical, etc.) has found its way into archaeology, and it is for us to decide whether it is producing worth-while results (McGovern 1995: 79).

It is not difficult to understand why science should play an important role in archaeology. The general principles and empirical procedures of stratigraphic excavation and record-keeping as well as site survey and landscape archaeology, themselves embody the empirical observation and systematization that characterize science. Unlike Chemistry and Physics (the "hard sciences"), experiments in archaeology cannot be repeated, but, like Geology or Astronomy, archaeology is concerned with evidence of past events (during the relatively short span of earth history over the past several million years) and the interpretation of that evidence within a more general theoretical context. In the historical natural sciences, a limited range of materials is subjected to a battery of analyses (material, imaging, and statistical), and interpretations are based on general scientific "laws" (uniformitarianism, the structure and mutation rates of DNA strands, the speed of light, and so forth). Even with their sophisticated tools (like the Hubble space tile-scope), there is room for disagreement on how the data should be interpreted. As just one example, not all scientists agree that the dinosaurs were warm-blooded, social creatures, or that they became extinct when an asteroid collided with the earth.

Archaeologists also aspire to generalized and de-tailed reconstructions in time and space, as well as establishing cause and effect relationships, based on an analysis of its restricted data base. Unfortunately, because of the disciplinary schizophrenia, most archaeologists are not trained in how to extract natural scientific information from their sites and the artifacts that they recover. Lacking a basic knowledge of the Natural Sciences, archaeologists are at a disadvantage in properly recovering and interpreting materials from sites that have certainly been altered by geological and biological processes and of which now mostly inorganic materials remain. Some archaeologists, recognizing the deficiency in their training, have the good sense to enlist the help of natural scientists in a multidisciplinary effort, which is the hallmark of most modern scientific projects. Unless the natural scientist's role is to be no more than "window-dressing', how-ever, there has to be a very serious attempt by all involved, archaeologist and natural scientist alike, to articulate the goals of the project in their respective "languages" and develop an effective research design for answering some significant cultural ques-tions. Placing specialist studies with little if any relationship to the archaeological interpretations at the end of an excavation report illustrates how not to do interdisciplinary research. Equally reprehensible is a scientific study of unprovenienced, possibly fake, archaeological material parading masses of data that may have been generated by the most sophisticated analytical tools available but which are archaeologically meaningless.

The communication gap between natural scientists and archaeologists is exacerbated by the human dimension, which cannot be easily factored into an interpretative schema and which makes archaeology a very "soft" science. Archaeological remains often appear to be an extension of the natural world, simply needing to be subjected to thorough physical and chemical investigation for their significance to be elucidated. In some instances, this may be true. The microstructure of a ceramic or metallurgical artifact may reveal how it was made, and by the cautious use of ethnographic analogy, even some facets of the organization of the industry. Certainly, the radiocarbon reservoir in the oceans and atmosphere was little affected by human intervention before the industrial revolution, so that one can have confidence in dates based on this technique (assuming adequate tree-ring calibration, elimination of contaminants, and statistical evaluation). On the other hand, what may appear to be the result of natural processes (e.g., pollen rain, a soil lens, or pagination on glass) might also have been affected by human activity, and cannot be explained solely by physicochemical factors.

Since scientific analyses such as a DNA and various forms of stable isotope analysis were first developed in the 1980s, these methods have increasingly gained ground in archaeology. This session aims at discussing how archaeology can benefit from and contribute to the latest scientific revolutions in a way that integrates archaeology’s approaches and results. How can cross-disciplinary collaboration provide a basis for continuing and reinforcing the theoretical developments within our discipline? We discuss problems and possibilities involved in such collaboration with a focus on how it may challenge and strengthen our interpretations and theories.

Especially during the past ten years, a massive amount of quantitative data on the origins of different materials has become available. Long-sought answers about the provenance of metals and other raw materials, or the affinity, homeland or migratory routes of humans are suddenly within reach. Data and terminology from the natural sciences have been enthusiastically welcomed and incorporated in archaeological interpretations, sometimes without serious consideration of what the results can actually say. Also, the increasing specialization seen in the different disciplines threatens to widen the gap between the humanities and the natural sciences instead of closing it. Inherent is the risk that the theoretical discussions about exchange, mobility, kinship systems, agency, ideology and materiality which characterized the archaeologies of the past three decades are left behind in the zealous claim that unequivocal answers are finally at hand thanks to cutting-edge science. Ideally, theories should arise from intersections between the disciplines rather than from one discipline serving as a supplier of conditions for the other.

In order to avoid a return to one-dimensional interpretations where migration and local evolution play the roles as mutually exclusive, self-explanatory factors, we need to approach the new data not as the final answers to old problems, but as a source of new theories. Comments upon how cross-disciplinary collaboration may strengthen the theoretical developments within both our and other disciplines are welcomed (Freestone and Vaughan 1995: 79-83).

Radiocarbon dating and establishment issues of new chronology of the Late Bronze Age in Southern Transurals

Collaboration between the natural sciences and archeology can reveal both local distinctions and international connections during the Bronze Age. From the second half of the 1990s, the traditional archeological chronology of the Late Bronze Age in the Volga-Ural region was revised. This was connected with the fact that natural sciences started to be comprehensively applied. In 1960s and 1970s the idea of a succession of population groups in the Late Bronze Age (17th–10th centuries BC) was developed. The Late Bronze Age in the Southern Trans Urals has significant amounts of archaeological monuments. The syncretic nature of the archaeological sources is characteristic for this region: evidence from the Abashevskaya, Surabaya and Alake archaeological cultures occurs in the same layer, embedded together. In 2007-2013 the first radiocarbon dates for this area were obtained (1890–1750 BC). The dates changed the chronology of the Late Bronze Age and showed the synchronous presence of two population groups in the region.

Ceramic technology, death and temporality: puzzling Migration Period choices as source of theoretical reflection

History project, which focuses on Migration Period (AD 400-550) ceramics and metalworking and seeks to integrate data from e.g. Archaeology and Geoscience. Thus far the petrographic, mineralogical, geochemical and isotope geochemical analyses of pottery from graves indicate certain puzzling technological choices. These fall within two ranges:

1) Aesthetics chosen over functionality

2) Transport of materials over longer distances while better alternatives were available locally.

Both ranges undermine the notion of past technologists as homo economics, as essentially utility-maximizing actors. This paper explores archaeology as constantly operating along the interfaces to other disciplines. Collaboration may spiral questioning and analysis into novel domains and the ensuing data may provide finer spatiotemporal resolution: a fine-grained chronology of how technological choices in production of certain grave material were linked to specific human-landscape interactions.

Genetics and anthropology: putting human genetic patterns into context

Remarkable progress has been made for methods to extract data from the bones of prehistoric people. Isotopes give us insight into diet and mobility during a lifetime, and DNA analysis allows a peak into the ancestry and kinship of the individuals. Yet the models put to use to evaluate and explain the data collected rarely rest upon critical questions about social organization, networks and kinship structures. I wish to highlight how taking anthropology into consideration, as well as known historic events and processes, is of paramount importance if we wish to understand the causes of the genetic patterns we see both in prehistory and today. DNA and isotope analysis should be used to probe and challenge the borders of material culture drawn by archaeologists. To be able to interpret the results we need to critically evaluate the source material, chronology, and geography and material culture and not view archaeological cultures as homogenous units.

A genetic approach to investigate the history of crops

Studies of pollen and macro fossils of crops constantly increase our knowledge of crop husbandry in the past. However, these studies seldom reveal more information than presence of a certain species at a time and location. DNA methodology and population genetic theory, e.g. phytogeography, could add another dimension to traditional archaeobotany and be used to model the spatial and temporal distribution of ancient crops. The power of DNA analyses however sometimes risk over-shadowing the context of the materials under investigation. Theory building of e.g. crop exchange is still vague due to unanswered questions of time-depth visible in studied materials. We discuss here how mutual efforts of geneticists and archaeologists could strengthen the study of crop history

Bimolecular Archaeology

Bimolecular Archaeology such as DNA and isotope analysis in a hauntology. The term was used in Derrida’s Specters of Marx (1993) to capture how traces of the past accumulates and leave traces that affect the future in ghost-like ways. The phenomena of hauntology has inspired film and music makers, but is keenly linked to the archaeological sciences.

Scientific approach on rituals: AMS-, OSL-, and SEM-analyses of material from Rapola cairns (Southern Finland)

The Iron Age cairn cemetery of Rapola is among the largest in Finland. An earlier and widely applied interpretation model portrays such cemeteries simply as assemblages of graves and “sacrificial cairns”. Past rituals should however not be seen in such an uncritical and shallow way. Based on artifact analyses, SEM-analysis and AMS and OSL dating’s, For example techno-compositional ceramic analysis revealed that ceramics originating from the same, presumably local, manufacture were distributed among different cairns, underpinning their socio-communal links. While scientific analyses offer new insights into old material and illuminate details of past religion, they above all raise questions that demand novel reasoning about past ritual processes. Scientific data emerges here as the core source for theories of fragmentation and sharing, which serves to answer questions about the very nature of Iron Age mortuary rituals.

Cultural heritage science: we are here not only to stay but to learn together

Archaeology today is becoming increasingly dependent on scientific techniques. The degradation of archaeological objects is understood in geological, biological, chemical, and technical terms. Therefore, a scientific approach is inevitable in order to understand long-term preservation challenges in situ, and on museum display. However, this is not "science coming to the rescue", but a consensual learning process. For the scientific community there are possibilities of new applications and development of methods and techniques. Trying to integrate complex projects within the cross-discipline cultural heritage science may be challenging but also very stimulating. The co-workers not only use different terminology, but may offer completely different interpretations on the state of preservation of archaeological objects. However, different disciplinary perspectives should be considered as vitalizing for the academic discussion and not be limited as "conflicts of interest". When finding the key to communication between archaeologists, conservators and natural scientists, the magic called cultural heritage science begin to happen (Louis and Miss. 1991).

.

Archaeology and inter-disciplinary articulation

With a few exceptions, archaeology has had limited influence on the public debate or on the development of general social theory. Archaeology has, however, benefitted from using knowledge produced in various other disciplines. There are several problems in the articulation between disciplines, in translating knowledge from one field to another, not least from fields in the humanities and social sciences to the natural sciences and exact sciences. In order to make information compatible, the particular framework in various fields must be taken into consideration to some extent. Collaboration between specialists in varied fields is crucial, but not only at a superficial level involving the exchange of data-sheets, but also through seminars and discussions. The aim of this paper is to discuss the conditions for such inter-disciplinary articulations in the case of archaeology. We believe better inter-disciplinary work will help enhance arguments and the influence from archaeology on society.

Archaeology and natural sciences: a cost-benefit evaluation

Beginning with the premise that the goal of archaeology is to obtain valid knowledge of the past, we argue that an integration of archaeology with the now many and varied relevant natural scientific disciplines must be a goal. At the same time, archaeology is an accommodating discipline and there is ample scope for different constellations of collaborative projects. Arguably, however, studies that have the greatest and longest-lasting impact on archaeology need to integrate disciplines also at an epistemological level. Such epistemological convergence requires a negotiation of the scientific and political 'corridors of power' related to funding and university politics, but may also require a significant epistemological (i.e. theoretical) shift within archaeology. True interdisciplinary comes at a price, especially when we think about the design of undergraduate and graduate curricula (St. Louis, Miss. 1991).

Archaeobotany: Macroremains

Palaeoethnobotany (or the shorter term, archaeobotany) is the study of the "direct interrelationships between humans and plants for whatever purpose as manifested in the archaeological record." No matter what the time period or geographical area, plants played an important role in human culture. As primary data about the natural environment, land-use practices, diet, architecture, and trade in exotic plant materials, plant remains also reflect many aspects of society, including social practices, such as eating, the organization of labor, and status differentiation.

The three major categories of archaeobotanical materials are macroremains, pollen, and phytoliths. Macroremains are relatively large items that generally comprise the bulk of plant remains re-covered from archaeological sites. They include seeds and seed-like plant structures, fruits, wood, leaves, tubers, etc. Typically, macroremains are recovered manually, by screening, and by flotation. Flotation enables the archaeologist to concentrate macro-remains dispersed in the site matrix, usually by dis-solving a soil sample in water.

Fig 1.11: Flotation system used to recover ancient plant remains at Gordion, Turkey, (Arbor 1969: 383-426).

No single category of remains provides a full picture of ancient plant use. When one considers the total amount of plant material intentionally brought to a site by ancient people (for food, fuel, fodder, construction, tools, and other artifacts), plus material unintentionally incorporated in the archaeobotanical record, one realizes that it is ordinarily the discards and residues of plant use that get de-posited initially, a subset of which is eventually pre-served (usually through carbonization, but some-times under dry or waterlogged conditions). Texts, too, are an important source of information that describe many aspects of the relationships between people and plants (e.g., agricultural treatises, receipts, recipes, and medical prescriptions). Yet such sources are often too limited or too general to provide more than a narrow window onto agricultural practices, the effects of land clearance, fuel-gathering, and irrigation, and all the other ways in which plants were integrated into the daily lives of ancient peoples. Thus, especially for the later periods, the information gleaned from texts complements, but does not supplant, that gained from detailed archaeobotanical studies. Although archaeologists have been saving plant remains from archaeological sites since the mid-19th century, the systematic sampling of archaeological sediments by means of flotation is a relatively recent development (Ibid).

Most of archaeobotanical work concentrated on the origins of agriculture, the major problem as defined in the United States by anthropologically trained archaeologists and in Europe by prehistorians. Now, in the 1990s, the aceramic Neolithic is increasingly well understood, but comprehensive syntheses of the later Neolithic and beyond have yet to be written. Even the early civilizations of the third millennium B.C., which have been given a fair amount of archaeobotanical attention, are poorly known. Later historical periods have been particularly ne-glected, probably because of undue reliance on writ-ten records.

Despite several decades of research, the full potential of archaeobotany for the investigation of ancient culture is yet to be realized. For both prehistoric and historical periods, plant remains enable us to assess human impact on the environment. As direct, site-specific evidence of agricultural and culinary activities, they can enrich our understanding of how people lived. Archaeobotanical research is meant to show both skeptics and the converted how bits and fragments of charred remains help create a picture of the lives of ancient people and the landscape they shaped and inhabited (Ibid).

Ancient Palynology

The study of micro- and macrofossils (including agricultural products such as carbonized hard grains - see the preceding section on Archaeobotany). Archaeology and the natural sciences work on early prehistoric sites in Iran and Turkey. The botanical investigation is an important aim of ancient palynological re-search is to reconstruct the palaeoenvironment of early humans, which includes the human impact on the environment. To obtain the optimal information from pollen samples, the nature of typical micro-fossils needs to be understood. Thousands of pollen grains are precipitated on each square inch of ground per year. Unless they are preserved under anaerobic conditions (e.g., under water), pollen will very rapidly disappear. The various pollen types are not equally sensitive to degradation, some being far more resistant than others. The identifiability of different pollen types also varies; while some pollen retain their characteristic features even after degradation, other pollen are impossible to identify even under weakly oxidative conditions.

The collection of pollen samples is done by manually coring the sediments. The samples are identified in the laboratory, using a light microscope, generally under 400 x magnifications.

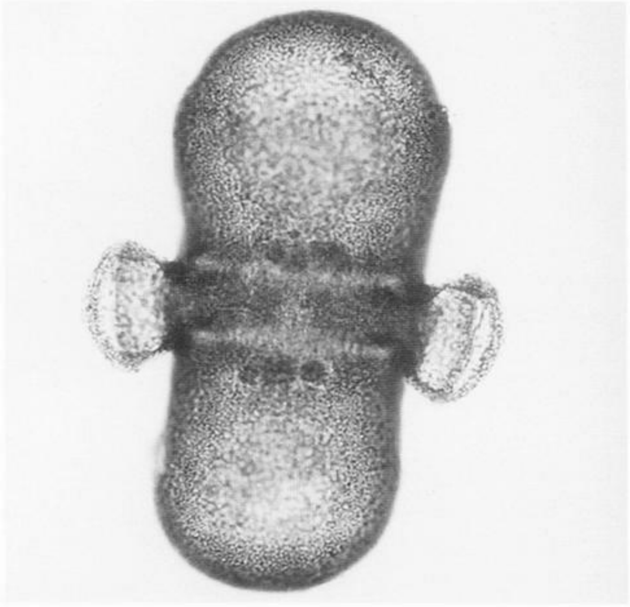


Fig 1.12: Pollen grain of Morina persica of the teasel family, measuring ca. 100, in length (90 x magnification), with prominent protuberances on the sides from which the pollen tubes grow. From a Bronze Age (Berlin 1991)

An important focus of future palynological research in the Near East will be to define the specific constraints for human settlement, especially in the forest-steppe regions. In general, the pollen evidence needs to be integrated with and interpreted in light of the results from other disciplines (e.g., Archaeobotany) and the available archaeological data to draw well-based conclusions (Ibid).

Archaeological Applications

The principal use of immunochemistry in archaeology has been to demonstrate the presence of a particular biological compound in material from an archaeological context. A typical example would be the detection of apohaemoglobin (a blood protein) in archaeological bone. To date, much of this work has largely been directed toward discovering how long biomolecules can survive in an immunologically recognizable form. So far, the direct archaeological benefits of this work have yet to be seen, but hold some promise for the detection of diseases that leave no lesions in bony tissue (Higuchi and Bowman 1993: 119-37).

In general, the applications of immunochemistry to palaeobiology and archaeology fall into the following three broad categories:

1. The demonstration of protein survival in "dinosaurs “and other fossilized species. More specifically, the degree of affinity between modern antibodies and extracted fossil antigens has

allowed a phylogenetic study of certain fossil and modern animals, such as mammoth, mastodon, and modern elephants or seals and terrestrial carnivores. Archaeologically more relevant are the studies of Neolithic and Bronze Age equids, and the preliminary work on Neanderthal, Homo erectus, Australopithecus robust us, and Cro-Magnon man. The assumption is that the affinity or degree of binding between an antibody rose against a particular protein from the modern species and an ancient antigen (the comparable protein extracted from the ancient sample) is a measure of the genetic similarity between the two species. Arguably, a better measure of this may now be provided by DNA homologies.

2. The detection of proteins in archaeological human bone and or mummified tissue. As noted above. Proteins in human bone that have been studied include apohaemoglobin (which, together with iron, is responsible for oxygen transport in the bloodstream) and albumin (the most abundant dissolved protein in serum). Complications arise with the immunochemical detection of degraded protein (see below), but potentially this approach could be used for the diagnosis of a range of diseases that are not currently visible in the archaeological record.

3. A third area of application is much more controversial -the use of immunochemical tests to identify blood residue proteins both on stone tools and as a pigment in rock art. The subject was first investigated in 1983, when T. Loy identified the species of origin of blood residues on stone tool surfaces from recrystallized hemoglobin, after confirming the presence of blood using test-strips. The latter are used as a very presumptive screening method for the detection of albumin and apohaemoglobin in fresh urine samples. Fresh samples are required, since, after one day, there is contamination by the products of bacterial metabolism that can give false positives. Myoglobin and chlorophyll, along with other porphyrin ring containing substances, also give false positives. Because of the caution with which dried blood residues are treated by forensic scientists and because it was unclear whether Loy's samples were uncontaminated, his results were greeted rather skeptically. Further work by Loy and others has now proved beyond a reasonable doubt that recognizable proteins can indeed survive for long periods, although a number of investigators still express concern about the techniques used in some of these blood residue studies. The oldest reported blood residue dates to 90,000 years ago, from Tabun Cave in Israel.

Archaeological Conservation

Every civilization has had people repairing and conserving objects of cultural importance. It is not uncommon, but always fascinating, to excavate artifacts that were repaired in antiquity. The conservation of archaeological material as we know it has slowly developed into a discipline over the past 200 years. In the 16th, 17th, and 18th centuries, much cleaning, repairing, and restoring of antiquities was done empirically by craftsmen or archaeologists and was not based on scientific principles. Heavy-handed restorations led to the alteration and sometimes destruction of a considerable amount of excavated material. By the early 19th century, reaction by archaeologists to these restorations precipitated a change resulting in a preference for antiquities in their original condition. At this time, publications also began to appear that dealt with the treatment of antiquities, as well as the analysis of the materials of which they were made. In 1888, the Royal Museums of Berlin established their Chemical Laboratory, and Friedrich Rathgen, its first director, became the first scientist hired to work in a museum laboratory. He recognized the need for a systematic approach to conservation and a scientific understanding of how and why artifacts deteriorate. Rathgen was actively involved in developing and applying physical and chemical methods to the preservation of archaeological materials, and he thus played an important role in the development of archaeological conservation as a science and profession. As similar lab-oratories were established at other museums, the number of scientists working on the conservation of artifacts grew.

Since European scientists were conducting chemical analysis on coins as early as the 18th century, it can be argued that the field has a history of 200 years; however, the individual who first engaged in the study of full-fledged archaeological science was most likely Martin J. Aitken. In 1958, he set up the “Research Laboratory for Archaeology and the History of Art” at Oxford University, and published a periodical research journal titled “Archaeometry” which means Archaeological Science (Ibid).

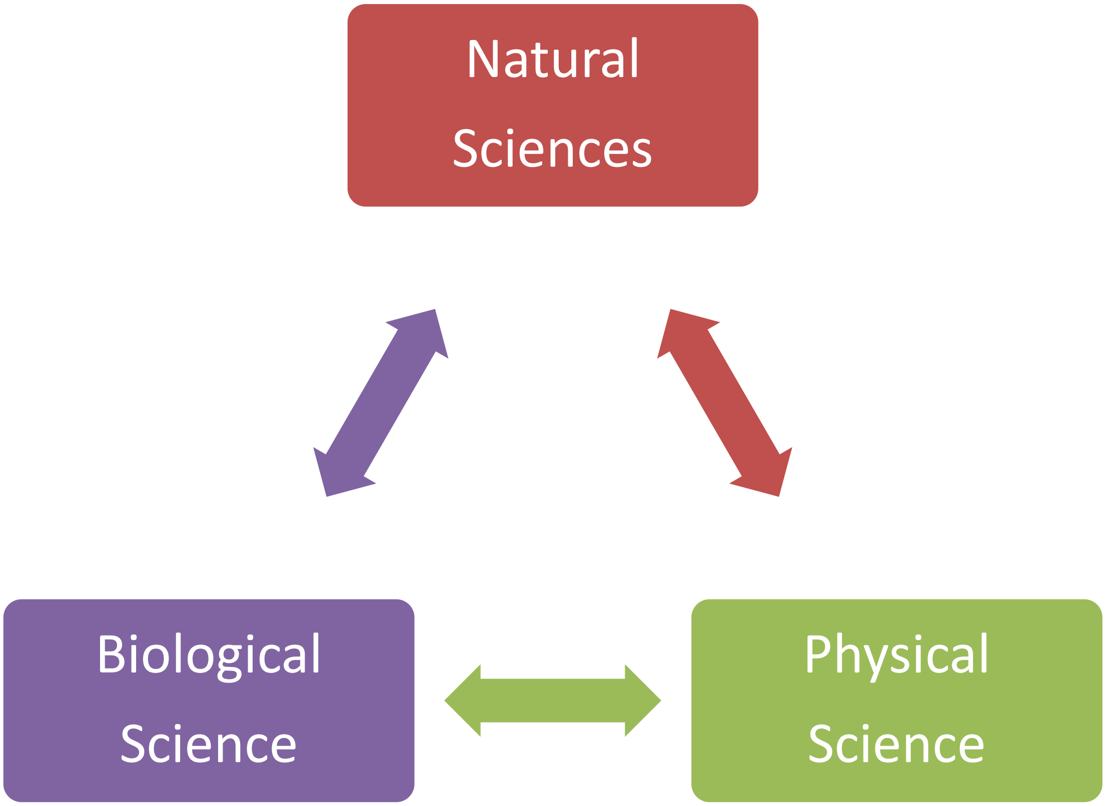
Since the aim of archaeology is the understanding of humankind. It is a humanistic discipline, a humane study. And since it deals with the human past it is a historical discipline. The scientist collects data (evidence), conducts experiments, formulates a hypothesis (a proposition to account for the data), tests the hypothesis against more data, and then in conclusion devises a model (a description that seems best to summarize the pattern observed in the data). The Archaeologist has to develop a coherent view of the natural world.

CHAPTER: 2

Application of Botany in Archaeology

Archaeology is a multidisciplinary field and every field of Social and Natural Sciences has its own value in this field. It has a tendency to absorb and adapt and to expand its lineage in other disciplines depending upon the nature of the material remain.

Natural Sciences play a massive role in archaeological research evolving it into the interdisciplinary research field. Natural Science can be broken into 2 main branches: Life Science **(Biology)** and Physical science. Each of these branches, and all of their sub-branches, are referred to as natural sciences.



By the Present Researcher

Table 2.1: Flow chart showing the sub branches of Natural Science

Biological Science

Biological sciences comprise the fields of science that involve the scientific study of living organisms such as microorganisms, plants, animals, and human beings as well as related considerations like bioethics. While Biology remains the centerpiece of the life sciences, technological advances in molecular biology and biotechnology have led to a burgeoning of specializations and interdisciplinary fields.

Some life sciences focus on a specific type of life. For example, zoology is the study of animals, while botany is the study of plants. Other life sciences focus on aspects common to all or many life forms, such as anatomy and genetics. Yet other fields are interested in technological advances involving living things, such as bio-engineering. Another major, though more specific, branch of life sciences involves understanding the mind neuroscience.

The life sciences are helpful in improving the quality and standard of life. They have applications in health, agriculture, medicine, and the pharmaceutical and food science industries.

Definition

The word **Biology** means, "The science of life", from the Greek **bios,** life, and **logos,** word or knowledge. Therefore, Biology is the science of Living Things. That is why Biology is sometimes known as Life Science.

Characteristics of Life

Not all scientists agree on the definition of just what makes up life. Various characteristics describe most living things. However, with most of the characteristics listed below we can think of one or more examples that would seem to break the rule, with something nonliving being classified as living or something living classified as nonliving. Therefore we are careful not to be too dogmatic in our attempt to explain which things are living or nonliving.

Living things are composed of matter structured in an orderly way where simple molecules are ordered together into much larger macromolecules. An easy way to remember this is **GRIMNERDC** All organisms; -
Grow, Respire, Interact, Move, Need Nutrients, Excrete (Waste), Reproduce, Death, Cells (Made of)

- Living things are sensitive, meaning they are able to respond to stimuli.
- Living things are able to grow, develop, and reproduce.
- Living things are able to adapt over time by the process of natural selection.
- All known living things use the hereditary molecule, DNA

- Internal functions are coordinated and regulated so that the internal environment of a living thing is relatively constant, referred to as homeostasis (http://en.wikibooks.org/wiki/botany 2).

The Life Science

Internal functions are coordinated and regulated so that the internal environment of a living thing is relatively constant, referred to as homeostasis. Living things are organized in the microscopic level from atoms up to cells. Atoms are arranged into molecules, and then into macromolecules, which make up organelles, which work together to form cells. Beyond this, cells are organized in higher levels to form entire multicellular organisms. Cells together form tissues, which make up organs, which are part of organ systems, which work together to form an entire organism. Of course, beyond this, organisms form populations which make up parts of an ecosystem. All of the Earth's ecosystems together form the diverse environment that is the earth. Example: - sub atoms, atoms, molecules, cells, tissues, organs, organ systems, organisms, population, community, eco systems.

Emergent property: is viewed in the biological organization of life, ranging from the subatomic level to the entire biosphere. Emergent properties are not unique to life, but biological systems are far more complex, making the emergent properties of life difficult to study.

Systems biology: is a biology-based inter-disciplinary field of study that focuses on complex interactions within biological systems, using a holistic approach.

Biologists study properties of life, with reductionist approach and holistic approach.

Nature of science

Science is a methodology for learning about the world. It involves the application of knowledge. The scientific method deals with systematic investigation, reproducible results, the formation and testing of hypotheses, and reasoning. Reasoning can be broken down into two categories, induction (specific data is used to develop a generalized observation or conclusion) and deduction (general information leads to specific conclusion). Most reasoning in science is done through induction. Science as we now know it arose as a discipline in the 17th century (http://en.wikipedia.org/2015).

Scientific method

The scientific method is not a step by step, linear process. It is an intuitive process, a methodology for learning about the world through the application of knowledge. Scientists must be able to have an "imaginative preconception" of what the truth is. Scientists will often observe and then hypothesize the reason why a phenomenon occurred. They use all of their knowledge and a bit of imagination, all in an attempt to uncover something that might be true.

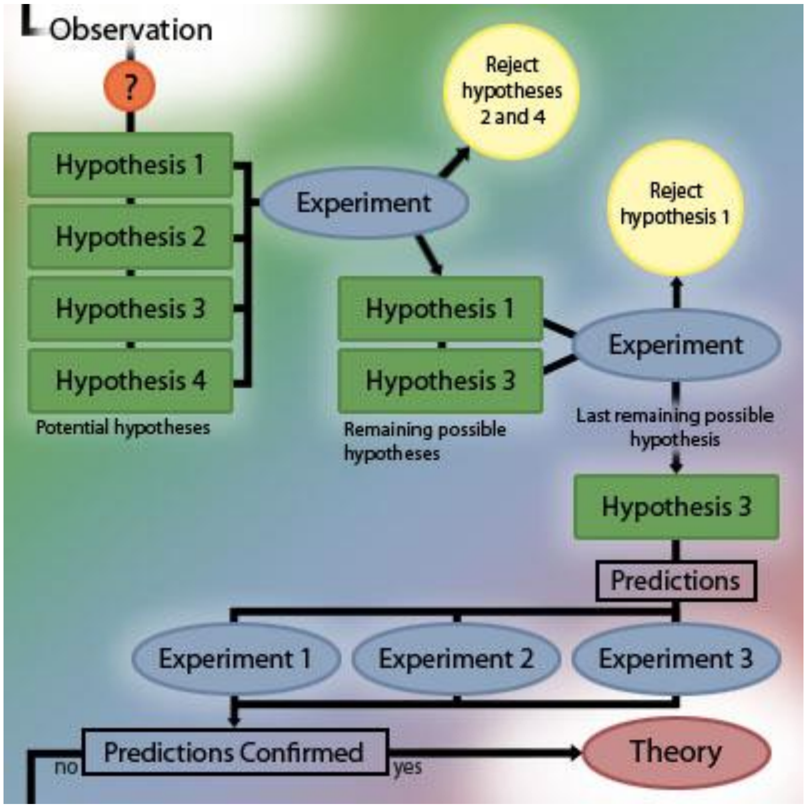


Table 2.2: A Flow Chart that illustrates scientific investigation (http://en.wikibooks.org/Scientific method).

Scientists first make observations that raise a particular question. In order to explain the observed phenomenon, they develop a number of possible explanations, or hypotheses. This is the inductive part of science, observing and constructing plausible arguments for why an event occurred. Experiments are then used to eliminate one or more of the possible hypotheses until one hypothesis remains. Using deduction, scientists use the principles of their hypothesis to make predictions, and then test to make sure that their predictions are confirmed. After many trials (repeatability) and all predictions have been confirmed, the hypothesis then may become a theory (Ibid).

History of Biological Sciences

The idea of organism-environment interaction, at least in its modern form, dates only to the mid-nineteenth century. After sketching the origins of the organism-environment dichotomy in the work of Auguste Comte and Herbert Spencer in Biology and Psychology, the environment was seen as a causal agent, highlighting questions of organismic variation and plasticity. In philosophy, organism-environment interaction provided a new foundation for ethics, politics, and scientific inquiry. Thinking about organism-environment interaction became indispensable, for it had restructured our view of the biological and social world (Lloyd 1978: 162).

Introduction

That creatures are shaped by the world around them is not news. Several centuries before the Common Era, the Hippocratic author of "Airs, Waters, and Places" argued that our forms and habits are affected by the climate, the air we breathe, and the water we drink.

The history of biology traces the study of the living world from ancient to modern times. Although the concept of biology as a single coherent field arose in the 19th century, the biological sciences emerged from traditions of medicine and natural history reaching back to Ayurveda, ancient Egyptian medicine and the works of Aristotle and Galen in the ancient Greco-Roman world. This ancient work was further developed in the middle Ages by Muslim physicians and scholars such as Avicenna. During the European Renaissance and early modern period, biological thought was revolutionized in Europe by a renewed interest in empiricism and the discovery of many novel organisms. Prominent in this movement were Vesalius and Harvey, who used experimentation and careful observation in physiology, and naturalists such as Linnaeus and Buffon who began to classify the diversity of life and the fossil record, as well as the development and behavior of organisms. Microscopy revealed the previously unknown world of microorganisms, laying the groundwork for cell theory. The growing importance of natural theology, partly a response to the rise of mechanical philosophy, encouraged the growth of natural history (although it entrenched the argument from design).

Over the 18th and 19th centuries, biological sciences such as Botany and Zoology became increasingly professional scientific disciplines. Lavoisier and other physical scientists began to connect the animate and inanimate worlds through Physics and Chemistry. Explorer-naturalists such as Alexander von Humboldt investigated the interaction between organisms and their environment, and the ways this relationship depends on geography laying the foundations for biogeography, ecology and ethology. Naturalists began to reject essentialism and consider the importance of extinction and the species. Cell provided a new perspective on the fundamental basis of life.

These developments, as well as the results from embryology and paleontology, were synthesized in Charles Darwin's theory of evolution by natural selection. The end of the 19th century saw the fall of spontaneous generation and the rise of the germ theory of disease, though the mechanism of inheritance remained a mystery

In the early 20th century, the rediscovery of Mendel's work led to the rapid development of genetics by Thomas Hunt Morgan and his students, and by the 1930s the combination of population genetics and natural selection in the "neo-Darwinian synthesis". New disciplines developed rapidly, especially after Watson and Crick proposed the structure of DNA. Following the establishment of the Central Dogma and the cracking of the genetic code, biology was largely split between organismal biology the fields that deal with whole organisms and groups of organisms and the fields related to cellular and molecular biology. By the late 20th century, new fields like genomics and proteomics were reversing this trend, with organismal biologists using molecular techniques, and molecular and cell biologists investigating the interplay between genes and the environment, as well as the genetics of natural populations of organisms (Lamarck 1801: 13-20).

Etymology of Biology

Before biology, there were several terms used for the study of animals and plants. Natural history referred to the descriptive aspects of biology, though it also included mineralogy and other non-biological fields; from the middle Ages through the Renaissance, the unifying framework of natural history was the scale nature or Great Chain of Being. Natural philosophy and natural theology encompassed the conceptual and metaphysical basis of plant and animal life, dealing with problems of why organisms exist and behave the way they do, though these subjects also included what is now Geology, Physics, Chemistry, and Astronomy. Physiology and (botanical) Pharmacology was the province of medicine. Botany, Zoology, and (in the case of fossils) Geology replaced natural history and natural philosophy in the 18th and 19th centuries before biology was widely adopted. To this day, "Botany" and "Zoology" are widely used, although they have been joined by other sub-disciplines of biology, such as mycology and molecular biology (Coleman 1975:1-2),

Ancient and Medieval Knowledge

Early Cultures

The earliest humans must have had and passed on knowledge about plants and animals to increase their chances of survival. This may have included knowledge of human and animal anatomy and aspects of animal behavior (such as migration patterns). However, the first major turning point in biological knowledge came with the Neolithic Revolution about 10,000 years ago. Humans first domesticated plants for farming, then livestock animals to accompany the resulting sedentary societies.

The ancient cultures of Mesopotamia, Egypt, the Indian subcontinent, and China, among others, produced renowned surgeons and students of the natural sciences such as Susruta and Zhang Zhongjing, reflecting independent sophisticated systems of natural philosophy. However, the roots of modern biology are usually traced back to the secular tradition of ancient Greek philosophy (Magner 1995: 3–9).

Ancient Chinese traditions

In ancient China, biological topics can be found dispersed across several different disciplines, including the work of herbologists, physicians, alchemists, and philosophers. The Taoist tradition of Chinese alchemy, for example, can be considered part of the life sciences due to its emphasis on health (with the ultimate goal being the elixir of life). The system of classical Chinese medicine usually revolved around the theory of yin and yang, and the five phases. Taoist philosophers, such as Zhuangzi in the 4th century BCE, also expressed ideas related to evolution, such as denying the fixity of biological species and speculating that species had developed differing attributes in response to differing environments (Needham, Joseph, Ronan and Alistair 1995: 101).

Ancient Indian traditions

One of the oldest organized systems of medicine is known from the Indian subcontinent in the form of Ayurveda which originated around 1500 BCE from Atharvaveda (one of the four most ancient books of Indian knowledge, wisdom and culture).

The ancient Indian Ayurveda tradition independently developed the concept of three humours, resembling that of the four humours of ancient Greek medicine, though the Ayurvedic system included further complications, such as the body being composed of five elements and seven basic tissues. Ayurvedic writers also classified living things into four categories based on the method of birth (from the womb, eggs, heat & moisture, and seeds) and explained the conception of a fetus in detail. They also made considerable advances in the field of surgery, often without the use of human dissection or animal vivisection. One of the earliest Ayurvedic treatises was the Sushruta Samhita, attributed to Sushruta in the 6th century BCE. It was also an early material medical, describing 700 medicinal plants, 64 preparations from mineral sources, and 57 preparations based on animal sources (Dwivedi 2007).

Ancient Mesopotamian traditions

Ancient Mesopotamian medicine may be represented by Esagil-kin-apli, a prominent scholar of the 11th Century BCE, who made a compilation of medical prescriptions and procedures, which he presented as exorcisms.

Ancient Egyptian traditions

Over a dozen medical papyri have been preserved, most notably the Edwin Smith Papyrus (the oldest extant surgical handbook) and the Ebers Papyrus (a handbook of preparing and using material medical for various diseases), both from the 16th Century BCE.

Ancient Egypt is also known for developing embalming, which was used for mummification, in order to preserve human remains and forestall decomposition (Moore May 2001: 13-24).

Ancient Greek and Roman traditions

Fig 2.1: Frontispiece to a 1644 version of the expanded and illustrated edition *Historia Plantarvm*, originally written by Theophrastus around 300 BC (Morgan, Sturtevant and Muller 1915).

The Pre-Socratic philosophers asked many questions about life but produced little systematic knowledge of specifically biological interest though the attempts of the atomists to explain life in purely physical terms would recur periodically through the history of biology. However, the medical theories of Hippocrates and his followers, especially humorism, had a lasting impact.

The philosopher Aristotle was the most influential scholar of the living world from classical antiquity. Though his early work in natural philosophy was speculative, Aristotle's later biological writings were more empirical, focusing on biological causation and the diversity of life. He made countless observations of nature, especially the habits and attributes of plants and animals in the world around him, which he devoted considerable attention to categorizing. In all, Aristotle classified 540 animal species, and dissected at least 50. He believed that intellectual purposes, formal causes, guided all natural processes.

Aristotle, and nearly all Western scholars after him until the 18th century, believed that creatures were arranged in a graded scale of perfection rising from plants on up to humans: the *scala naturae* or Great Chain of Being. Aristotle's successor at the Lyceum, Theophrastus, wrote a series of books on Botany the *History of Plants* which survived as the most important contribution of antiquity to Botany, even into the Middle Ages. Many of Theophrastus' names survive into modern times, such as *carpos* for fruit, and *pericarpion*for seed vessel. Dioscorides wrote a pioneering and encyclopedic pharmacopoeia, *De Materia Medica*, incorporating descriptions of some 600 plants and their uses in medicine. Pliny the

Elder, in his *Natural History*, assembled a similarly encyclopedic account of things in nature, including accounts of many plants and animals.

A few scholars in the Hellenistic period under the Ptolemies particularly Herophilus of Chalcedon and Erasistratus of Chios amended Aristotle's physiological work, even performing dissections and vivisections. Claudius Galen became the most important authority on medicine and anatomy. Though a few ancient atomists such as Lucretius challenged the teleological Aristotelian viewpoint that all aspects of life are the result of design or purpose, and teleology (after the rise of Christianity, and natural theology) would remain central to biological thought essentially until the 18th and 19th centuries. Ernst W. Mayr argued that "Nothing of any real consequence happened in biology after Lucretius and Galen until the Renaissance." The ideas of the Greek traditions of natural history and medicine survived, but they were generally taken unquestioningly in medieval Europe (Ibid).

Medieval and Islamic knowledge

The decline of the Roman Empire led to the disappearance or destruction of much knowledge, though physicians still incorporated many aspects of the Greek tradition into training and practice. In Byzantium and the Islamic world, many of the Greek works were translated into Arabic and many of the works of Aristotle were preserved.

Fig 2.2: A biomedical work by Ibn al-Nafis, an early adherent of experimental dissection who discovered the pulmonary circulation and coronary circulation (Mason and Stephen 1956: 35-39).

Fig 2.3: *De arte venandi*, by Frederick II, Holy Roman Emperor, was an influential medieval natural history text that explored bird morphology (Ibid).

During the High Middle Ages, a few European scholars such as Hildegard of Bingen, Albertus Magnus and Frederick II expanded the natural history canon. The rise of European universities, though important for the development of Physics and Philosophy, had little impact on biological scholarship (Ibid).

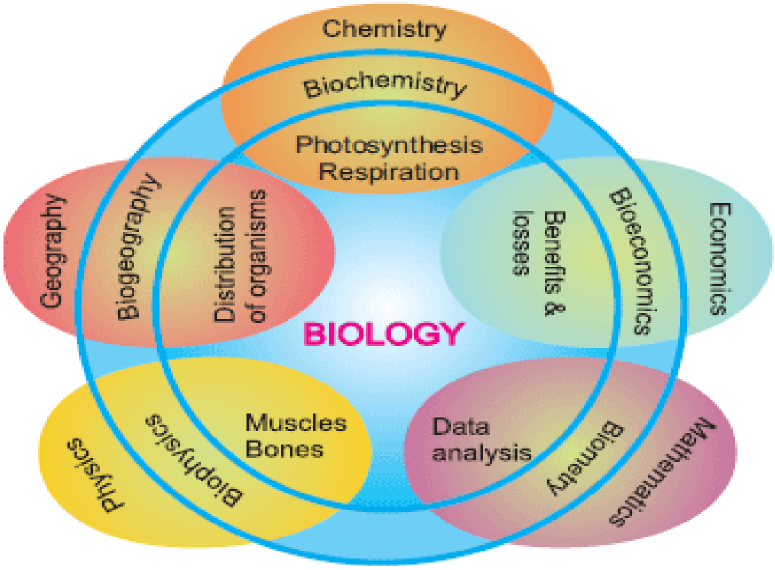
Modern Biological Sciences

At the beginning of the 21st century, modern biological sciences converged with previously differentiated new and classic disciplines like Physics into research fields like Biophysics. Advances were made in analytical Chemistry and Physics instrumentation including improved sensors, optics, tracers, instrumentation, signal processing, networks, robots, satellites, and compute power for data collection, storage, analysis, modeling, visualization, and simulations. These technology advances allowed theoretical and experimental research including internet publication of molecular biochemistry, biological systems, and ecosystems science. This enabled worldwide access to better measurements, theoretical models, complex simulations, theory predictive model experimentation, analysis, worldwide internet observational data reporting, open peer-review, collaboration, and internet publication. New fields of biological sciences research emerged including Bioinformatics, Neuroscience, Theoretical biology, Computational genomics, Astrobiology and Synthetic Biology (Sulston and John.2002:105).

Relation of Biology with other Sciences

Initially biology was a descriptive science which aimed at studying morphology of living beings and their systematic arrangement into groups and subgroups based on similarities and differences. Presently, our knowledge about living beings has reached molecular level.

It has established that living systems are made up of same kinds of atoms, molecules and organic macromolecules. Also their life processes are the result of interactions of these molecules.



By the Present Researcher

Table 2.3: Showing the relationship of biology with other disciplines

Our present knowledge in the field of biology has been achieved with the assistance of physical sciences i.e., Physics and Chemistry. This interdisciplinary or multidisciplinary approach is essential because:

1. All living organisms are composed of inorganic and organic compounds, dissolved in water.

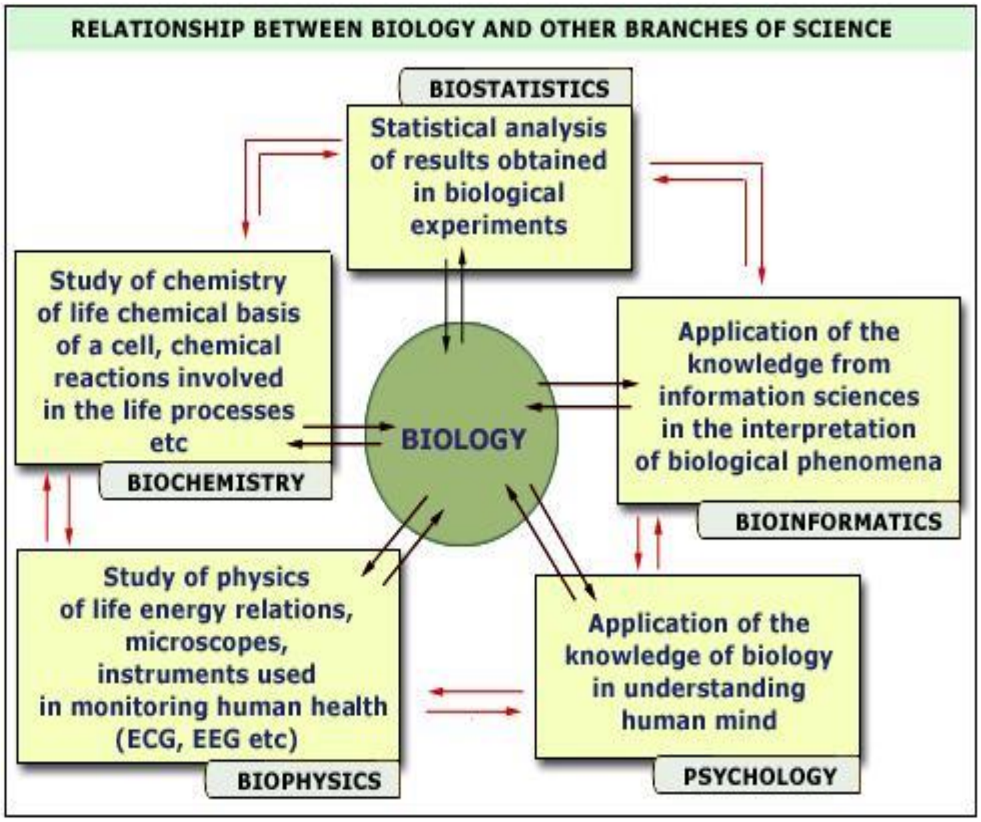
2. Inorganic compounds occur in the form of ions. These influence the internal environment of living beings and consequently the life processes.

3. Acid-base equilibrium maintains specific pH inside the organisms to afford most suitable environment for the completion of various biochemical reactions.

4. Surface tension and capillarity produced due to cohesive and adhesive force of liquids also help in certain life processes.

5. Diffusion and osmosis are responsible for the movement of ions and molecules in and out of cells.

6. Energy transfer and energy transformation are two major events in all living cells.



By the Present Researcher

Table 2.4: Show the relation between biology with other branches of science

Relation with Chemistry

- Body of all living organisms made up of organic and inorganic compounds.
- All the metabolic activities inside the body of living beings involve chemical reactions and chemical changes.
- Genetic materials DNA and RNA are also chemicals. Enzymes and hormones produced in the body of living organisms are also exclusively chemicals.
- Acid-base equilibrium in a cell maintains the pH of the protoplasm for proper functioning.
- Molecules move in and out of the cells by diffusion and osmosis.

Relation with Physics

- Biological instruments such as microscopes, X-rays, ECG etc. are based on the principles of physics.

- Light induces various effects on living organisms.
- Study on the structure and functioning of human eye require knowledge of optics.
- Physical techniques such as: electron microscopy, X-ray diffraction, fractionation, Chromatography etc. have made possible the study of finer details of cellular and sub-cellular components.

Relation with Geography

- Distribution of plants and animals vary different geographical factors e.g. Climate, altitude, temperature, etc.

Relation with Mathematics and Statistics

- Census of wild animals is based on application of mathematical and statistical applications. Such applications are helpful in data compilation and analysis of living organisms.

Relation with Sociology

- Study of human behavior, social relationship and antisocial relationships needs idea of biological science. For example, investigation on criminals and terrorists requires the study of human nervous system and study of glands, hormones, etc.
- It also requires the knowledge of principles of inheritance, pedigree analysis, etc.

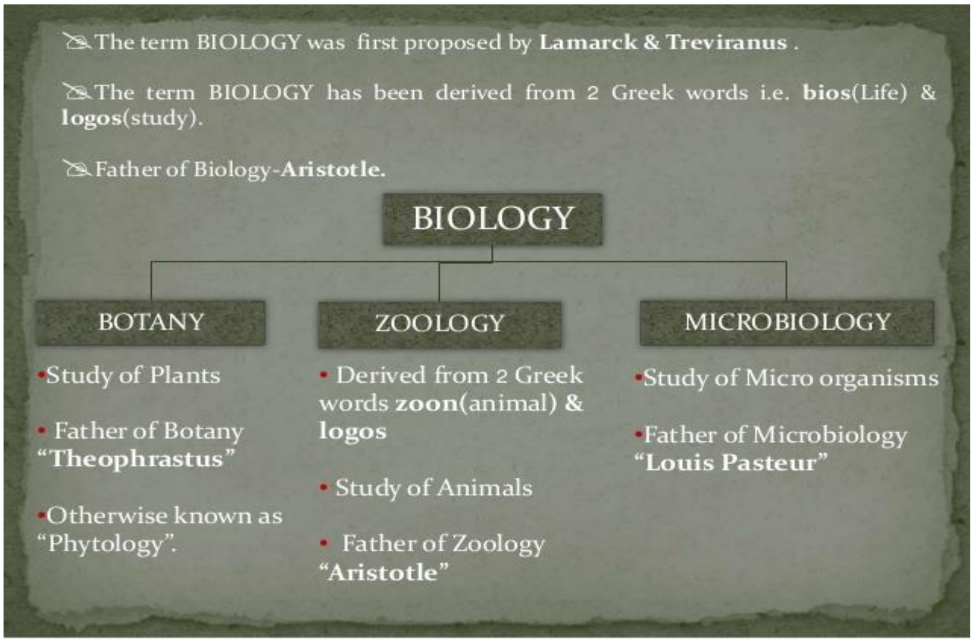
Branches of Biological Sciences

Biology is a natural science concerned with the study of life and living organisms, including their structure, function, growth, origin, evolution, distribution, and taxonomy. Sub disciplines of biology are recognized on the basis of the scale at which organisms are studied and the methods used to study them: Biochemistry examines the rudimentary chemistry of life; Molecular Biology studies the complex interactions of systems of biological molecules; Cellular Biology examines the basic building block of all life; Physiology examines the physical and chemical functions of the tissues, organs, and organ systems of an organism; and Ecology examines how various organisms interact and associate with their environment.

There are three main branches of biology

1. Botany
2. Zoology
3. Micro-biology

1.Botany: Botany is that branch of biology which deals with the study of "Plants"
2.Zoology: Zoology is that branch of biology which deals with the study of animals.
3. Micro-biology: Micro-biology is that branch of biology which deals with the study of micro-organisms such as bacteria etc.



- The term BIOLOGY was first proposed by **Lamarck & Treviranus** .
- The term BIOLOGY has been derived from 2 Greek words i.e. **bios**(Life) & **logos**(study).
- Father of Biology-**Aristotle.**

BIOLOGY

BOTANY

- Study of Plants
- Father of Botany **"Theophrastus"**
- Otherwise known as "Phytology".

ZOOLOGY

- Derived from 2 Greek words **zoon**(animal) & **logos**
- Study of Animals
- Father of Zoology **"Aristotle"**

MICROBIOLOGY

- Study of Micro organisms
- Father of Microbiology **"Louis Pasteur"**

Table 2.5: Showing the three main branches of biological sciences

These three branches are further divided into so many branches

Sub-Branches of Biology

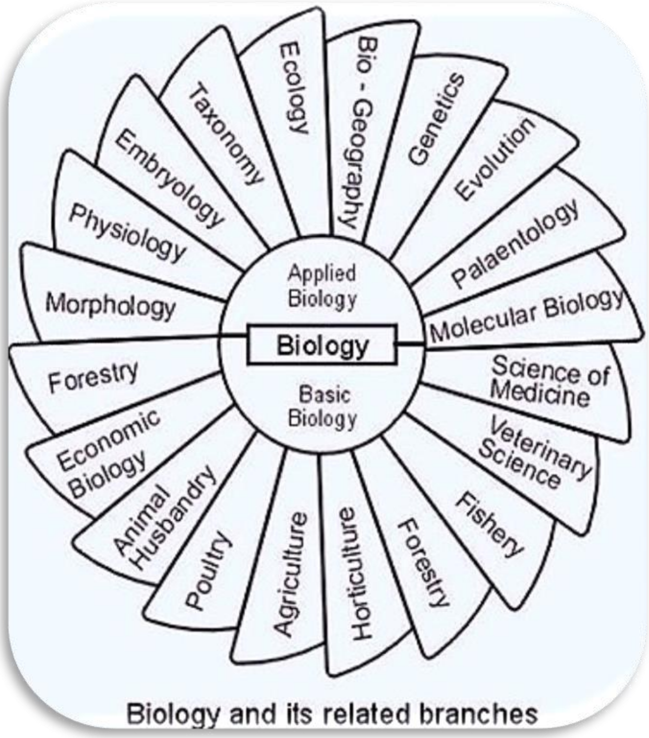


Table 2.6: Circle chart showing the sub branches of biology (www.biozoomer.com)

- **Aerobiology:** the study of airborne organic particles.

- **Agriculture**: the study of producing crops from the land, with an emphasis on practical applications.

- **Anatomy:** the study of form and function, in plants, animals, and other organisms, or specifically in humans.

- **Bioengineering:** the study of biology through the means of engineering with an emphasis on applied knowledge and especially related to biotechnology.

- **Biomathematics or Mathematical Biology:** the quantitative or mathematical study of biological processes, with an emphasis on modeling.

- **Biotechnology**: a new and sometimes controversial branch of biology that studies the manipulation of living matter, including genetic modification and synthetic biology.
- **Botany:** the study of plants.

- **Cell biology:** the study of the cell as a complete unit, and the molecular and chemical interactions that occur within a living cell.

- **Ecology:** the study of the interactions of living organisms with one another and with the non-living elements of their environment.

- **Epidemiology:** a major component of public health research, studying factors affecting the health of populations.

- **Epigenetics:** the study of heritable changes in gene expression or cellular phenotype caused by mechanisms other than changes in the underlying DNA sequence.

- **Ethology:** the study of animal behavior.

- **Evolutionary Biology:** the study of the origin and descent of species over time.

- **Genetics:** the study of genes and heredity.

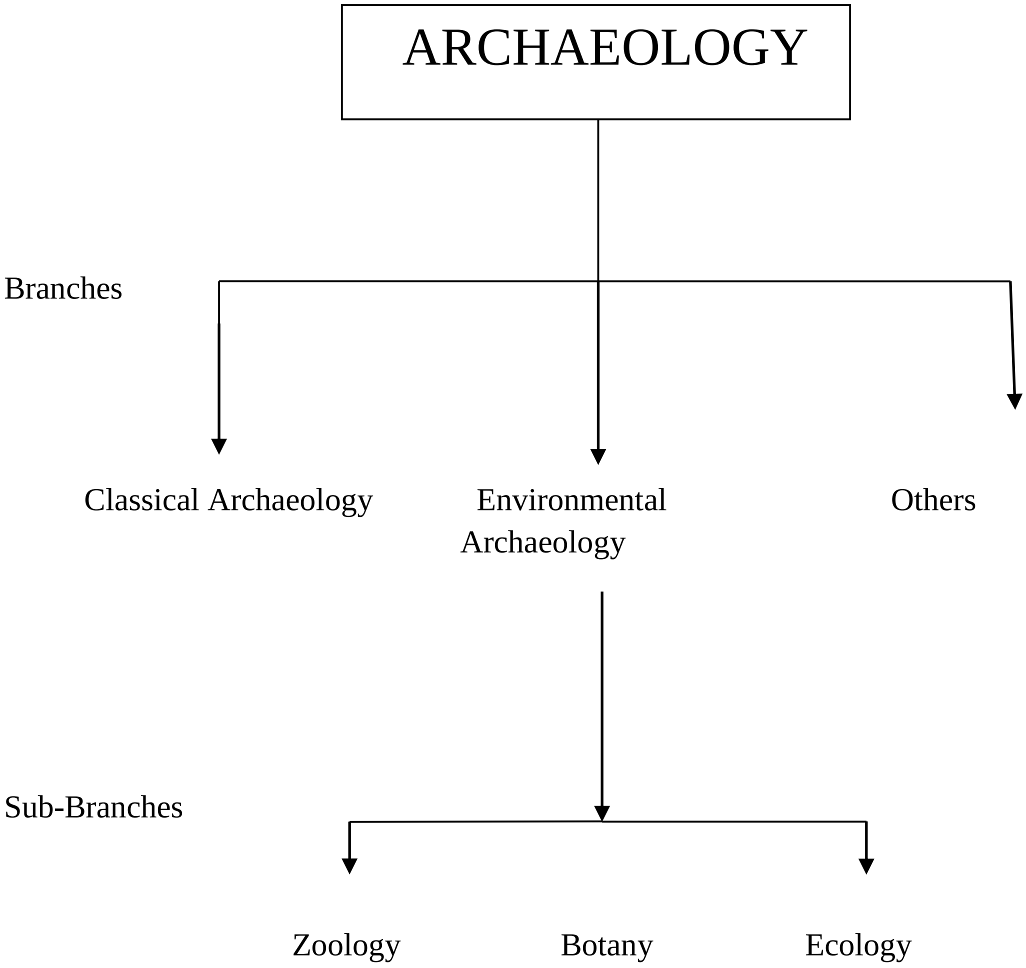
- **Herpetology:** the study of reptiles and amphibians.

- **Histology:** the study of cells and tissues, a microscopic branch of anatomy.

- **Ichthyology:** the study of fish.
- **Marine Biology:** the study of ocean ecosystems, plants, animals, and other living beings.
- **Microbiology:** the study of microscopic organisms (microorganisms) and their interactions with other living things.
- **Molecular Biology:** the study of biology and biological functions at the molecular level, some cross over with biochemistry.
- **Mycology:** the study of fungi.
- **Oceanography:** the study of the ocean, including ocean life, environment, geography, weather, and other aspects influencing the ocean.
- **Oncology:** the study of cancer processes, including virus or mutation oncogenesis, angiogenesis and tissues remolding.
- **Population genetics:** the study of changes in gene frequencies in populations of organisms.
- **Paleontology:** the study of fossils and sometimes geographic evidence of prehistoric life.
- **Pathobiology or pathology:** the study of diseases, and the causes, Parasitology — the study of parasites and parasitism.
- **Pharmacology:** the study and practical application of preparation, use, and effects of drugs and synthetic medicines.
- **Physiology:** the study of the functioning of living organisms and the organs and parts of living organisms.
- **Phytopathology:** the study of plant diseases (also called Plant Pathology).
- **Psychobiology:** the study of the biological bases of psychology.
- **Virology:** the study of viruses and some other virus-like agents.
- **Zoology:** the study of animals, including classification, physiology, development, and behavior (See also Entomology, Ethology, Herpetology, Ichthyology, Mammalogy, and Ornithology).

Environmental studies from Archaeological perspective

Environmental archaeology studies about relationship of human life in past from archaeological perspective. The relationship guided by theories and practices drawn from biological, chemical, physical and social sciences. It has sub-branches that explain different aspects of the environment related to the past peoples like Ecology, Botany, Zoology etc. (Reitz 2012: 1).



By the Present Researcher

Table 2.7: Flow chart showing branches of archaeology with special focus on sub-branches of environmental archaeology

The researcher interested in one of the important and closely related field ‘Botany’. It comprises the study of plant remains and pollen analysis to understand the interaction of humans with agriculture. Botany studies in archaeology can help for the better reconstruction of the past. Botany is an important sub-discipline in Archaeology; it studies under the root of environmental archaeology that explains about relation of people with an environment and the importance of plant in an environment and factors of environment effecting plants.

Botany

Botany is the scientific study of plants. "Plants," to most people, means a wide range of living organisms from the smallest bacteria to the largest living things the giant sequoia trees. By this definition plants include: algae, fungi, lichens, mosses, ferns, conifers and flowering plants.

Botany, the science of the vegetable kingdom, is one of the most attractive, most useful, and most extensive departments of human knowledge. It is above every other, the science of beauty (Joseph Paxton).

Botany is the branch of biology, also called plant sciences or plant biology. The term “botany” comes from the Ancient Greek word βοτάνη (*botanē*) meaning “pasture”, “grass” or “fodder.

Fig 2.4: The fruit of *Myristica fragrans*, a species native to Indonesia, is the source of two valuable spices, the red aril (mace) enclosing the dark brown nutmeg (Addelson and Barbara December 2003).

Excludes algae (live in water) and fungi (no photosynthesis) and bacteria (unicellular). All of these have been traditionally part of botany, in which plants were defined as anything that wasn’t an animal.

Traditionally, botany has also included the study of fungi and algae by mycologists and phycologists respectively, with the study of these three groups of organisms remaining within the sphere of interest of the International Botanical Congress. Nowadays, botanists study approximately 400,000 species of living organisms of which some 260,000 species are vascular plants and about 248,000 are flowering plants (Ibid).

Botany originated in prehistory as herbalism with the efforts of early humans to identify and later cultivate edible, medicinal and poisonous plants, making it one of the oldest branches of science. Medieval physic gardens (herb garden with medicinal plants), Botanical gardens developed from them, often attached to monasteries, contained plants of medical importance. They were forerunners of the first botanical gardens attached to universities, founded from the 1540s onwards. One of the earliest was the Padua botanical garden. These gardens facilitated the academic study of plants. Efforts to catalogue and describe their collections were the beginnings of plant taxonomy, and led in 1753 to the binomial system of Carl Linnaeus that remains in use to this day.

In the 19th and 20th centuries, new techniques were developed for the study of plants, including methods of optical microscopy and live cell imaging, electron microscopy, analysis of chromosome number, plant chemistry and the structure and function of enzymes and other proteins. In the last two decades of the 20th century, botanists exploited the techniques of molecular genetic analysis, including genomics and proteomics and DNA sequences to classify plants more accurately.

Modern botany is a broad, multidisciplinary subject with inputs from most other areas of science and technology. Research topics include the study of plant structure, growth and differentiation, reproduction, biochemistry and primary metabolism, chemical products, development, diseases, evolutionary relationships, systematics, and plant taxonomy. Dominant themes in 21st century plant science are molecular genetics and epigenetics, which are the mechanisms and control of gene expression during differentiation of plant cells and tissues. Botanical research has diverse applications in providing staple foods and textiles, in modern horticulture, agriculture and forestry, plant propagation, breeding and genetic modification, in the synthesis of chemicals and raw materials for construction and energy production, in environmental management, and the maintenance of biodiversity (Stopes 1912: 54).

History of Botany

The study of Botany as we know it today began when primitive people started to study plants closely. They studied plant life for self-preservation. For example, they needed to know which types of plants are edible, which can kill them if eaten or which can cure illnesses if they are sick. Most of these primitive people who studied botany were primitive witch doctors and medicine men.

Nomadic hunter-gatherer societies passed on, by oral tradition, what they knew (their empirical observations) about the different kinds of plants that they used for food, shelter, poisons, medicines, for ceremonies and rituals etc.

The uses of plants by these pre-literate societies influenced the way the plants were named and classified their uses were embedded in folk-taxonomies, the way they were grouped according to use in everyday communication.

The nomadic life-style was drastically changed when settled communities were established in about twelve centers around the world during the Neolithic Revolution which extended from about 10,000 to 2500 years ago depending on the region. With these communities came the development of the technology and skills needed for the domestication of plants and animals and the emergence of the written word provided evidence for the passing of systematic knowledge and culture from one generation to the next (Morton 1981: 2).

Plant lore and plant selection

Fig 2.5: A Sumerian harvester's sickle dated to 3000 BC (Morton 1981: 7)

During the Neolithic Revolution plant knowledge increased most obviously through the use of plants for food and medicine. All of today's staple foods were domesticated in prehistoric times as a gradual process of selection of higher-yielding varieties took place, possibly unknowingly, over hundreds to thousands of years. Legumes were cultivated on all continents but cereals made up most of the regular diet: rice in East Asia, wheat and barley in the Middle East, and maize in Central and South America. By Greco-Roman times popular food plants of today, including grapes, apples, figs, and olives, were being listed as named varieties in early manuscripts. Botanical authority William Stearn has observed that "*cultivated plants are mankind's most vital and precious heritage from remote antiquity*".

It is also from the Neolithic, in about 3000 BC, that we glimpse the first known illustrations of plants and read descriptions of impressive gardens in Egypt. However protobotany, the first pre-scientific written record of plants, did not begin with food; it was born out of the medicinal literature of Egypt, China, Mesopotamia and India. Botanical historian Alan Morton notes that agriculture was the occupation of the poor and uneducated, while medicine was the realm of socially influential shamans, priests, apothecaries, magicians and physicians, who were more likely to record their knowledge for posterity (Ibid: 7-29).

Early botany

Botany originated as herbalism, the study and use of plants for their medicinal properties. The early recorded history of botany includes many ancient writings and plant classifications. Examples of early botanical works have been found in ancient texts from India dating back to before 1100 BC, in archaic Avestan writings, and in works from China before it was unified in 221 BC (Armstrong and Hearst 1996: 228–37).

Modern botany traces its roots back to Ancient Greece, specifically to Theophrastus (c. 371–287 BC), a student of Aristotle who invented and described many of its principles and is widely regarded in the scientific community as the "Father of Botany". His major works, *Enquiry into Plants* and *On the Causes of Plants*, constitute the most important contributions to botanical science until the middle Ages, almost seventeen centuries later.

Another work from Ancient Greece that made an early impact on botany is *De Materia Medica*, a five volume encyclopedia about herbal medicine written in the middle of the first century by Greek physician and pharmacologist Pedanius Dioscorides. *De Materia Medica* was widely read for more than 1,500 years. Important contributions from the medieval Muslim world include Ibn Wahshiyya's *Nabatean Agriculture*, Abū Ḥanīfa Dīnawarī's (828–896) the *Book of Plants*, and Ibn Bassal's *The Classification of Soils*. In the early 13th century, Abu al-Abbas al-Nabati, and Ibn al-Baitar (d. 1248) wrote on botany in a systematic and scientific manner (Bird and Adrian May 2007 396-8).

In the mid-16th century, "botanical gardens" were founded in a number of Italian universities the Padua botanical garden in 1545 is usually considered to be the first which is still in its original location. These gardens continued the practical value of earlier "physic gardens", often associated with monasteries, in which plants were cultivated for medical use. They supported the growth of botany as an academic subject. Lectures were given about the plants grown in the gardens and their medical uses demonstrated. Botanical gardens came much later to northern Europe; the first in England was the University of Oxford Botanic Garden in 1621. Throughout this period, botany remained firmly subordinate to medicine (Braselton 2013).

German physician Leonhart Fuchs (1501–1566) was one of "the three German fathers of botany", along with theologian Otto Brunfels (1489–1534) and physician Hieronymus Bock (1498–1554) (also called Hieronymus Tragus). Fuchs and Brunfels broke away from the tradition of copying earlier works to make original observations of their own. Bock created his own system of plant classification.

Physician Valerius Cordus (1515–1544) authored a botanically and pharmacologically important herbal *Historia Plantarum* in 1544 and a pharmacopoeia of lasting importance, the *Dispensatorium* in 1546. Naturalist Conrad von Gesner (1516–1565) and herbalist John Gerard (1545–c. 1611) published herbals covering the medicinal uses of plants. Naturalist Ulisse Aldrovandi (1522–1605) was considered the *father of natural history*, which included the study of plants. In 1665, using an early microscope, PolymathRobert Hooke discovered cells, a term he coined, in cork, and a short time later in living plant tissue (Chaffey and Nigel 2007: 785).

In the 17th Century there was a great awakening of scientific interest all over Europe, and after the invention of the printing-press books on botany were published. Among them was the work of John Ray who wrote in 1660: *Catalogus Plantarum circa Cantabrigiam*, this initiated a new era in the study of Botany (Smith 1975: 4). Ray "influenced both the theory and the practice of botany more decisively than any other single person in the latter half of the seventeenth century" (Morton, 1981).

However no real progress was made in the scientific study of algae until the invention of the microscope in about 1600. It was Anton van Leeuwenhoek (1632–1723) who discovered bacteria and saw the cell structure of plants. His unsystematic glimpses of plant structure, reported to the Royal Society between 1678 and his death in 1723, produced no significant advances (Ibid: 180).

As adventurers explored the world more species of all animals and plants were discovered, this demanded efforts to bring order out of this quickly accumulating knowledge.

The first Australian marine plant recorded in print was collected from Shark Bay on the Western Australian coast by William Dampier who described many new species of Australian wildlife in the 17th century (Huisman, 2000: 7).

Early modern botany

During the 18th century, systems of plant identification were developed comparable to dichotomous keys, where unidentified plants are placed into taxonomic groups (e.g. family, genus and species) by making a series of choices between pairs of characters. The choice and sequence of the characters may be artificial in keys designed purely for identification (diagnostic keys) or more closely related to the natural or phyletic order of the taxa in synoptic keys. By the 18th century, new plants for study were arriving in Europe in increasing numbers from newly discovered countries and the European colonies worldwide. In 1753 Carl von Linné (Carl Linnaeus) published his Species Plantarum, a hierarchical classification of plant species that remains the reference point for modern botanical nomenclature. This established a standardised binomial or two-part naming scheme where the first name represented the genus and the second identified the species within the genus. For the purposes of identification, Linnaeus's *Systema Sexuale*classified plants into 24 groups according to the number of their male sexual organs. The 24th group, *Cryptogamia*, included all plants with concealed reproductive parts, mosses, liverworts, ferns, algae and fungi.

Increasing knowledge of plant anatomy, morphology and life cycles led to the realization that there were more natural affinities between plants than the artificial sexual system of Linnaeus had indicated. Adanson (1763), de Jussieu (1789), and Candolle (1819) all proposed various alternative natural systems of classification that grouped plants using a wider range of shared characters and were widely followed. The Candolle an system reflected his ideas of the progression of morphological complexity and the later classification by Bentham and Hooker, which was influential until the mid-19th century, was influenced by Candolle's approach. Darwin's publication of the *Origin of Species* in 1859 and his concept of common descent required modifications to the Candolle and system to reflect evolutionary relationships as distinct from mere morphological similarity.

Botany was greatly stimulated by the appearance of the first "modern" text book, Matthias Schleiden's *Grundzüge der Wissenschaftlichen Botanik*, published in English in 1849 as *Principles of Scientific Botany*. Schleiden was a microscopist and an early plant anatomist who co-founded the cell theory with Theodor Schwann and Rudolf Virchow and was among the first to grasp the significance of the cell nucleus that had been described by Robert Brown in 1831. In 1855, Adolf Fick formulated Fick's laws that enabled the calculation of the rates of molecular diffusion in biological systems (Morton 1981: 323-357).

Modern botany

The discipline of plant ecology was pioneered in the late 19th century by botanists such as Eugenius Warming, who produced the hypothesis that plants form communities, and his mentor and successor Christen C. Raunkiær whose system for describing plant life forms is still in use today. The concept that the composition of plant communities such as temperate broadleaf forest changes by a process of ecological succession was developed by Henry Chandler Cowles, Arthur Tansley and Frederic Clements. Clements is credited with the idea of climax vegetation as the most complex vegetation that an environment can support and Tansley introduced the concept of ecosystems to biology.[32][33][34] Building on the extensive earlier work of Alphonse de Candolle, Nikolai Vavilov (1887–1943) produced accounts of the biogeography, centers of origin, and evolutionary history of economic plants.

Particularly since the mid-1960s there have been advances in understanding of the physics of plant physiological processes such as transpiration (the transport of water within plant tissues), the temperature dependence of rates of water evaporation from the leaf surface and the molecular diffusion of water vapour and carbon dioxide through stomatal apertures. These developments, coupled with new methods for measuring the size of stomatal apertures, and the rate of photosynthesis have enabled precise description of the rates of gas exchange between plants and the atmosphere. Innovations in statistical analysis by Ronald Fisher, Frank Yates and others at Rothamsted Experimental Station facilitated rational experimental design and data analysis in botanical research. The discovery and identification of the auxinplant hormones by Kenneth V. Thimann in 1948 enabled regulation of plant growth by externally applied chemicals. Frederick Campion Steward pioneered techniques of micro propagation and plant tissue culture controlled by plant hormones. The synthetic auxin 2, 4

Dichlorophenoxyacetic acid or 2, 4-D was one of the first commercial synthetic herbicides (Chapman 1968: 13).

20th century developments in plant biochemistry have been driven by modern techniques of organic chemical analysis, such as spectroscopy, chromatography and electrophoresis. With the rise of the related molecular-scale biological approaches of molecular biology, genomics, proteomics and metabolomics, the relationship between the plant genome and most aspects of the biochemistry, physiology, morphology and behavior of plants can be subjected to detailed experimental analysis. The concept originally stated by Gottlieb Haberlandt in 1902 that all plant cells are totipotent and can be grown *in vitro* ultimately enabled the use of genetic engineering experimentally to knock out a gene or genes responsible for a specific trait, or to add genes such as GFP that report when a gene of interest is being expressed. These technologies enable the biotechnological use of whole plants or plant cell cultures grown in bioreactors to synthesize pesticides, antibiotics or other pharmaceuticals, as well as the practical application of genetically modified crops designed for traits such as improved yield.

Modern morphology recognizes a continuum between the major morphological categories of root, stem (caulome), leaf (phyllome) and trichome. Furthermore, it emphasizes structural dynamics. Modern systematics aims to reflect and discover phylogenetic relationships between plants. Modern Molecular phylogenetic largely ignores morphological characters, relying on DNA sequences as data. Molecular analysis of DNA sequences from most families of flowering plants enabled the Angiosperm Phylogeny Group to publish in 1998 a phylogeny of flowering plants, answering many of the questions about relationships among angiosperm families and species.

The theoretical possibility of a practical method for identification of plant species and commercial varieties by DNA barcoding is the subject of active current research (Morton 1981: 432).

The Leading Branches of botany

Botany is a natural science concerned with the study of plants. The main **branches of botany** (also referred to as "Plant science") are commonly divided into three groups:

Core topics

- Concerned with the study of the fundamental natural phenomena and processes of plant life such as,Paleobotany, Palynology the classification and description of plant diversity.

Applied topics

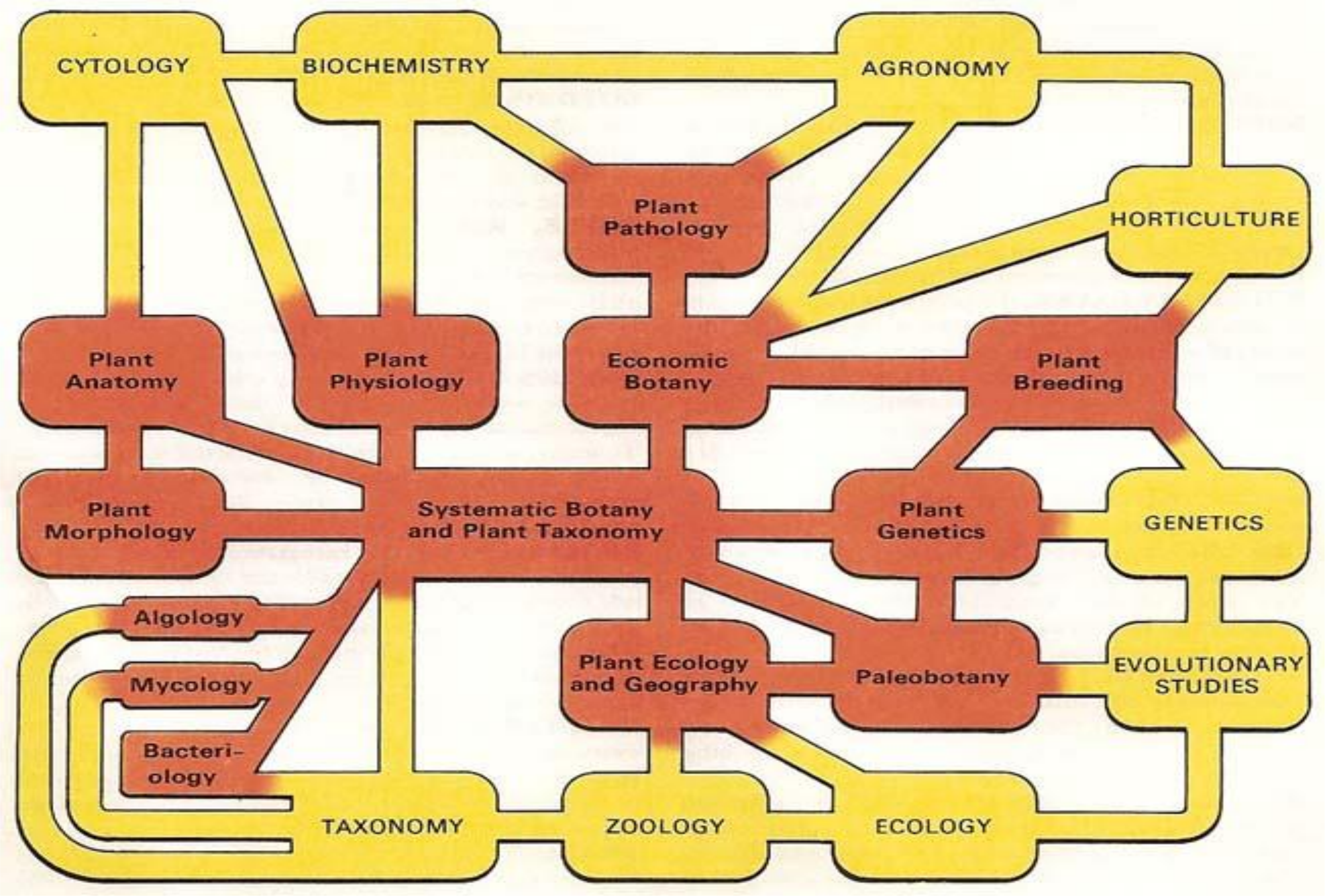
- Which study the methods in which plants may be used for economic benefit in horticulture, agriculture and forestry.

Organism topics

- Which focus on plant groups such as algae, mosses or flowering plants.

Core topics

In the group of Core topics we are study several features of the natural phenomena and processes of plant life such as, Paleobotany, Palynology etc. Plant responses to climate and other environmental changes can inform our understanding of how these changes affect ecosystem function and productivity. For example, plant phonology can be a useful proxy for temperature in historical climatology, and the biological impact of climate change and global warming. Palynology, the analysis of fossil pollen deposits in sediments from thousands or millions of years ago (Martin 1919: 97).



By the Present Researcher

Table 2.8: Flow Chart showing the branches of botany

- **Cytology:** Cell structure, chromosome number.
- **Epigenetics:** Control of gene expression.
- **Paleobotany:** Study of fossil plants and plant evolution.
- **Palynology:** Pollen and spores.
- **Plant biochemistry:** Chemical processes of primary and secondary metabolism.
- **Phenology:** Timing of germination, flowering and fruiting.
- **Phytochemistry:** Plant secondary chemistry and chemical processes.
- **Phytogeography:** Plant Biogeography, the study of plant distributions.
- **Phytosociology:** Plant communities and interactions.
- **Plant anatomy:** Structure of plant cells and tissues.
- **Plant ecology:** Role and function of plants in the environment.

- **Plant evolutionary developmental biology:** Plant development from an evolutionary perspective.
- **Plant genetics:** Genetic inheritance in plants.
- **Plant morphology:** Structure of plants.
- **Plant physiology:** Life functions of plants.
- **Plant reproduction:** Processes of plant reproduction.
- **Plant systematics:** Classification and naming of plants.
- **Plant taxonomy:** Classification and naming of plants.

Applied topics

- **Agronomy:** Application of plant science to crop production.
- **Arboriculture:** Culture and propagation of trees.
- **Biotechnology:** Use of plants to synthesize products.
- **Dendrology:** Study of woody plants, shrubs, trees and lianas.
- **Economic botany:** Study of plants of economic use or value.
- **Ethnobotany:** Plants and people. Use and selection of plants by humans.
- **Forestry:** Forest management and related studies.
- **Horticulture:** Cultivation of garden plants.
- **Marine botany:** Study of aquatic plants and algae that live in seawater.
- **Micropropagation:** Rapid propagation of plants using cell and tissue culture.
- **Pharming (genetics):** Genetic engineering of plants to produce pharmaceuticals.
- **Plant breeding:** Breeding of plants with desirable genetic characters.
- **Plant pathology (Phytopathology):** Plant diseases.
- **Plant propagation:** Propagation of plants from seed, bulbs, tubers, cuttings and grafting.
- **Pomology:** Fruit and nuts.

Organismal topics

- **Agrostology:** Grasses.
- **Bryology:** Mosses, liverworts, and hornworts.
- **Lichenology:** Lichens.
- **Mycology:** Fungi.

- **Orchidology:** Orchids.
- **Phycology:** Algae.
- **Pteridology:** Fern and their allies.
- **Synantherology:** Compositae (Martin 1919: 99-102).

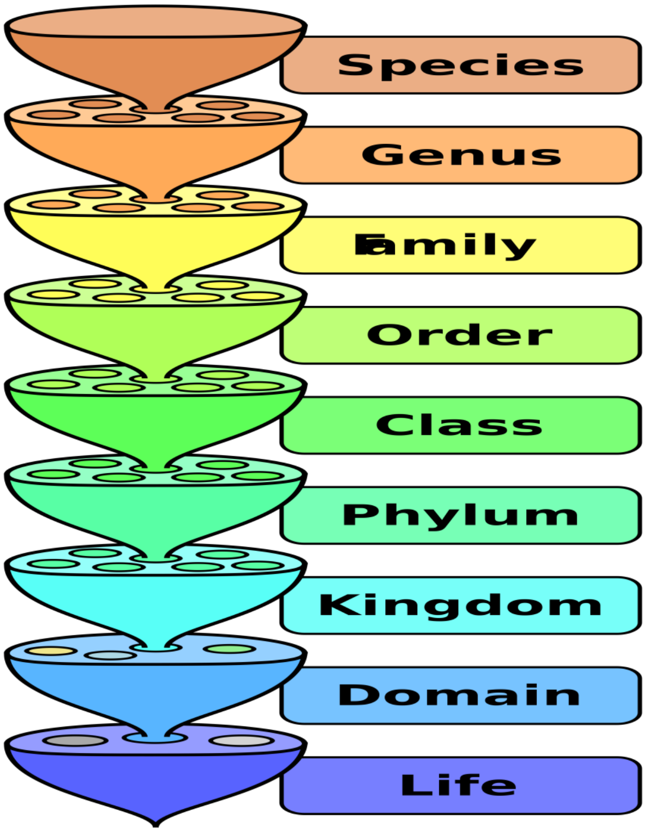
Botany is a sub-discipline of environmental science that also relates to archaeology to study about past environments. It is all about plant to study about them with every aspect under different biological disciplines which help to observe and study evolutionary process, comparative anatomy, plant behaviors, habitats, structure of ancient plants, genetics and plant physiology.

Taxonomy

In order to understand them and study them systematically, these living organisms, mainly the plants and animals are grouped under different categories. The branch of biology dealing with identification, naming and classifying the living organisms is known as **Taxonomy**. Taxonomy in Greek means rendering of order. The word **Systematics** means to put together. It was **Carolus Linnaeus** who used this word first in his book ‘**Systema Naturae’**. Systematics may be defined as the systematic placing of organisms into groups or **taxa** on the basis of certain relationships between organisms (Nalini and Rajagovidan 2005: 11).

Need for Classification

It is not possible for anyone to study all the organisms. But if they are grouped in some convenient way the study would become easier as the characters of a particular group or a family would apply to all the individuals of that group. Classification allows us to understand diversity better (Ibid).



By the Present Researcher

Table 2.9: Flow Chart of biological classification

After the recognizing about the Taxonomy, botanist should have understanding about the structure of a plant.

Core concepts of botany

- **General structure of flowering plant**

Flowering plants are complex organisms and show a wealth of diversity. To describe the distinguishing characteristics of a plant species, a large vocabulary of descriptive terms has been developed. Some of these terms are technical and often have a Latin base. From archaeological perspective, plant structures that are found from archaeological site are mostly in fossils form due to decomposition under the soil only some part of plant left behind for excavators. Part of the plant found from archaeological site is not always possible to identify about their type and specie. So to study about proper structure of the plant is very important.

Basic Structural Plan (The plant body)

A flowering plant consists of an axis divided into two main systems the root and shoot. The shoot system is composed of a stem, leaves, and flowers. Roots, stems, leaves, and flowers often are referred to as plant organs (Mujeera and Fathima 2007: 22).

- The basic parts: roots, shoots, leaves, flowers, fruits.

Most photosynthesis occurs in the **leaves**. Photosynthesis produces sugar (sucrose), which is used to feed the rest of the plant.

Water and mineral nutrients come from the soil: they are absorbed into the plant by the **roots.**

Stems hold the leaves and flowers up in the air: off the ground, above things that might block the sun, away from predators and decay organisms. Stems contain the plumbing that carries nutrients to different parts of the plant.

Flowers are the reproductive structures, which produce the plant equivalents of sperm and egg.

Fruits hold the seeds (products of reproduction) and provide nutrients and a means of dispersing the seeds to new locations (Ibid).

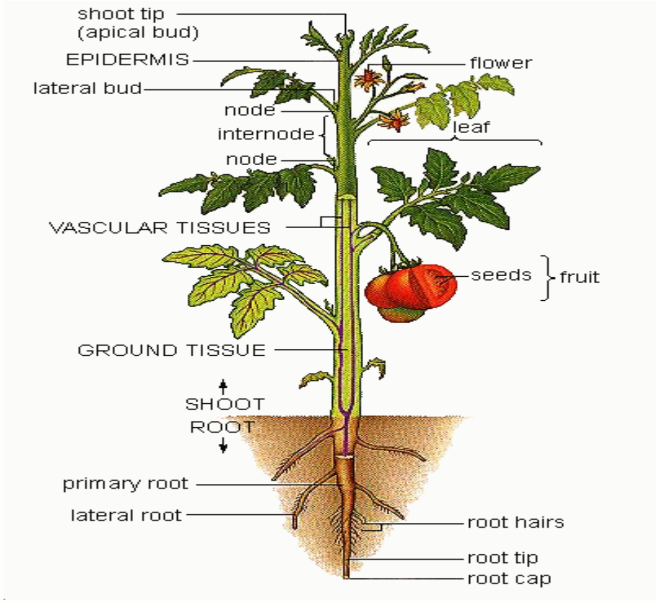


Fig 2.6: General structure of flowering plant (Mujeera Fathima 2007: 22).

- **Plant Cell**

All living things are made of cells. Plant cells are very similar to animal cells: plants and animals are both eukaryotes (as opposed to prokaryotes, which are more primitive single celled things like bacteria and archaea) eukaryote means the cell's DNA is enclosed in a nucleus all cells are surrounded by a cell membrane, which keeps the inside separated from the outside.

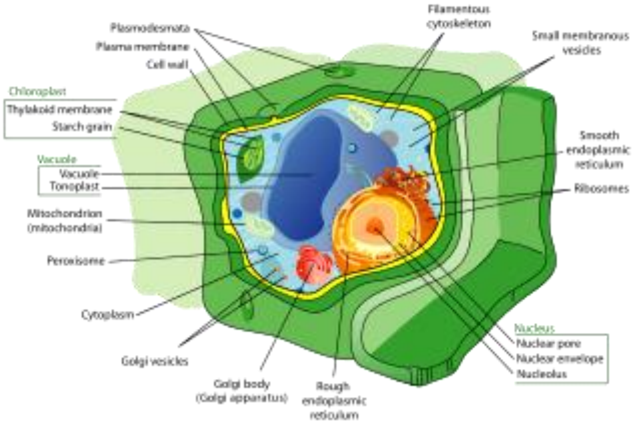


Fig 2.7: Plant Cell Structure (Ibid).

The cytoplasm is everything between the cell membrane and the nucleus. It contains lots of useful organelles which do all the metabolic activity and chemical changes needed to keep the cell alive.

- **Cell Wall**

The **cell wall** is a very tough, flexible and sometimes rigid layer that surrounds some types of cells. It surrounds the cell membrane and provides these cells with structural support and protection. In addition, the cell wall acts as a filtering mechanism. A major function of the cell wall is to act as a pressure vessel, preventing over-expansion when water enters the cell. Cell walls are found in plants, fungi and prokaryotic cells but not in mycoplasmas.

The material in the cell wall varies between species and can also differ depending on cell type and developmental stage. The primary cell wall of land plants is composed of the polysaccharides cellulose, hemicellulose and pectin. In bacteria, peptidoglycan forms the cell wall. Archaean cell walls have various compositions, and may be formed of glycoprotein S-layers, pseudo peptidoglycan, or polysaccharides. Fungi possess cell walls made of the glucosamine polymer chitin, and algae typically possess walls made of glycoproteins and polysaccharides. Unusually, diatoms have a cell wall composed of biogenic silica. Often, other accessory molecules are found anchored to the cell wall.

- **Chlorophyll**

Chlorophyll is a term used for several closely related green pigments found in cyanobacteria and the chloroplasts of algae and plants. Its name is derived from the Greek words χλωρός, *chloros* ("green") and φύλλον, *phyllon* ("leaf"). Chlorophyll is an extremely important biomolecule, critical in photosynthesis, which allows plants to absorb energy from light. Chlorophyll absorbs light most strongly in the blue portion of the electromagnetic spectrum, followed by the red portion. Conversely, it is a poor absorber of green and near-green portions of the spectrum, hence the green color of chlorophyll-containing tissues. Chlorophyll was first isolated and named by Joseph Bienaimé Caventou and Pierre Joseph Pelletier in 1817.

Fig 2.8: Chlorophyll (Ibid).

- **Chloroplasts**

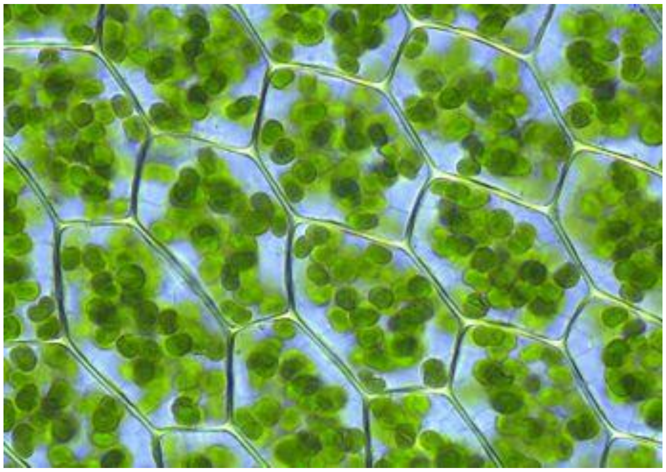


Fig 2.9: Chloroplasts (Ibid).

Chloroplasts are organelles, specialized subunits, in plant and algal cells. Their discovery inside plant cells is usually credited to Julius von Sachs (1832–1897), an influential botanist and author of standard botanical textbooks sometimes called "The Father of Plant Physiology". Their main role is to conduct photosynthesis, where the photosynthetic pigment chlorophyll captures the energy from sunlight and converts it and stores it in the energy-storage molecules ATP and NADPH while freeing oxygen from water. They then use the ATP and NADPH to make organic molecules from carbon dioxide in a process known as the Calvin cycle. Chloroplasts carry out a number of other functions, including fatty acid synthesis, much amino acid synthesis, and the immune response in plants. The number of chloroplasts per cell varies from 1 in algae up to 100 in plants like Arabidopsis and wheat.

- **Photosynthesis**

Photosynthesis uses energy from light to convert carbon dioxide (CO_2) into sugar. Occurs in the chloroplasts, which were once free-living bacteria that got swallowed up by endosymbiosis. In other parts of the plant, chloroplasts get used for storage of food or other pigments (like in flowers). Two parts to photosynthesis: **Light Reactions** (occur only in the light) and the **Calvin Cycle** (occurs in both light and dark).

Light Reactions: Light energy is captured by chlorophyll and used to extract electrons from water, which converts it to oxygen.

Calvin Cycle: The high energy electrons are used to convert carbon dioxide into sugar. This is called carbon fixation.

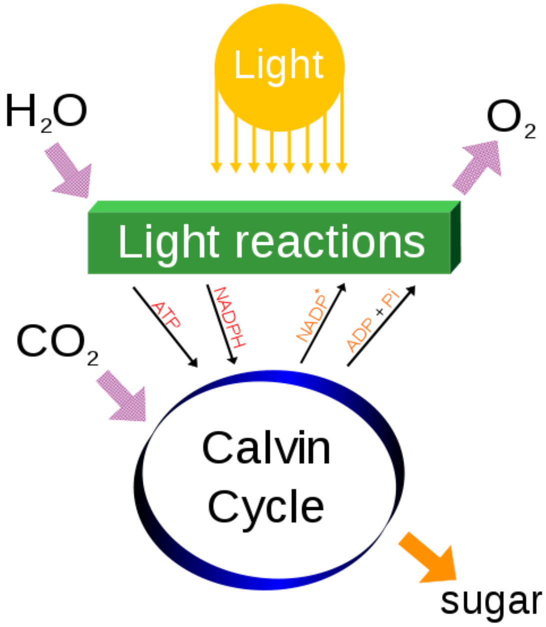


Fig 2.10: Process of Photosynthesis (Ibid).

- **Bud**

In botany, a **bud** is an undeveloped or embryonic shoot and normally occurs in the axil of a leaf or at the tip of the stem. Once formed, a bud may remain for some time in a dormant condition, or it may form a shoot immediately. Buds may be specialized to develop flowers or short shoots, or may have the potential for general shoot development. The term bud is also used in zoology, where it refers to an outgrowth from the body which can develop into a new individual.

Fig 2.11: Structure of flower buds (Ibid).

- **Flora**

Fig 2.12: Plant species diversity (Ibid).

Flora is the plant life occurring in a particular region or time, generally the naturally occurring or indigenous native plant life. The corresponding term for animal life is fauna. *Flora*, *fauna* and other forms of life such as fungi are collectively referred to as biota. Sometimes bacteria and fungi are also referred to as flora, as in the terms gut flora or skin flora.

- **A Flower**

Fig 2.13: A poster with flowers or clusters of flowers produced by twelve species of flowering plants from different families (Ibid).

Flower sometimes known as a bloom or blossom, is the reproductive structure found in flowering plants (plants of the division Magnoliophyta, also called Angiosperms). The biological function of a flower is to effect reproduction, usually by providing a mechanism for the union of sperm with eggs. Flowers may facilitate outcrossing (fusion of sperm and eggs from different individuals in a population) or allow selfing (fusion of sperm and egg from the same flower). Some flowers produce diaspores without fertilization (parthenocarpy). Flowers contain sporangia and are the site where gametophytes develop. Flowers give rise to fruit and seeds. Many flowers have evolved to be attractive to animals, so as to cause them to be vectors for the transfer of pollen.

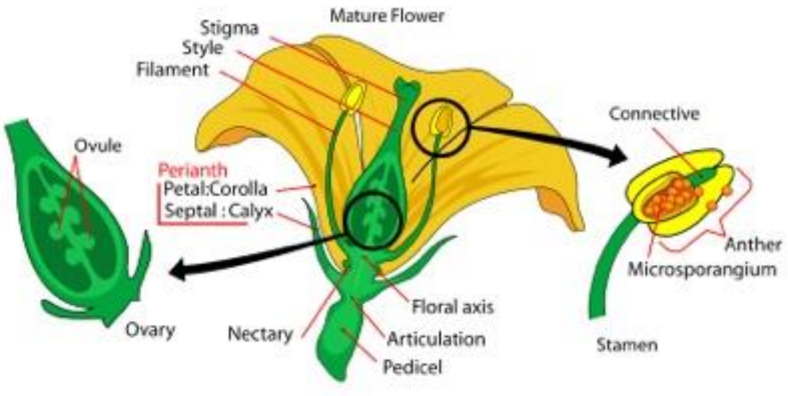


Fig 2.14: Diagram showing the parts of the flower (Ibid).

In addition to facilitating the reproduction of flowering plants, flowers have long been admired and used by humans to beautify their environment, and also as objects of romance, ritual, religion, medicine and as a source of food.

- **Fruit**

In botany, a **fruit** is a part of a flowering plant that derives from specific tissues of the flower, one or more ovaries, and in some cases accessory tissues. Fruits are the means by which these plants disseminate seeds. Many of them that bear edible fruits, in particular, have propagated with the movements of humans and animals in a symbiotic relationship as a means for seed dispersal and nutrition, respectively; in fact, humans and many animals have become dependent on fruits as a source of food. Fruits account for a substantial fraction of the world's agricultural output, and some (such as the apple and the pomegranate) have acquired extensive cultural and symbolic meanings. The section of a fungus that produces spores is also called a fruiting body.

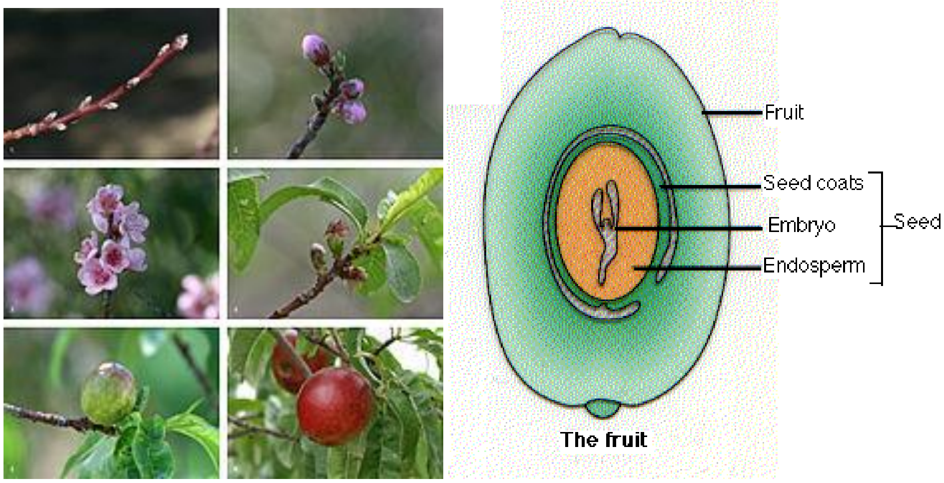


Fig 2.15 a, 2.15 b: The development sequence of a typical drupe, the nectarine (*Prunus persica*) over a 7.5 month period, from bud formation in early winter to fruit ripening in midsummer (see image page for further information (Ibid).

- **Pollen**

Pollen is a fine to coarse powder containing the micro gametophytes of seed plants, which produce the male gametes (sperm cells). Pollen grains have a hard coat made of sporopollenin that protects the gametophytes during the process of their movement from the stamens to the pistil of flowering plants or from the male cone to the female cone of coniferous plants. If pollen lands on a compatible pistil or female cone, it germinates, producing a pollen tube that transfers the sperm to the ovule containing the female gametophyte. Individual pollen grains are small enough to require magnification to see detail. The study of pollen is called palynology and is highly useful in Paleoecology, Paleontology, Archaeology, and Forensics.

Pollen in plants is used for transferring haploid male genetic material from the anther of a single flower to the stigma of another in cross-pollination. In a case of self-pollination, this process takes place from the anther of a flower to the stigma of the same flower.

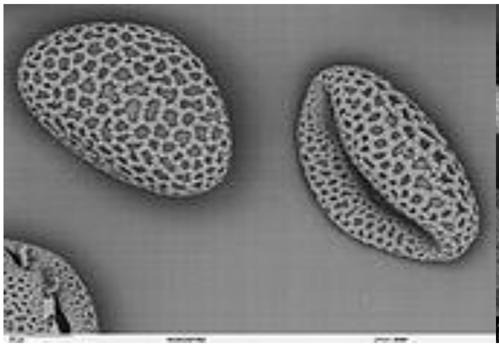


Fig 2.16 a: Pollen of Lilium auratum showing single sulcus (monosulcate)

Fig 2.16 b: *Arabis* pollen has three colpi and prominent surface structure (Ibid).

- **A Seed**

A **seed** is an embryonic plant enclosed in a protective outer covering known as the seed coat.

It is a characteristic of spermatophytes (gymnosperm and angiosperm plants) and the product of the ripened ovule which occurs after fertilization and some growth within the mother plant. The formation of the seed completes the process of reproduction in seed plants (started with the development of flowers and pollination), with the embryo developed from the zygote and the seed coat from the integuments of the ovule.

Seeds have been an important development in the reproduction and spread of gymnosperm and angiosperm plants, relative to more primitive plants such as ferns, mosses and liverworts, which do not have seeds and use other means to propagate themselves. This can be seen by the success of seed plants (both gymnosperms and angiosperms) in dominating biological niches on land, from forests to grasslands both in hot and cold climates.

The term "seed" also has a general meaning that antedates the above anything that can be sown, e.g. "seed" potatoes, "seeds" of corn or sunflower "seeds". In the case of sunflower and corn "seeds", what is sown is the seed enclosed in a shell or husk, whereas the potato is a tuber.

Many structures commonly referred to as "seeds" are actually dry fruits. Plants producing berries are called baccate. Sunflower seeds are sometimes sold commercially while still enclosed within the hard wall of the fruit, which must be split open to reach the seed. Different groups of plants have other modifications, the so-called stone fruits (such as the peach) have a hardened fruit layer (the endocarp) fused to and surrounding the actual seed. Nuts are the one-seeded, hard-shelled fruit of some plants with an indehiscent seed, such as an acorn or hazelnut.

Fig 2.17 a: Brown flax seeds

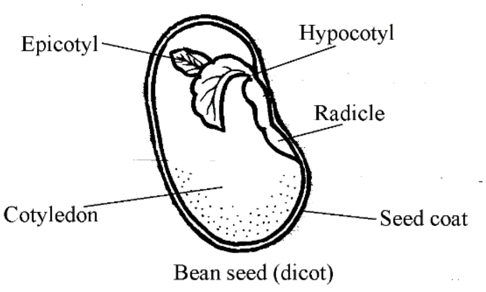


Fig 2.17 b: Bean seed (Ibid).

- **A Spore**

In biology, a **spore** is a unit of asexual reproduction that may be adapted for dispersal and for survival, often for extended periods of time, in unfavorable conditions. By contrast, gametes are units of sexual reproduction. Spores form part of the life cycles of many plants, algae, fungi and protozoa. Bacterial spores are not part of a sexual cycle but are resistant structures used for survival under unfavorable conditions. Myxozoan spores release amoebulae into their hosts for parasitic infection, but also reproduce within the hosts through the pairing of two nuclei within the plasmodium, which develops from the amoebula.

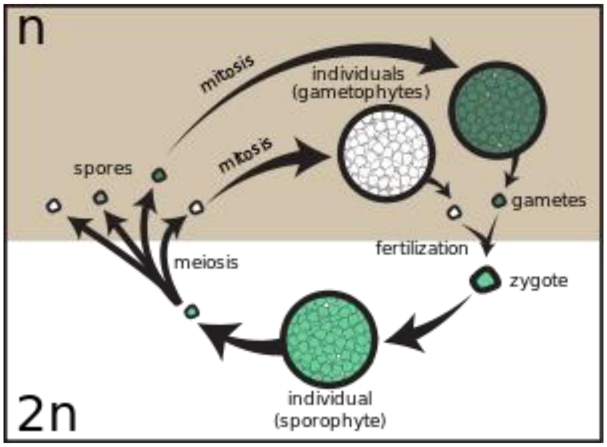


Fig 2.18: Spores produced in a spore’s life cycle (Ibid).

Spores are usually haploid and unicellular and are produced by meiosisin the sporangium of a diploid sporophyte. Under favorable conditions the spore can develop into a new organism using mitotic division, producing a multicellular gametophyte, which eventually goes on to produce gametes. Two gametes fuse to form a zygote which develops into a new sporophyte. This cycle is known as alternation of generations.

The spores of seed plants, however, are produced internally and the megaspores, formed within the ovules and the microspores are involved in the formation of more complex structures that form the dispersal units, the seeds and pollen grains (Ibid: 22-65).

Kinds of plants

Categorizing is an important process by which we humans gain understanding of the world around us, and something we all do to some degree as part of our observation of things and events that we encounter. In biology, as the concept of evolution was formulated, it became obvious that this concept could be the basis for categorization.

If plants that are similar in form are indeed closely related at least more closely related than plants that are dissimilar in form then a system of classification could be devised that reflected these relationships. This approach has important implications. Related plants have common properties, a fact that can be exploited in agriculture and other practical botanical fields (Kim and Archibald 2009: 13).

Some Types of Plants Used in Testing, Research and Education.

Major plant groups

- **Algae**
    - Cyanobacteria
    - Brown algae
    - Charophyta
    - Chlorophyta
    - Desmid
    - Diatom
    - Red algae
    - Green algae
- **Bryophytes**
    - Anthocerotophyta (hornworts)
    - Bryophyta (mosses)
    - Marchantiophyta (liverworts)
- **Pteridophytes**
    - Lycopodiophyta (club mosses)
    - Pteridophyta (ferns&horsetails)
    - Rhyniophyta (early plants)
- **Gymnosperms**
    - Pteridospermatophyta (seed "ferns")
    - Cycadophyta

- Ginkgophyta
- Gnetophyta
- Pinophyta (conifers)

- **Angiosperms**
  - Dicotyledon
    - Asteraceae (sunflower family)
    - Cactaceae (cactus family)
    - Fabaceae (legume family)
    - Lamiaceae (mint family)
    - Rosaceae (rose family)
  - **Monocotyledon**
    - Araceae (arum family)
    - Arecaceae (palm family)
    - Iridaceae (iris family)
    - Orchidaceae (orchid family)
    - Poaceae (grass family) (Kim and Archibald 2009: 13-17).

Application of Botany in Archaeology

This research explores the close links between botany and archaeology. It explains the kinds of palaeobotanical remains that archaeologists can recover and the methods used to analyse them. The importance of iconographic and textual evidence is also underlined. Examples of key research areas that focus on ancient plants are discussed: diet and palaeoeconomy, medicines, poisons, psychotropics, perfumes, cosmetics, dyes and prestige.

Botany meets archaeology: people and plants in the past

Archaeology is more often associated with the discovery of tombs, temples, and palaces than with plants. Yet small and fragile plant remains can be every bit as valuable, if not more so, than these large, permanent structures in providing information about human life in the past. During the eighteenth and early nineteenth centuries, archaeology fell under the broad umbrella of natural sciences, and by the start of the twentieth century, botanists, geologists, and zoologists were working with archaeologists to research a shared interest in the past (Wilkinson and Stevens 2008).

It is only in the last 50 years, however, that archaeologists have truly realized the wealth of knowledge that can be gained from a careful collection and study of ancient botanical remains and have developed analytical techniques and research questions accordingly. This has led to the rise of specialists within archaeology who focus on palaeobotany (palaeobotanists or archaeobotanists), although the corresponding increase in the resulting specialist analyses has contributed to a distinction between ‘science’ and ‘interpretation’ in perceptions and publications.

Fig 2.19: Fossilized plants of the Pennsylvanian sub period of the Carboniferous period (Ibid).

This research explores the techniques used by archaeologists to recover ancient botanical material, explains what can and cannot be recovered, and then discusses some of the key areas of research that have been approached using floral remains specifically. The emphasis is on the agriculture of Classical world of ancient Ghandara Civilization, although palaeobotanical remains and the social practices they represent occur across the world (Ibid).

At the crossroads of Botany and Archaeology

Palaeobotany deals with the reconstruction of ancient climate and ecological systems through the study of plant fossils. Palaeobotanical remains can be divided in two types: **Macrofossils** and **Microfossils**. Macrofossils include among others, charcoal, impressions on clay and grains. Microfossils need magnification to be visible and generally are pollen (palynology) and phytoliths. Phytoliths, from Greek “plant stone”, are silica deposits in plant tissues that survive after plant death. To recover the pollen, usually sediment cores are extracted of environments was pollen is preserved, like lacustrine areas. Phytoliths generally provide better information since with pollen many times the identification can be done only at the genus level (e.g. *Quercus*).

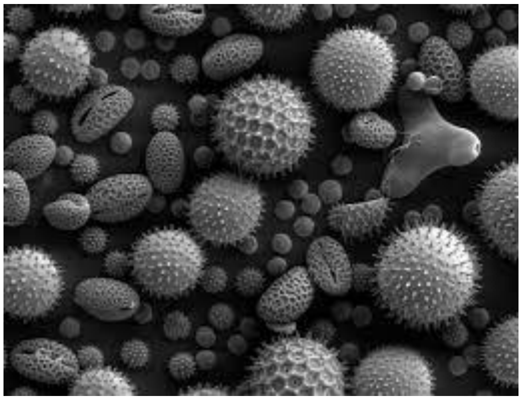


Fig 2.20: Scanning electron microscope image of pollen grains from a variety of common plants (Marino August 1, 2013).

Molecular biology studies, as genetic analysis, are now also very helpful to gain information from paleobotanical remains. For example, DNA was isolated from classical amphoras from Chios and revealed that they contained olive (*Olea europaea*), oregano (*Origanum vulgare*) and *Pistacia* species (Ibid).

Forensic Botany or the uses of Plants in Criminal Investigations

Forensic botany is the application of plant sciences to criminal investigations. A relatively new discipline, forensic botany incorporates several sub-disciplines: palynology (the study of pollens), dendrochronology (the study of tree rings), limnology (the study of aquatic environments), systematics (the classification of plants), ecology (the study of ecosystems), and molecular biology.

Unlike forensic anthropologists, forensic botanists do not normally deal with human remains. Their primary role in an investigation is in making connections between evidence and a crime. For example, pollen can be used to connect a suspect to a victim or scene. Pollen is a powder-like substance released by plants as part of their reproductive cycle. Since it is produced in large volumes and is easily transported by wind, pollen grains are often found on clothes, hair or skin. If investigators find a rare plant type near a murder victim, the presence of its pollen on a suspect could place them at the scene. Even for common plants, each environment has its own unique combination of pollens, and this 'signature' can link an individual or object to a location. Pollen signatures may also indicate that a body has been moved or suggest the type of area where the original crime took place (Hansen 2006).

Ancient DNA (a-DNA)

Ancient DNA any DNA recovered from biological samples can provide a direct approach to reconstructing history of life

- Bones and scales

- Preserved seeds and resting eggs
- Permafrost and ice samples
- Fossil animals
- Fossil plant material (seeds, pollen)
- Sediments

a-DNA may provide insights into extant and extinct populations and species and inform us about biological change through time.

In theory, could provide ‘**evolutionary time travel**’ to explore empirically how biota and species, including *Homo sapiens*, have responded to environmental change. Results are of importance to biologists, ecologists, phylogeographers, anthropologists, medical scientists, geneticists, climatologists, and archaeologists and economists interested in the economies of past civilisations.

a-DNA was, in 2010, considered one of the top ten ‘**big ideas**’ of the decade, leading to

- Draft nuclear sequence of Neanderthals
- Discovery of a new hominid from Denisova Cave in Siberia.

Ancient Plant DNA

Plant diaspores, tissues and wood are preserved in natural and anthropogenic sediments. Also, over the past centuries, plants have been collected in herbaria. These plant remains carry macroscopic and molecular information, making them a rich source for reconstructing past plant use, agriculture, diet or vegetation they are thus proxies for past economies, ecology, migrations or trade. The application of ancient DNA analyses from plants excavated at archaeological sites. A short methodological section is added to illustrate possibilities and limitations of ancient DNA research in plants. Keywords Plant macroremains Ancient DNA Cereals Fruit Wood Genetics Introduction After death DNA is degraded by various biotic and abiotic processes, resulting in fragmentation and modification of original sequence information (Stiller 2006).

a-DNA from plants extracted from permafrost soils, dry cave earths, lake sediments, fossil pollen, fossil seeds, fossil wood in archaeological sites, peat, rodent middens

Also bacterial and fungal DNA from lake sediments and permafrost soils. a-DNA preserved in varying amounts and with varying preservation in a range of sedimentary environments – not necessarily of great age.

Wood remains	1000 yrs	Liepelt *et al*. (2006)
Peat	10-450 yrs	Suyama *et al*. (2008)
Bacteria	7000 yrs	Madeja *et al*. (2009)
Leaves	17-20 million yrs	Kim *et al*. (2004)

Ancient DNA and pollen

So far, the organisms that produced the a-DNA are not all known and a-DNA is being used as a means of identification.

Alternative approach is to extract a-DNA from identified fossils to reconstruct past lineages. Pollen contains haploid DNA and is the means of dispersal to haploid DNA of ovules. Consists of 2-3 haploid cells (large vegetative cells including several plastids and mitochondria). Organelle DNA is thus present in pollen.

These DNA fragments still contain information which may help us to understand agricultural or vegetation history. Archaeobotanists reconstruct the past by morphological analysis of all types of plant remains. Interpretation of botanical remains through morphological evidence has many advantages: the analysis is comparatively quick, technically simple and extensive reference collections are available to help interpretation (Burger 1999).

Recovery of palaeobotanical remains

The analysis of botanical remains from archaeological excavations is a three-step process: recovery, identification, interpretation (Pearsall 2000). Recovery rates of archaeobotanical evidence depend on both the strategy of the excavation and the environmental conditions of the site. It is crucial that a sampling strategy be devised prior to excavation and in consultation with an archaeobotanist, although it can always be modified as the project progresses. This ensures sufficient samples for producing statistically significant results as well as for applying a range of relevant analytical techniques to answer the research questions of the project. It is important to be aware of the taphonomic processes that can introduce plant material to any archaeological site. Although archaeologists focus on the potential anthropogenic activities indicated by the plants, animal activity, erosion, deposition, and aeolian action can also all contribute to a site's palaeobotanical record and must be considered prior to interpretation of the archaeological record.

Preservation of botanical remains

Environmental conditions and the soil pH will affect the preservation and recovery of botanical remains. Desiccation common to arid regions can preserve remains not usually found in the archaeological record such as fruits, flowers, leaves, and membranes (Wilkinson and Stevens 2008). This is the process that allows spectacular survival of plant material in Egypt (e.g. Murray 2000), including the dried flower garlands found in tombs such as that of Tutankhamun which included cornflowers (Centurea cyanis) and mayweed (Anthemis pseudocotula) (Hepper 2009). Waterlogging also leads to greater preservation of organic remains, perhaps at its most exceptional in the case of shipwrecks (Gorham and Bryant 2001). For example, underwater excavation of the Late Bronze Age wreck discovered at Ulu Burun, off the coast of Turkey, yielded enormous quantities of organic materials (Haldane, 1993). These were a combination of plant products that were traded across the eastern Mediterranean as well as those used for food on board the ship and included almond (Amygdalus communis), olive (Olea europaea), pomegranate (Punica granatum), fig (Ficus carica), grape (Vitis vinifera), coriander (Coriandrum sativum), and thorny burnet (Sarcopoterium spinosum) used as dunnage (padding to keep the cargo in position in the ship's hold) (Ibid).

It is important to mention archaeological survey as well as excavation. Developed to provide diachronic information about a region rather than one specific site, contemporary landscape and vegetation has become an integral part of these studies (e.g. Watrous 2004). It is not expected that landscapes will have remained the same since human activity began, but understanding the diversity of species and ecological niches contributes towards a more holistic study of the region. It is also possible to carry out Geographical Information Systems analyses incorporating vegetation and landscape features into modelling past routes.

Types of Palaeootanical remains

Palaeobotanical material can be divided into macrofossils, visible to the naked eye, and microfossils that require magnification to examine. The identification of any botanical remains is dependent on analogies with modern flora and with archaeological reference collections. Flowers and vegetative remains are rarely preserved in the archaeological record, except in special environmental conditions (Dincauze 2000).

Macrofossils

This category includes charcoal, carbonized or charred seeds, shells, and grains, root casts, impressions on clay, mineralized petrified remains, and coprolites (mineralized or desiccated faces). In the carbonization is the most common way that ancient botanical material has been preserved and ranges from large pieces of charcoal indicating structural destruction or firewood to charred seeds. These charred seeds tend to come from plants that require processing prior to consumption (e.g. cereals), often performed near a hearth, as well as any weeds that were accidentally harvested (Wilkinson and Steven 2008). It is important to consider that plants eaten away from the settlement are unlikely to occur in archaeological assemblages; hence any picture of ancient diet based on macrofossils alone may be incomplete.

The practice of taking casts where plant roots once pierced the soil has reached its fullest potential at the site of Pompeii, buried by the eruption of Vesuvius in AD 79. Pioneered by Wilhelmina Jashemski, it is possible to identify not only the plant species that once grew here but to piece together the planting pattern and even irrigation systems of ancient gardens (Jashemski 1974, 1979). Casts can also be made of plant impressions, usually found on ceramics or other baked clay artefacts (Magid and Krzywinski 1995). For example, vine leaves are recognizable on the base of a ceramic basin from Myrtos Fournou Korifi in southern Crete (Warren 1972), hinting at the exploitation of the grape by humans early in the Bronze Age (c.3000 BC). Impressions like these on the bases of vessels are usually the result of the ceramics standing on mats to dry before firing, but others result from plant material that may have been deliberately incorporated as a temper for the clay or used in cords that were wound around the vessel.

Mineralized plant remains are rare, requiring a special set of conditions for their creation, whereby dissolved minerals replace the plant cellular structure or encase the remains, such as caves or rock shelters (Hansen, 2001) and cesspits (Wilkinson and Stevens 2008). Roman latrines are an excellent source of mineralized plant remains; at Sagalassos in Turkey, complex depositional processes have led to a combination of charred plant material with mineralized seeds in fifth–seventh-century AD latrine deposits, including fig (*Ficus carica*), plum (*Prunus* sp.), grape (*Vitis vinifera*), coriander (*Coriandrum sativum*), and dill (*Anethum graveolens*), showing the inhabitants ate a typical Roman–Early Byzantine diet, apart from a notable lack of olives (Baeten 2012).

In contrast to other types of botanical remains, plant matter from coprolites is a reasonably secure indicator of plants that were consumed and defecated by humans, especially if the remains come from latrines, mummy intestines, or burials (Reinhard and Bryant 1992). Specific biomarkers also allow a distinction between human and animal faecal matter to be made, crucial when it comes to drawing conclusions about ancient human diet (Shillito 2011). Coprolites are better preserved in arid regions and thus are more common finds in New World archaeology; indeed coprolite analysis has shown that edible flowers (e.g.*Yucca*, *Agave*, *Opuntia*, *Cucurbita* spp.) played an important role in the diet of the prehistoric peoples (Reinhard and Bryant 1992).

Microfossils and biomolecular analysis

Microfossils such as phytoliths and pollen need magnification to be visible and such studies are complemented by an increasing number of biomolecular studies. Phytoliths, or the silica skeletons from plant tissue, survive after a plant has died and their analysis can provide valuable information about use of space within a structure or site. For example, a study of the phytoliths from surfaces in the Neolithic village of Makri in northern Greece indicates the settlement was inhabited all year long and engaged in cereal farming and pastoralism, as well as helping identify areas for crop processing (Tsartsidou 2009). Phytoliths can also be recovered from artefacts, showing, for example, whether a quern was used primarily for cereals or tubers (Wilkinson and Stevens 2008).

As pollen grains are produced in varying amounts, shapes, and sizes by the male reproductive organs of all spermatophyte plants, palynology can be a useful tool in reconstructing the vegetation cover of landscapes in the past. Only those which are anemophilous are recoverable through archaeological methods (taking sediment cores from marshes or lacustrine areas where pollen is preserved in the waterlogged, anaerobic environment), leading to a preponderance of forest and grassy plants in any sample. It is also possible to recover pollen from coprolites, complementing the information on general vegetation cover with details about animal grazing or fodder practices, as well as human diet even including whether plant matter was cooked (Hunt 2001).

A deposit of pollen will usually be a combination of local pollen from contemporary vegetation, regional pollen brought via wind, water, or soil erosion, and residual pollen accumulated over time (Evans and O'Connor 1999). This highlights one of the main advantages of phytolith studies compared to palynology for archaeologists, as the phytoliths tend to be deposited in the soil where the plant decays, thus giving a more immediate location for its growth or use. Moreover, pollen is often only identifiable to genus level (e.g. *Quercus*), so may not provide adequate specificity for any meaningful interpretation. For this reason, palynology is generally used by archaeologists to look at vegetation on a regional level rather than providing site-specific information. Palynological investigation of the cores from Lake Kournas on Crete has revealed changes in the Holocene environment such as the arrival of the carob (*Ceratonia siliqua*) that can be linked to human activity, as well as to the Late Bronze Age eruption of the volcano on Santorini (Bottema and Sarpaki 2003). Vegetation burning and grazing can also be identified in the pollen record, furthering the understanding of prehistoric land management practices (Atherden 2000).

Biomolecular studies are increasing in prominence and accuracy. Residue analysis uses the separation and identification (via gas chromatography and mass spectrometry) of biomarkers associated with plants. Tartaric acid and calcium tartrate in vessels from 6th-millennium BC Iran suggests that grapes were their content, most likely wine as evidenced by the terebinth resin used as a preservative for the alcohol in ancient times (McGovern 1996).

It now seems possible to isolate plant DNA from inside ceramic vessels producing a more accurate picture of their contents and hence of ancient trade: Classical amphoras from Chios yielded DNA of olive (*Olea europaea*), oregano (*Origanum vulgare*), and an unspecified *Pistacia* species (Hansson and Foley 2008). Stable isotope analysis of human hair and bone can reveal important information about diet, such as whether plant foods were derived from C3 or C4 carbon sugars; in the case of Nubian mummies, a seasonal fluctuation was recognized between summer consumption of millet and sorghum and the year-round staples of wheat and barley (Aufderheide 2003). Indirect evidence of plants in ancient diet can also be gained from osteological studies. Dental micro wear may indicate a carbohydrate-rich diet or the accidental chewing of stone from grinding tools used in cereal preparation (Eshed 2006) while skeletal stress markers can indicate agricultural activities like harvesting (Peterson 2000).

Literary and Iconographic Sources

Literary Sources

Although flowers are poorly represented in typical archaeobotanical assemblages, literary sources can fill out the picture of their uses in antiquity to a much greater degree. Studies of Classical Antiquity differ from many other archaeological subfields because of the wealth of texts that survive and complement the information gained from excavations and landscape studies. In the case of agriculture, Roman authors wrote books focusing specifically on agricultural practices, most famously Varro (*Res Rustica*), Columella (*De Re Rustica*), and Cato the Elder (*De Agri Cultura*). Yet such texts served literary and moral functions, and while they do provide important descriptions of ancient farming, there is little place in these for ornamental flowers rather than useful crops. The classification of the natural world rather than its cultivation was of interest to earlier Greek authors, and Aristotle wrote books on plant systematics over a millennium before Linnaeus developed the system still in use today. Unfortunately, Aristotle's main works on botany do not survive but two books by his student Theophrastus discuss plant anatomy, classification, and propagation (*De Historia Plantarum* and *De Causis Plantarum*). Medicinal texts are another key source, and the works attributed to Hippocrates, Galen, and Dioscorides include many flowers within their pharmacognosies. Incidental references to flowers can be gleaned from many other types of Greek and Roman texts, including drama, poetry, and history.

Ancient Egypt and the Near East also left behind copious textual evidence. In the Near East, these take the form of clay tablets written in cuneiform. The medical tablets from the library at Nineveh are filled with lists of plants used in healing, as well as the incantations needed to cure the sick. In contrast, the epic of Gilgamesh records the hero's trip to the bottom of the sea to collect a magical thorny plant that will make him young again just one example of the occurrence in ancient mythologies of plants with special powers. Without textual evidence it would be impossible to know about such imagined plants.

Egyptian medical texts also survive, most famously the Ebers Papyrus, which records how plants were combined with other substances into healing remedies. For example, a urinary problem could be treated by taking a concoction of water, duat-plant, uam seeds, linseed, gruel, berry of the uan-tree, abu-plant from Lower Egypt, abu-plant from Upper Egypt, crocus from the Delta, and crocus from the hills

(Bryan, 1930). Reading such a list highlights one of the main problems when working with ancient texts translating the names of plants can be extremely problematic.

Linear B, the script in use in the palaces of Late Bronze Age Greece, was used to write an early form of Greek, so plant names there are usually more easily translated. One of the most important agricultural commodities listed in these clay tablets was saffron, a valuable spice derived from crocuses (*Crocus sativus* or *Crocus cartwrightianus*) (Day, 2011a). Interestingly, pulses are never recorded in Linear B, although palaeobotany has proven that they were an integral part of diet in the Late Bronze Age (Sarpaki 1992). This omission reflects rather that lentils and beans were not deemed worth recording by the palaces, which focused their attention on overseeing higher-value crops like wheat, barley, and saffron. This is a good example of how a combination of textual and archaeobotanical sources can provide a more complete picture of ancient diet than either used in isolation.

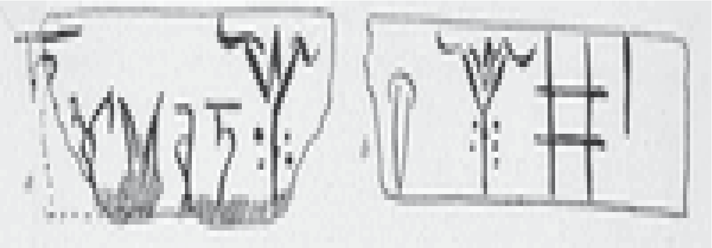


Fig 2.21: Drawings of Linear B tablets from Knossos showing saffron (Evans 1935).

Iconography

Images of plants and flowers survive in abundance from the ancient Mediterranean, and can be found on ceramics, frescoes, and jewellery, to name some more common media. It is easy to assume that iconography avoids the authorial bias inherent in many texts, but images too arise from a combination of cultural conditions, artist's knowledge, and patron's desires. More intriguing are the depictions of imaginary plants. Nevertheless, floral iconography has been used by archaeologists to learn about multiple roles of plants in the past, including trade, ritual, diet, daily life, and the environment (Atherden 2000: 62-78).

Imaginary plants

Classical Greek and Roman pottery tends to feature floral imagery in borders of scenes, such as ivy or rosettes, but earlier material is rich. The plentiful floral imagery on the pottery of the Minoans, the Bronze Age inhabitants of Crete, has always exerted a fascination, and, along with the floral frescoes, is responsible for this society becoming known as a peaceful 'flower-loving' civilization. The stylized plant-like motifs of Middle Bronze Age Kamares ware pottery gave way to more realistic flowers in

Late Minoan times before a return to stylized flowers once more in later Mycenaean art. Crocuses and lilies are two of the most prevalent species represented by Minoans, and rather than seeing them as simply nice decoration for vessels or walls, it is likely that the choice of motif was closely tied to the cultural and religious associations of these plants (Day 2011b).

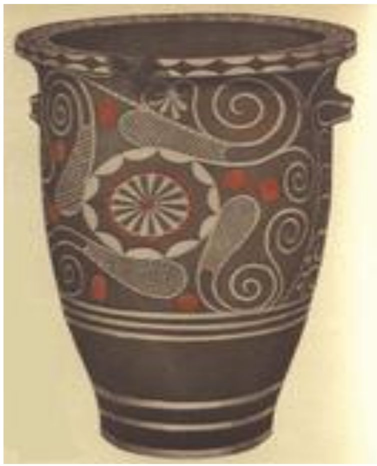


Fig 2.22: Kamares Ware ceramic vessel from Knossos

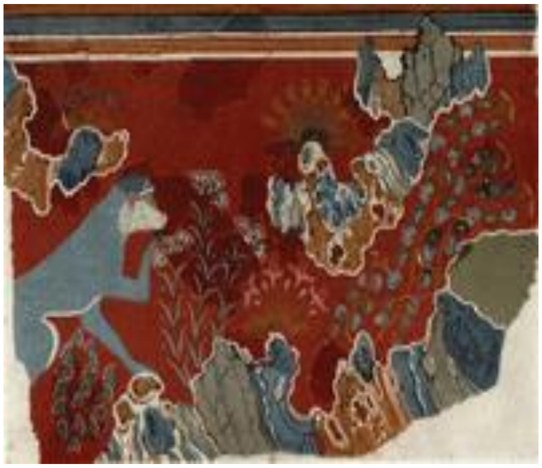


Fig 2.23: Section of the Birds and Monkeys fresco

(Evans 1928).

What do the remains of plants teach us about life in the past?

This section moves on from considering the types of remains that archaeologists use to elucidate information about the roles of plants in the ancient world to the broader research questions about both daily life and special events that can be approached through this information. Several themes have been selected as especially pertinent to flowers: **diet** and **palaeoeconomy; medicine, poison,** and **psychotropics; perfumes, cosmetics,** and **dyes; prestige**. These represent only a sample of the ancient uses of the botanical world. Plant material was also essential for building materials like timbers, roofs, mud brick, and rope. The existence of containers made in perishable materials such as baskets woven from reeds are accessed predominantly via iconography or texts, while the gourds thought to be used for holding liquids in Neolithic and Early Bronze Age times survive in the round-bottomed, long-necked ceramic jugs that mimic their shape.

Within archaeology, it was a popular belief that questions relating to economy and technology could better be approached through material remains than those that deal with ideology or ritual known as ‘Hawkes’ ladder of inference’ after the originator of the concept, it relegated palaeobotanical studies (amongst other scientific analyses) to exploring mainly economic prehistory (Trigger 1989). The development of ‘post-processual’ approaches in archaeology, however, led to the realization that consumption practices are embedded within a culturally specific ideological framework and therefore the plants used for food, medicine, fuel, building, etc. can be used to access interpretations of society.

Diet and Palaeoeconomy

Piecing together ancient diet is, of course, closely connected to the study of botanical remains. Animal and fish bones attest to the consumption of meat, and associated dairy practices can be gleaned from residue analysis, zooarchaeological remains, or texts. The majority of people in the ancient world, however, only ate meat on special occasions such as after sacrifices; vegetables, fruits, pulses, grains, and olive oil provided the bulk of calories (Megaloudi 2006). Grapes, grain, and olive oil became known to scholars as the 'Mediterranean Triad' for their key role in diet in the region (Sarpaki 1992).

Beyond the specifics of human diet, the remains of food plants can be used to learn about wider social practices associated with food production and consumption. Domestication of many crops can be followed through comparing changing seed or stone morphology with modern wild and cultivated samples (e.g. the olive, Margaritis and Jones 2008). Weeds that accompany the harvested grains into settlement contexts tell of cultivation practices such as manuring and can indicate the sowing and harvesting times (Wilkinson and Stevens 2008).

The locations of the fields from which the Philistine city of Ashkelon imported wheat has been suggested based on a comparison of the ancient weed seeds with vegetation zones; moreover, the presence of young capsules of white-flowered toadflax (*Linaria chalapensis*) is interpreted as indicating the farmers' early harvest of crops before the arrival of the approaching Babylonian army (Weiss and Kislev 2004).

Fig 2.24: Late Bronze Age wine pressing assemblage at Vathypetro,

Fig 2.25: Late Bronze Age stone mortar for pounding cereals at Gournia, (Ibid).

Medicines, poisons, and psychotropics

As opposed to their limited roles as foodstuffs, many plants are a source of medicinal, poisonous, and psychotropic substances. Texts are hugely important in filling in the details about *materia medica* in the Classical world, but archaeology and iconography again provide complementary evidence. Crucially, the distinction between a plant's therapeutic use and its use as a poison was often merely one of dosage (Cilliers and Retief 2000).

One of the most popular medicines in the ancient Mediterranean was the sap of the opium poppy (*Papaver somniferum*). A variety of evidence demonstrates that this plant and it's by products were used and traded across the eastern Mediterranean from the Bronze Age. Of course, the poppy provides food for humans its seeds can be eaten and made into oil and it has been found in domestic archaeobotanical assemblages (Megaloudi 2006).

Over 50 years ago, Late Bronze Age Cypriot ceramic juglets known as Base Ring Ware were proposed to be containers for opium suspended in liquid because, when inverted, the vessel shape bears a striking similarity to an opium poppy capsule, compounded by the painted or incised lines that mimic the cuts in the capsule through which the sap is exuded (Ibid). These small vessels have been found all around the eastern Mediterranean, in Syria, Palestine, and Egypt as well as Cyprus, and their shape would have been an advertisement for their contents (Collard 2011).

Fig 2.26: Base Ring Ware juglet from Enkomi, Cyprus (Ibid).

Various chemical tests later seemed to confirm opium as the contents, although this remains debated (for details (Collard 2011). Other indicators of the poppy's early use can be found on Crete, including the terracotta 'Gazi goddess', who has incised poppy capsules in her headdress, and the ceramic globular vessels (rhyta) from Mochlos with incisions and painted scars (Nicgorski 1999 and Merlin, 2003). Poppies also occur on the gold Acropolis ring and dress pins with crystal heads found at Mycenae (Ibid).

In later Classical times, many written sources refer to the poppy (*mékon*) and opium (also called *mekónion*). Hippocrates recognized its use as a narcotic, and Dioscorides discussed the preparation of a poppy-derived sleeping aid (Kritikos and Papadaki: 1967).

Psychotropic use of plants in the Classical World is little studied, perhaps partly because of a scholarly reluctance to ascribe 'drug taking' to the cultures that are seen as the origins of Western civilization. Although the Mediterranean does not contain the same diversity of psychotropic plants that can be found in Amazonia, for example, there are still a number of species that can alter consciousness, especially members of the Solanaceae family (Schultes and Hofman 1992; Merlin 2003). As with many traditional societies, the consumption of mind-altering plants would have been carried out within carefully controlled ritual circumstances, often by ritual specialists, rather than simply for individual pleasure. It is in the context of ritual activity, therefore, that use of psychotropics in Classical Antiquity should be explored.

Regular interaction with the Olympian deities did not require the consumption of any kind of mind-altering substance, relying instead on prayers, festivals, and sacrifices. Exceptional cases may, however, have made use of pyschotropics. The oracle of Apollo at Delphi made pronouncements via a priestess who sat upon a tripod in a trance, the cause of which has been much debated. One theory suggested that the Pythia, the priestess, chewed laurel leaves (*Lauris nobilis*) or inhaled fumes from burning them (Devereux 1997). This plant was a symbol of Apollo, and wreaths of it were awarded to victors in athletic competitions. The lack of psychotropic alkaloids in laurel makes its use for entering trance unlikely, and other suggested plants include henbane (*Hyoscyamus niger*) and *Datura* sp. (Devereux, 1997), while recent research has turned towards noxious gases as the source of oracular inspiration (Spiller 2002).

Perfumes, cosmetics, and dyes

There is a lot of information available in ancient books regarding the use of flowers to manufacture perfumes, such as the book written by Theophrastus (4th or 3rd century BC). Apart from the literary sources, ancient perfumeries have also been excavated wherein a significant number of jars and equipment has been found.

The analysis of residues from jars and vessels has allowed the identification of a number of oils and resins. For example, traces of oil of iris were identified in the residues of vessels from c. 2000 BC in Crete. Also, a jar from the Late Bronze Age was found in Turkey containing terebinth (*Pistacia* sp.) resin, most likely for use in aromatics. Many fragrant resins were also used in the mummification process in Egypt, like myrrh (*Commiphora* sp.) and frankincense (*Boswellia* sp.). Interestingly, these plants do not grow in Egypt and they had to be imported from other regions of the south of the Red Sea. Surely vegetal dyes were also used for giving color to clothes, like saffron (yellow) and kermes (red).

Plants and prestige

Plants did not have to be eaten or made into perfume to bring prestige to those who owned them. Often their display was enough. For example, Roman Emperors exhibited balsam trees (*Commiphora* sp.) from Judae in Rome as symbol of military victories. Egyptian pharaohs also used to bring plants from their campaigns.

Royal gardens have always been an important symbol of power and knowledge. For example an Inscription of King Tiglath Pileser I (1114 – 1076 BC) says “I took cedar, box tree, Kanish oak from the lands over which I had gained dominion and planted in the orchards of my land”. Another use of gardens has been related to growing plants for their use in rituals. Egyptian temple gardens provided offerings for deities such as lettuces for Min, the god of fertility, whose milky sap was reminiscent of semen. Also, being associated with certain plants could bring fortune and fame, for instance with the extinct silphium (believed to be a plant of the genus *Ferula*) depicted on coins and mentioned in literary resources (Koerper and Kolls 1999).

The Future of Plants and Archaeology

Although the integration of archaeology and botany has progressed enormously throughout the last century, there are many paths open for future cooperation. Interest in contemporary climate change and its effect on vegetation is reflected by an increasing recognition of the impact that environmental change would have had on ancient societies. As scientific data unraveling ancient weather patterns becomes both more accurate and more plentiful, studies linking archaeology, landscapes, and paleoclimatology will perhaps become more common (Moody 2005).

Advances in analytical techniques will undoubtedly lead to further developments in identifying plant remains on a microscopic or chemical level, and the continued presence of palaeobotanists on fieldwork projects will ensure that plant remains are not overlooked in favor of ceramics or other more obvious remains. Moreover, continuing archaeological fieldwork and research based upon texts and iconography will augment current knowledge with new discoveries. Fresh ways of thinking about the roles of plants in ancient society has highlighted the relevance of palaeobotany not just for studies of subsistence but also for issues such as status, identity, and ritual. To some extent, ethnobotanical studies must be as responsible for this as the changes within archaeological discourse, as they demonstrate to archaeologists the enormously rich and intertwined lives of people and plants. The rise too in archaeological interest in feasting and sensory experiences means that plant derived substances are no longer viewed as merely calorie providers but facilitators of social dynamics and even of communication with divinities (Ibid).

Archaeobotany or Palaeobotany

1. Introduction

In this research, a modest attempt is made to initiate a debate on the current theory, methodology and objectives of the study of archaeological plant remains with special emphasis on issues relevant to archaeology and archaeological research on ancient plant remains. The paper also includes some suggestions (that are open to discussion) on prospective contribution of archaeobotanical research to applied science, and hence the needs of the contemporary world. However, as the title indicates, this presentation is to be viewed neither as an exhaustive listing or coverage of all the debatable theoretical, methodological and interpretative nor as one that proposes definite answers, new ideas and / or solutions to the questions, problems and issues raised. Rather, it is meant to provoke a debate that will perhaps contribute new proposals and ideas and/or raise more issues.

In this debate, the phrase ¨archaeological plant (or archaeobotanical) remains¨ is meant to denote all types of ancient plant remains which are recovered from archaeological sites or from other areas with the intention of studying human-plants interrelationship and the context (environment) in which they took place. These remains are often found in two main forms: namely, macrobotanical and microbotanical remains (Magid 1989: 65).

The macrobotanical remains are those which can be seen by the naked eye or low power microscope, such as seeds/grains, stones of fruits, leaves, charcoal, etc. The microbotanical remains cannot be seen by the naked eye and require high power microscope (ibid: 64), e.g. pollen and phytoliths. Macro and microbotanical remains are deposited in or brought to archaeological sites by natural and /or cultural processes. They are preserved by carbonization, water logging, desiccation, and mineralization, as stomach contents and residues, e.g. coprolites, impressions in pottery (ibid: 64). They are identified (on the basis of their external morphology) by comparing them with reference collections, manuals, and by sorting types, size, measurements, shape and surface texture (ibid: 74)

2. The state of the study of archaeological plant remains

In this section, a broad outline on the history and the current position of the study of the archaeobotanical remains is presented in order to establish areas of its development and debate those areas of its weaknesses.

Interest in recovery and study of ancient plant remains captured the interest of researchers in the Old World since 1826, e.g. C. Knut work on desiccated seeds and fruits from ancient Egyptian tombs (Renfrew 1973: 1). In the New World, the study of ancient plants can be traced to1895 but interest in archaeological plant remains started to developed during the 1930’s (Pearsall 1989: 1). As it became an established fact that carbonized, desiccated and waterlogged plant remains (e.g. seeds, fruits, etc.) could survive for thousands of years, studies on ancient plant remains started to unfold. Most (if not all) of these studies were mainly concerned with reporting the finding of a species at a particular site or evaluating a particular plant species. Eventually, studies in the Old World began to focus on botanical taxonomy and precise description of plant remains. Those studies which were carried out in the New World (mainly in North America) emphasized more the cultural aspects such as the presence and use of plants at a site (ibid).

The field of Ethnobotany was first introduced at the end of the 19th century mainly to study the relationship between contemporary small scale (and undifferential) societies and plants (ibid). this field witnessed two main developments in its scope and conceptions since the early 1940’s. These are: -

A. Introduction of interdisciplinary approaches in which anthropological and botanical methods and techniques were used in ethnobotanical studies. Ideally, a researcher who is familiar with methods, techniques and approach of both botany (plant sciences) and anthropology should conduct interdisciplinary (ethnobotanical/anthropological) research.

B. Expansion of the concept of ethnobotany whereby it included the relationship between plants of both ancient communities and industrial societies. Accordingly, the term ethnobotany was applied to the study of human- plant relationship, without limit to time or to the degree of cultural development (ibid).

Toward the end of 1950's Palaeoethnobotany was introduced as a part (or sub-field) of ethnobotany that is specifically concerned with the study of human-plant relations in the past through the study of archaeological plant remains such as macrobotanical remains as well as pollen, phytoliths analysis (ibid). Hence, the European and Old World studies started to move away from their traditional focus on taxonomy and morphology of remains towards cultural interpretations. In the New World and America, there was increased interest on reconstructing subsistence and palaeoenvironment, and greater emphasis was put (during the 1950's and 1960's) on recovering and studying macro-remains and pollen (ibid: 5).

Quantitative pollen analytical studies (which were known and first used in 1916) became fairly widespread in archaeological research during the 1960's. In addition, phytoliths analysis was known and used in the Old World since the beginning of the 20th century (1900, 1914) and in the New World since the 1960's (ibid: 326). However it was only during the 1970‘s and 1980's that the introduction and development of techniques and methodology of these were applied on a wider and more systematic scale in archaeological research. Finally, a major advancement in recovery methods of marcobotanical remains was made when the method of Froth Flotation was introduced and widely applied (ibid: 7-9).

The development, refinement and wide application of pollen, phytolith analysis and the method of Froth Flotation in archaeological research are largely attributed to increased interest in the origins and spread of agriculture and the past human interaction with the environment. In turn, studies on archaeobotanical remains have witnessed a dramatic increase in recent years (ibid: 4) and for the last three decades or so, such studies got out of the laboratory and became an integral part of many archaeological projects (Greig 1989: 2). That is to say, archaeologists developed a (healthy) trend toward interdisciplinary research in which biological science started to play an active role.

The foregoing outline shows that the studies of archaeological plant remains have undergone a remarkable development in their conceptions and scope mainly due to developments and changes in interests and the nature of the questions asked. The results and quality of these developments have been further promoted by introducing and/or refining field and laboratory methods and techniques. Nowadays, archaeobotanical research address a variety of questions and new issues, the most common and widely researched ones are:

1. The study of the past human-plants relationships and their change over time. This includes studies on: plant foods, extractive strategies of plant foods and their change of overtime, the craft uses of plants e.g. in construction, basketry, textiles, clothing, medicine, etc. and uses of plants for fuel.

2. The effects of resource availability on settlement patterns.

3. The surrounding environment at the time of the formation of the deposit (i.e. occupation of the site). Thus, many areas of developments and changes in the field may be viewed as positive, yet there are other areas which remained unchanged or that the changes introduced are disadvantageous, or conflicting and controversial in their implications.

3. Definition and application of terms: Archaeobotany or Palaeobotany

Definition

Archaeobotany or Palaeobotany is the study of plant remains from archaeological sites to better understand the environmental context of past societies and how the environment was exploited and modified. Particular research emphases include diet and food procurement, whether through gathering or cultivation, and the transformation of plants and landscapes through domestication. The types of plant remains studied here include macro-remains (from seeds, wood, and parenchyma tissues) and micro-remains (especially phytoliths and starch grains). The Institute has a large reference collection with an Old World emphasis (Mason 2002).

Applications

People have used and modified plants since the earliest human presence in the world. Human diets have always involved some proportion of plant intake (although this has varied in relation to animal-derived foodstuffs). With the introduction of agricultures, humans have managed and modified plants and crops on an increasingly large and complex scale. The remains of seeds, grain, fruit stones and nut shells can tell us about land-use, diets, gathering strategies, forms of cultivation and even spiritual beliefs (a cultural area closely connected to the use of plants for medicinal and perception-altering effects). Wood, plant fibers and charcoal can tell us about buildings and industrial production (and are also used in dendro and radiocarbon dating techniques). In common with other environmental archaeologists, Archaeobotanists are primarily interested in reconstructing past ecology, and understanding the role of humans in selecting and modifying the flora of their own environment.

Botanical remains are normally collected from excavated material using a flotation system which passes water through a soil sample and separates tiny seeds, fibers and wood fragments from the soil, sieving them to a size which can be as small as 300 microns (0.03 cm). Charred grains (which were burnt during drying or preservation processes) are often particularly well preserved. The plant remains are then examined identified and analyzed using microscopes.

More recently, studying plant DNA has become of greater interest to archaeobotanists. Extracting plant DNA is a much more elaborate scientific process, but early results promise a new and informative source of information on ancient techniques of plant domestication, food residues on pottery, and plant-derived products such as dyes and fibers used in artifact production (Evans and O'Connor 2001).

4. Main approaches in Archaeobotany

At the beginning, the interest of archaeobotany was centred on the origin of cultivated plants, from a genetic point of view, as well as on the processes associated to plant domestication and agriculture. Later, as the number of data available increased and new techniques became available, the initial interest on taxonomy*per se* derived into the study of the complex interactions between human communities and plants. This change in direction was evidenced through the foundation of the International Work Group of Palaeoethnobotany (IWGP) in 1968, which has served as a productive discussion forum for European archaeobotanists. Nowadays, the interest of archaeobotanists includes both the inference of plant exploitation strategies in the past and the reconstruction of palaeovegetation. For the latter, it is of special relevance a subdiscipline of archaeobotany, the anthropology or charcoal analysis, which is devoted to the study of wood remains. This approach has been well developed in Europe through the work of Vernet and his numerous co-workers and disciples (Bazile 1977; Ros 1997; Vernet and Thiebault 1987).

Nevertheless, the use of charcoal analysis to reconstruct vegetation is rather controversial, as it attempts to derive vegetation from material that has been collected by human groups, thus assuming that this would reflect plant communities. However, charcoal remains from archaeological contexts reflect the interaction between vegetation and their use by human groups. Some charcoal studies are indeed focused on the socio-economic (e.g. fuel exploitation, collection strategies) implications of this kind of remains (Piqué 1998; Willcox 1999). Thus, plant macro remains might provide also useful information from a palaeoenvironmental point of view, but the interpretation of results require a careful consideration of other factors determining the composition of plant assemblages.

5. Ideal situation for efficient research

As Archaeoboatny is marginal between botany and archaeology, the ideal situation is to have a researcher trained in both archaeology and botany. Unfortunately, until now there are a very few specialists who have such qualifications and it still is a matter of debate whether it is better for archaeobotanist to be first good botanist and then to learn about archaeology, or whether archaeologists can become good botanists. The current positive tendency towards interdisciplinary research work might motivate future archaeobotanists to acquire training in both disciplines. Until then, it may be practical to suggest that both archaeologists and botanists embark on developing a language of communication that enables each to learn the fundamentals of his partner’s field of research. By so doing, they will be able to promote a language which enables them to plan and investigate jointly those points at which plant science and archaeology overlap and to interpret the mutual significance of their interrelationship (Greig 1989: 3). In short, archaeologists and archaeobotanists need to acquire language by which they can understand and communicate the questions to be asked, the plans to be made, the work to be carried out, analysis to be done and objectives to be achieved.

6. Possible contribution of Archaeobotany to the present day needs

Nowadays, the validity of any science or field of research lies in its durability and ability to render tangible services to human-needs and expectations in different situations at different places and environments. If it fails to meet these conditions, then both interest and need for it rapidly decline. Consequently, research-grants progressively dwindle until they cease to flow. So, one may ask whether Archaeoboatny is capable of meeting such challenges and if the answer is yes, how can it contribute to the needs of people in the times we live in? In a recent work, the present writer attempted to address the relevance of Archaeoboatny to our today's world, its needs and expectations (Magid 2003). He concluded that Archaeobotany has the potentials to restore and conserve (rapidly disappearing) indigenous knowledge on plants and their uses. It also contributes to resettlement and/or development of displaced people due to famines, civil wars and political instability (ibid).

Archaeobotany also has the potentiality to furnish pharmaceutical research with raw-materials and recipes and to promote the current healthy trend in the (Developed) World towards the use of natural herbs for different purposes (e.g. remedies, dietary, body-grooming, natural cosmetics, etc.). Archaeobotanical research could contribute to serving these goals by assembling detailed information on ancient plants, their types, properties and applications. This information can be used to reviving ancient herbal recipes/applications and adding unknown ones to the present formulas.

In short, Archaeoboatny has the potential of addressing issues related to current socio-economic crises and rural development as it contribute to solving problems of food-crises and resettlement of displaced communities. It also has the potentials to enriching newly found old (e.g. remedial, cosmetic, etc.) ways of using plants.

Aims and Objectives of Archaeobotany

Archaeology can be understood as a sub-branch of archaeology where the scientist is specifically interested in studying how people used plants in the past. It is not only an historical endeavor but scientists in the field also hope that by investigation of ancient plant practices, that there will, be practical agricultural benefits of or modern farming enterprises.

The science of palaeobotany deals with study of past plant relics found in sedimentary rocks.

Speaking on the occasion of Foundation Stone laying ceremony of the Institute Prof. Sahni very aptly said:
"*Palaeobotany is the common ground between Botany and Geology it is in fact the botany of the rocks*".

An integration of plant and earth sciences in the pursuit of palaeobotanical researches is the primary aim of this organization. Researches on various broad topical aspects, applied and basic both, supported by state of the art instrumentation, computational technology, well-equipped laboratories with qualified experts give a true meaning to this Fusion-Science. Interaction through National and International collaborations and different research projects are operational to achieve the desired goals.

- To develop palaeobotany in all its botanical and geological aspects.
- To constantly update data for interaction with allied disciplines.
- To co-ordinate with other palaeobotanical and geological research centers in the areas of mutual interest, such as diversification of early life, exploration of fossil fuels, vegetation dynamics, climatic modeling, conservation of forests.
- To disseminate palaeobotanical knowledge in universities, educational institutions and other organizations.

CHPTER: 3

Palynological Archaeology

Introduction

This research focuses on “Application of palynology in Archaeology”: A case study of Badalpur site in Taxila’, in which I have mentioned and discussed about the interdisciplinary collaboration between Archaeology and Botany. My research work is a form of coherent bond between these two disciplines. This disciplinary research will place Archaeology in the modern sciences and also described how ancient pollens can be able to reconstruct ancient diets, funeral practices, the functions and use of discovered artifacts, the source of raw materials for tools or food consumption, the use of natural topography and artificial landscape changes, the domestication and cultivation of food plants and the study of human impact on the ancient environment. Main aim of my research was the comparative study of Gandhara period plants with present existing plants will reveal the agriculture evolution in Gandhara.

It seems that archaeology is a multidisciplinary field and every field of social and natural sciences has its own value in this field. It has tendency to absorb and adapt and to expand its lineage in other disciplines depending upon the nature of the material remain. The researcher is interested in one of the important and close related field ‘Botany’. It comprises the study of ‘plants’, they play an important role in human culture. They provide information about the natural environment, land use patterns, diet, architecture and trade in exotic plant materials. Plant remains also explain many aspects of society, including social practices.

Botanical research has diverse applications in providing staple foods and textiles, in modern horticulture, agriculture and forestry, plant propagation, breeding and genetic modification, in the synthesis of chemicals and raw materials for construction and energy production, in environmental management, and the maintenance of biodiversity.

There are three major categories of archaeobotancial remains; macro-remains, pollens and phytoliths. It also helps to reconstruct the vegetation of certain areas. Plant remains enabled us to assess human impact on the environment and explain how to people live (Martin 1919: 97).

As pollen analysts working primarily in the field of archaeology, we have often been asked to explain how one should collect pollen samples and to outline the various ways that pollen data are useful in archaeology. This chapter is our attempt to answer those questions.

Palynology

Palynology is the "study of dust" (from Greek παλύνω, *palunō*, "strew, sprinkle" and -logy) or "particles that are strewn". A classic palynologist analyses particulate sample collected from the air, water, or from deposits including sediments of any age. The condition and identification of those particles, organic and inorganic, give the palynologist clues to the life, the environment, and energetic conditions that produced them.

The term is sometimes narrowly used to refer to a subset of the discipline, which is defined as "the study of microscopic objects of macromolecular organic composition (i.e. compounds of carbon, hydrogen, nitrogen and oxygen), not capable of dissolution in hydrochloric or hydrofluoric acids." It is the science that studies contemporary and fossil palynomorphs, includingpollen, spores, orbicules, dinocysts, acritarchs, chitinozoans andscolecodonts, together with particulate organic matter (POM) and kerogen found in sedimentary rocks and sediments. Palynology does not include diatoms, foraminiferans or other organisms with siliceous or calcareous exoskeletons.

Palynology is an interdisciplinary science and is a branch of Earth Science (geology or geological science) and Biological Science (biology), particularly Plant Science (botany). Strati graphical palynology is a branch of micropaleontology and paleobotany, which studies fossil palynomorphs from the Precambrian to the Holocene (Sarjeant 2002: 273-327).

Fig 3.1: Pollen under Microscope (http://www.palynology.org/pollen).

Palynology, the study of pollen grains, is one of the most effective tools we have to reconstruct past environment. Because exines, the hard outer shells of pollen grains, of different species are unique (illustrated at left) and can survive in favorable conditions for thousands of years, palynolgists can identify many plants that were present in the past. Working with this information, archaeologists can then discover more about how humans in the past interacted with their environment.

On a large scale, palynology can identify broad environmental trends. Pollen grains are the tiny male reproductive bodies of flowering plants. Different types of flowering plants have evolved different methods of ensuring that these male reproductive bodies reach their appropriate female counterpart. One of these methods is windblown distribution. Because the wind randomly distributes the pollen grains, the plant must produce a huge amount of extra pollen to ensure that at least some of it reaches its intended destination. This extra pollen, called pollen rain, is eventually deposited on the ground where, if conditions are favorable, it may persist for thousands of years. Lake sediments and peat bogs are particularly valuable for preserving pollen grains not only because they are chemically suitable but also because they accumulate over time. Thus as the pollen rain falls in these places, it is incorporated into the ever growing sedimentary or plant deposits. When pollen falls on regular soil, it tends to migrate downwards with the water percolating through the soil. By mixing modern and ancient pollen together, this creates a more difficult, but not impossible, situation for the palynologist to evaluate.

By taking samples from a continuous sequence of soil depths and then extracting, identifying, and counting the pollen in each level, palynologists create a pollen profile of an area over a specific time. The pollen profile can then be plotted as a graph. For example, in the pollen profile illustrated below, continuous samples of a meter of soil were taken from between two meters and three meters depth. Dates for the different levels were established by other methods using associated data.

Palynology is the study of micro organic material such as spores, pollen, dinoflagellates and microfossils is a method employed by a range of disciplines all concerned with the environment. It is not an undergraduate degree subject due to its limited scope, and though there are some Master's programmes in most countries, those wishing to enter into the field may approach the subject from many different directions. They come from botany, plant biology and chemistry, from environmental science, from archaeology, from landscape studies, geography and several other “Earth Sciences” making the method one of the most diverse and broadest of environmental science tools (Ibid).

One of the most fascinating aspects and perhaps underappreciated by most people is how landscapes change over time in terms of the plant life that grows there. We can learn much about the landscape itself, the natural and human history of that landscape (including the changes it has undergone as a result of natural or human processes), and of the changing climate and what impact that has upon plant life. Flora - trees, flowers, grasses, mosses, lichen and even fungi have environmental conditions that they prefer and other conditions in which they will not survive for very long. Moving from a dry to wet climate (or vice versa), from temperate to ice age (or vice versa) and even whether and when a piece of land was once tidal salt marsh but is now pasture, can all affect the makeup of the landscape's flora.

One of the most useful extant remains of a plant that will survive under certain conditions is its pollen or spores. These are the elements of the plant used for sexual reproduction during the spring season. We call this study of pollen and spores *pollen analysis*. Palynology though, looks at other evidence types that we will cover here such as microscopic marine life, microfossils and other minute organic samples (Ibid).

Pollen and spores do not survive in all conditions all of the time. Though they are hardier than the plants that grow from them, generally we get most of our surviving material (in temperate regions at least) when we dig it up waterlogged soil (Ibid). Some of the best surviving examples of pores and pollen have come from the bottoms of rivers and lakes. They are most common in areas where there is, or once was, a high water table and anaerobic conditions have protected them from the elements. What we know from the study of pollen and spores is dictated by not only conditions, but by virtue of the fact that the sheer weight of numbers during the pollen season leaves us with any evidence at all.

Whether using sexual reproduction, photosynthesis or parasitism, microscopic marine life forms such as plankton are also a major evidence type in palynology. Like pollen and spores, they survive best in waterlogged soils and fossilized samples are best acquired from dried up sea and riverbeds (http://www.palynology.org/spores).

A Brief History

Pollen and spores and other microfossils have been subject to study since the advent of naturalism in the mid17th century; the first credited person to study this type of evidence was Nehemiah Grew, who theorized that pollen was vital to sexual reproduction in plants. In fact, Grew was practically the inventor of the science of plant physiology and was one of the most celebrated scientists of the 17th century and most people today have not heard of him. It was also in the 17th century that the microscope was invented, this made the study of this microscopic life much easier and it became the one essential tool in the study of fossilized spores and pollen (http://www.palynology.org/2015).

The oil industry is first credited with realizing the importance of the wider study of organic inclusions within geological stratigraphic layers something that had commercial applications for their industry as well as vast academic potential to researchers. It really came to the fore as a science in the early 1900s, when Swedish scientists named Lennart von Post calculated the percentage survival rates of some pollen in peat bogs. Until that point, it was more qualitative than quantitative, making predictions and understanding of survival rate far less mathematical and therefore it was difficult to calculate a population size or density within a given area. The move to a more scientific and quantitative approach made it far more conducive to understanding the science of the Ice Age and how vegetation levels and numbers are affected by the changes in climate. How did certain plant species survive? How did they adapt? How did the vegetation change? Which died out and which thrived? These are just some of the questions that palynologists hoped to answer. Researchers found that in Ice Age Europe, birch and pine were amongst the first tree species to recolonize the soils with pine making an aggressive invasion to replace birch in some areas, meaning rainfall had dropped.

Despite this growth of study, the world “palynology” was not introduced until the end of World War II when the fledgling science of studying tiny organisms was finally given its name. The word “palynology” has been adapted from a Greek word that means “strewn” or “sprinkled”. Thus, palynology is the study of small *sprinkled things* (Ibid).

Early history

The earliest reported observations of pollen under a microscope are likely to have been in the 1640s by the English botanist Nehemiah Grew, who described pollen, the stamen, and correctly predicted that pollen is required for sexual reproduction in flowering plants.

By the late 1870s, as optical microscopes improved and the principles of stratigraphy were worked out, Robert Kidston and P. Reinsch were able to examine the presence of fossil spores in the Devonian and Carboniferous coal seams and make comparisons between the living spores and the ancient fossil spores. Early investigators include Christian Gottfried Ehrenberg (radiolarians, diatoms and dinoflagellate cysts), Gideon Mantell (desmids) and Henry Hopley White (dinoflagellate cysts).

Palynology 1890s to 1940s

Quantitative analysis of pollen began with Lennart von Post's published work. Although he published in the Swedish language his methodology gained a wide audience through his lectures. In particular, his Kristiania lecture of 1916 was important in gaining a wider audience. Because the early investigations published in the Nordic languages or Scandinavian languages the field of pollen analysis was confined to those countries. The isolation ended with the German publication of Gunnar Erdtman's 1921 thesis. The methodology of pollen analysis became widespread throughout Europe and North America and revolutionized Quaternary vegetation and climate change research.

Earlier pollen researchers were Früh (1885), who enumerated many common tree pollen types, and a considerable number of spores and herb pollen grains. There is a study of pollen samples taken from sediments of Swedish lakes by Trybom (1888), Pinus (Pine) and Picea (Spruce) pollen was found in such profusion that he considered them to be serviceable as "index fossils". Georg F.L. Sarauw studied fossil pollen of middle Pleistocene age (Cromerian) from the harbour of Copenhagen. Lagerheim (Witte 1905) and C.A.Weber (Weber 1918) appear to be among the first to undertake 'percentage frequency' calculations.

Palynology 1940s to 1989

The term *palynology* was introduced by Hyde and Williams in 1944, following correspondence with the Swedish geologist Antevs, in the pages of the Pollen Analysis Circular (one of the first journals devoted to pollen analysis, produced by Paul Sears in North America). Hyde and Williams chose *palynology* on the basis of the Greek words *paluno* meaning 'to sprinkle' and *pale* meaning 'dust' (and thus similar to the Latin word *pollen*).

Palynology 1990s to 21st Century

Pollen analysis advanced rapidly in this period due to advances in optics and computers. Much of the science was revised by Johannes Iversen and Knut Fægri in their textbook on the subject (Faegri and Knut 1973: 5-12).

The Evidence of Palynology

So what sort of things does palynology look at? All materials used in palynology are referred to as palynomorphs. They are organic materials too small to see with the naked eye**,** anything that is a palynomorph will come under palynology. The scientific definition of palynomorph is “an organic walled microfossil 5 to 500 micrometers in size”.

Pollen: This is the most common evidence type and the one that comes immediately to mind when we talk about palynology. First appearing in the fossil record over 300 million years ago, their evolution has been a boon for human understanding of the development and colonization by plant species. During the spring season, a plant that uses pollen for reproduction may use one of two methods to propagate itself.

- **Wind**: a male part of a plant releases thousands upon thousands of pollen and lets nature take its course by carrying it on the wind until it meets with the female part of another plant. This method requires a lot of energy expenditure on the part of the plant. The air can often be dense with the pollen hence that so many people suffer with hay fever during the peak of spring. Typically, this type of pollen is light though it has a shell, it will not be as hard or as heavy as the second type. It is also very abundant as the wind will carry it in all directions and lay it evenly around a landscape. Most of the pollen studies in palynology will come from wind-blown pollen.

- **Insect**: Some plants have another route through which to distribute their pollen using the available animals such as bees, butterflies and other pollinating insects. It doesn't need to blow out tonnes of pollen every day because insects come to it, feed on the nectar, and the pollen gets stuck to their bodies and transferred to another plant when it visits a neighbour. This is often much heavier than wind-blown pollen, and because of the more limited distribution, we have to look in other places for this type of evidence, from the bodies of dead or trapped insects (modern and ancient) or from extant honey residue**.**

Spores: Specific to moss and fungi such as mushrooms and toadstools, these travel the landscape in more or less the same way that wind-blown pollen gets about. This also means that it survives in more or less the same places that wind-blown pollen survives in. The walls of the pollen and the spore are remarkably similar so many of the concepts behind the study of each will be the same too. What is likely though is that spores represent the first method by which marine plant life took hold on land. Some may have been distributed through water and took hold in soil as waters retreated (tidal for example). This is still the case for marine plant species that still use spores but like their land-based plant brothers and sisters, they have also evolved to be carried on the wind.

Dinoflagellates: These single cell organisms survive in the ocean. They are quite remarkable and though they serve a different function to pollen and spores (they are a life form in themselves - some reproduce sexually, others asexually, others still through photosynthesis with some that are parasitic) they also fall under the flag of palynology. They live on sunlight and often are the primary food source for most forms of marine life, so abundant are they that at certain times of the year we see ocean blooms; plankton is arguably the best-known type of dinoflagellate *(*Ibid).

1. Define Pollen

Pollen is very fine powder that comes from trees, grasses, flowers and weeds. Wind and birds carry this pollen from plant to plant to fertilize them. When people who have a pollen allergy

Fig 3.2: Tip of a tulip stamen with many grains of pollen (Johnstone and Adam 2001: 95).

Pollen is a fine to coarse powder containing the micro gametophytes of seed plants, which produce the male gametes (sperm cells). The study of pollen is called palynology and is highly useful in paleoecology, paleontology, archaeology, and forensics.

Pollen in plants is used for transferring haploid male genetic material from the anther of a single flower to the stigma of another in cross-pollination. In a case of self-pollination, this process takes place from the anther of a flower to the stigma of the same flower (Ibid).

Structure of Pollen Grains

Pollen grains represent the male portion of the reproductive process in plants and trees. These tiny bodies are swirling in the air and on the legs of insects so that they can join the female part of the plant to create a new seed. This important process is known as fertilization.

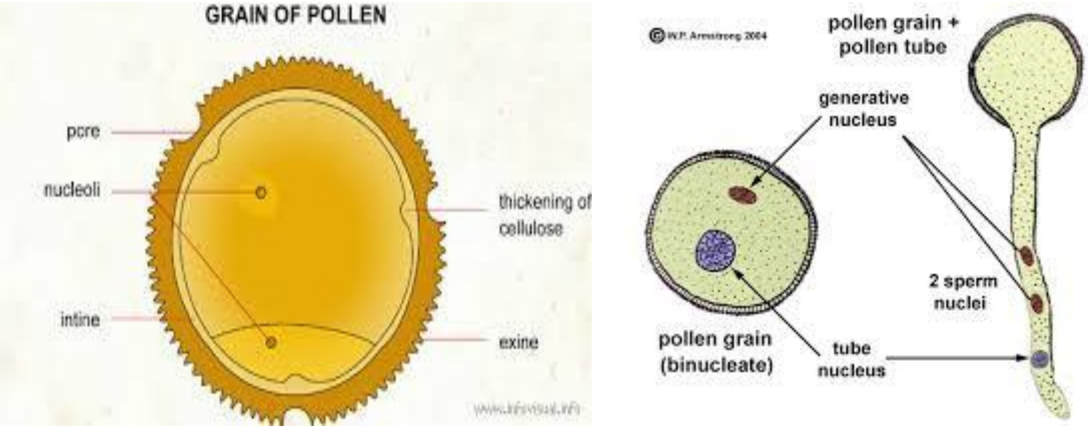


Fig 3.3 a, 3.3 b: Structure of Pollen Grain (Sporne and Kenneth 1972: 181-185).

Pollen grains are microscopic structures that vary in size and shape. Some are tiny *orbs*, while others are *egg-shaped*. Although too small to see individually, they can be seen by the naked eye in large quantities.

Viewed through a microscope, a pollen grain hardly looks real. An extremely durable body, it has a tough outer coating. This hardy coat offers great protection from the harsh outdoor environment. This is important because inside this tough shell lie two cells: the tube cell, which will eventually become the pollen tube, and a generative cell, which contains the male sperm nuclei needed for fertilization.

Let's zoom in to take a closer look. There are three main components of a pollen grain. The inside of the grain is made up of cytoplasm. This fluid medium houses the aforementioned living cells, keeping them moist and alive. The outer shell is made up of two layers. The inside layer is aptly named the intine (think interior). It is composed partly of cellulose, a common component in the cell walls of plant cells.

The tough-as-nails outer layer is known as the exine (think exterior). This highly sophisticated and complex outer layer is rich in a compound known as sporopollenin. Waterproof, resistant to deterioration and very stiff, this shell is basically one of nature's most advanced polymers. It ensures that the tender cells inside have a strong chance of survival.

In addition, often times the exine have *folds, creases* and *spikes* rising from its surface. Like extra armor, these features add to the protective nature of this layer. They also play an important role in the mobility of the grains, making it more likely that they will stick to the legs of insects as well as catch the wind (Ibid).

Cell wall of pollen grains

The wall of the pollen grain always consists of two layers: the inner intine wall and the outer exine wall. Both inner and outer cell wall of pollen grains often has a typical structure that depends on the species. The deposition of these walls begins already during meiosis and continues until final maturation of the pollen grain. The inner layer is laid by the cells themselves, the outer wall is deposited by the tapetum (in figures on pollen development). The inner wall consists of cellulose and hemicellulose, but glucose is always present (see fluorescingcallose labeling of pollen tubes). Glucose is nearly absent in "normal" cell walls. The outer wall consists mainly of sporopollenin, a mixture of stable biopolymers containing i.e. fatty acids. Sporopollenin protects the living vegetative and generative cell in the pollen grain against mechanical damage, chemical break-down and too rapid desiccation and it provides a shield against the agressive ultraviolet radiation of the sun. On the surface of the outer wall and in cavities remnants of the tapetum can be found. Sometimes the grain is covered by a liquid, fatty substance, so-called "pollen kit". Intine, exine and cytoplasm can all three contain allergens that may cause hay.

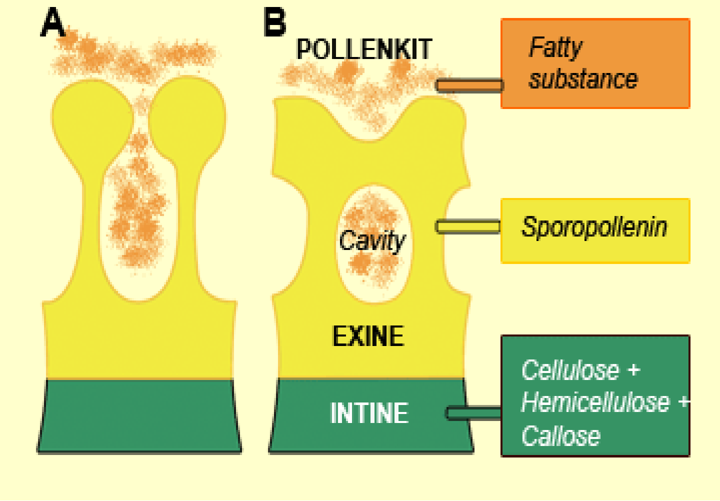


Fig 3.4: Cell wall of Pollen grain (Simpson and Michael 2011: 453-464).

The outer wall consists always of a closed lower layer (foot layer) covered by a very variable species-specific stratification. An intermediate layer of columns (bacula or columella) is often observed which lay in a regular pattern. These columns are generally enlarged on the upper side (see diagram here above), so that they make contact with each other and build a kind of roof (tectum) that gives rise to linear or reticulate patterns, like in *Arabidopsis thaliana*. Sometimes they form a more or less solid surface bearing cavities (lumen). Above the tectum other ornamentations may occur in the shape of rains, points, spikes and ribs with.

So-called colpi (elongated aperture) and sometimes small germination pores often indicate the spots where pollen grains will germinate. In these areas an outer wall is often absent and the inner wall is very thin, but sometimes just very thick. When a germination pore exists, a little cover of outer wall may occur, the operculum (Ibid).

Pollen observation with a microscope

Pollen grains are very small; therefore the use of a light or electron microscope is required to observe them. Here below examples are shown of various types of microscopically views:

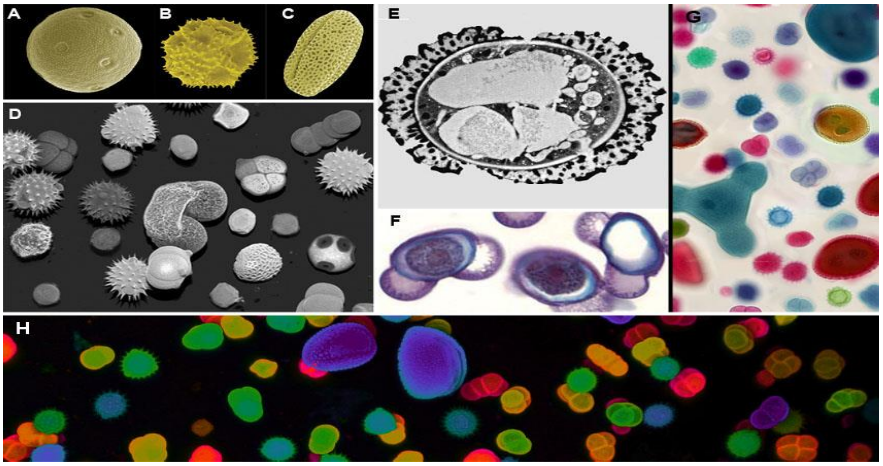


Fig 3.5: Various types of microscopically of pollen grains (Ibid).

A Ribwort Plantain (*Plantago lanceolata*), B Dandelion (*Taraxacum* sp.) and C Arabidopsis (*Arabidopsis thaliana*): Scanning electron microscopy (colorized)

D Mixed pollen grains: Confocal Laser Scanning Microscopy (shadow projections of z-series)

E Arabidopsis (*Arabidopsis thaliana*): Transmission electron microscopy

F Pine (*Pinus sylvestis*): Light microscopy

G Mixed pollen grains (bright field light microscopy, stained)

H Mixed pollen grains (autofluorescence in confocal laser scanning microscopy: depth color-coded z-projection).

Spectrum of possible pollen types

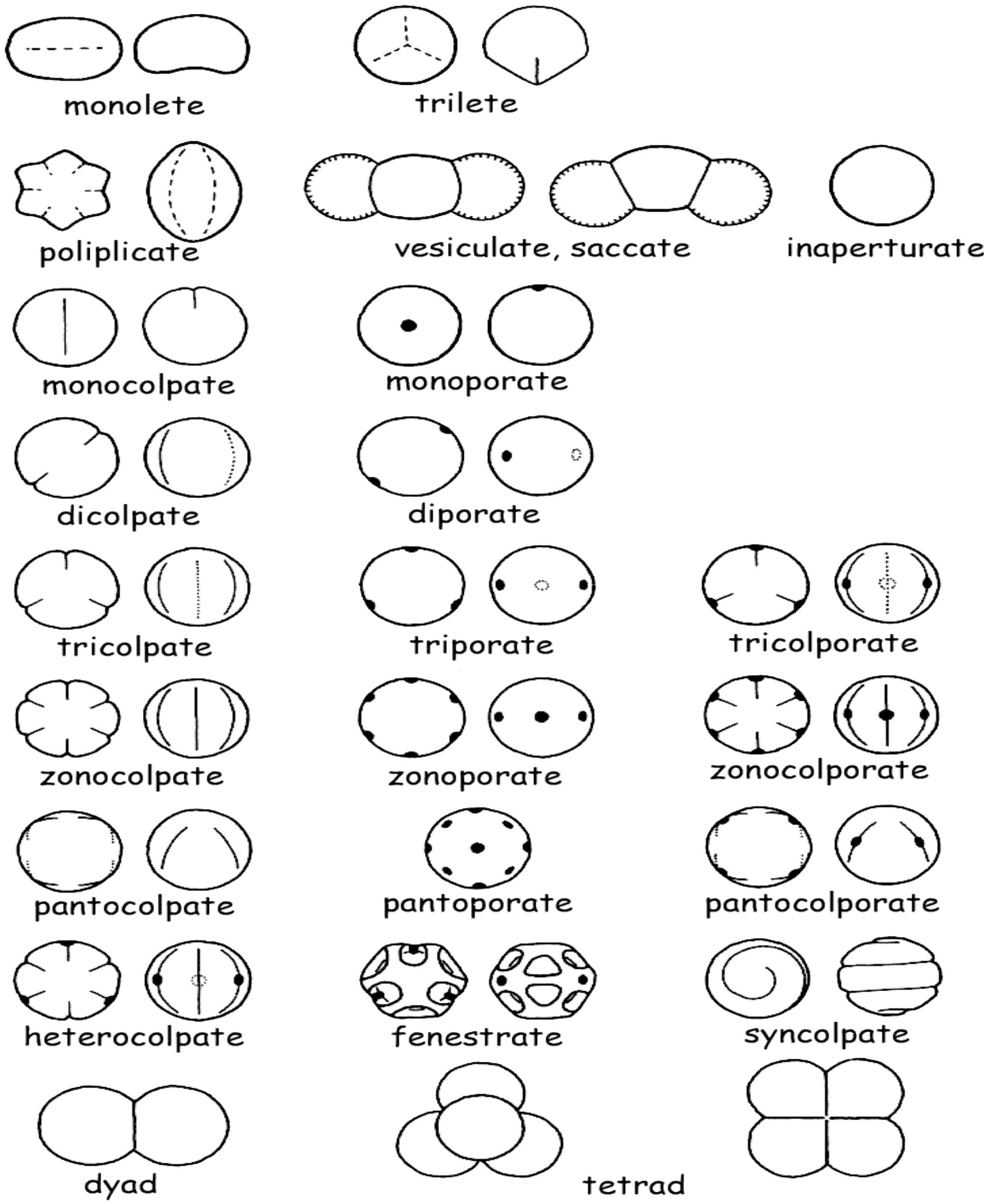


Fig 3.6: Spectrum of possible pollen types (lbid).

Pollens are propagules from vascular plants and spores are the propagules from the nonvascular plants. Spores have a shell (exine) consisting of one layer, though a loose outer sack, the perine, may be present (see fern spores for an example). Pollens have an exine typically of two or more layers. Spores are not optically active, that is when they are viewed between crossed polarizing filters they disappear. Pollens are often optically active or contain starch grains that are optically active. These pollens are visible when viewed between crossed polarizing filters. As pollen grains age they lose the optical activity and the starch grains dissipate into the environment. These starch grains carry the allergen for that pollen with them. Most standard guides to pollen identification are based on "catalyzed" grains, chemically processed pollen that removes the contents of the grain and most of the optical activity of the grain. It also swells the grain. This is a necessary practice in the analysis of fossil grains but for environmental analysis the fresh pollen grain is more characteristic. Most of the pollen grains shown here are fresh. They are from honeybee frass (fecal pellet), regional honey samples, or from recent environmental samples.

Palynologists usually use Latin or scientific names (link) to refer to plants. Groups of related plants often have very similar pollen, and scientific nomenclature allows for greater specificity. Sometimes pollen is identified to a “group” or “type” to reflect a broader range of possible classifications.

Vesiculate Pollens

Vesiculate Pollens: Pollens with air sacks to increase buoyancy. The sacks are typically two per grain at the bottom of the grain, but may also be doughnut shaped under the grain.

Vesiculate pollens are found in the Abies (Fir), Picea (Spruce), Pinus (Pine), Podocarpus (Podocarpus), and Tsuga (Hemlock).

Fig 3.7 a, 3.7 b and 3.7 c: Vesiculate pollens

1. Trilete or Trichotomocolpate

Trilete or Trichotomocolpate: Pollens with three furrows joined at one pole.

Trilete (Trichotomocolpate) pollens are found in the Cocos (Coconut), Sphagnum (Peat Moss), Pteridophyta (Fern), and Lycopodium (Clubmoss).

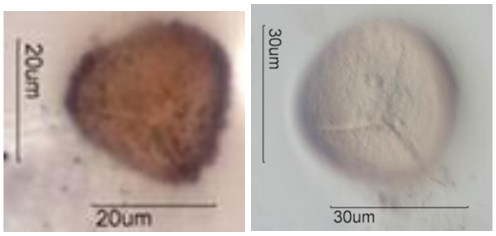


Fig 3.8 a, 3.8 b: Trilete (Trichotomocolpate) pollens

Inaperturate

Inaperturate Pollens: Pollens without air sacks that don't have any visible openings in the exine.

Inaperturate pollens are found in the Cupressaceae (Cedar), Equisetum (Horsetails), Larix (Tamarack), Pseudotsuga (Douglas fir)), and Salicaceae (Cottonwood and Aspen).

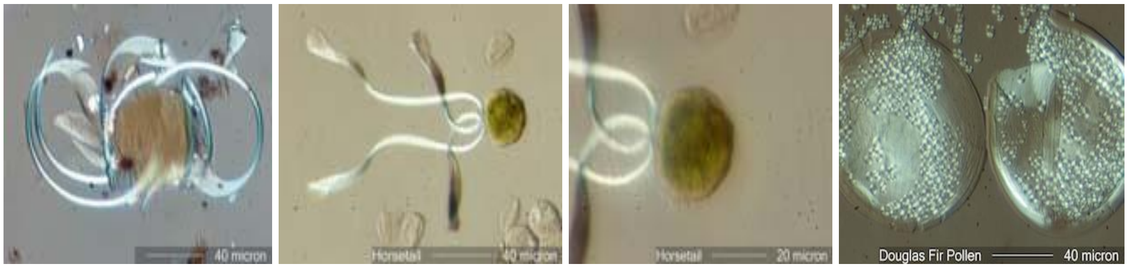


Fig 3.9 a, 3.9 b, 3.9 c and 3.9 d: Inaperturate pollens

Polyplicate

Polyplicate: Pollens with numerous sharp meridional ridges.

Monolete

Monolete: Kidney-shaped fern spores with one furrow and without an associated pore or transverse furrow.

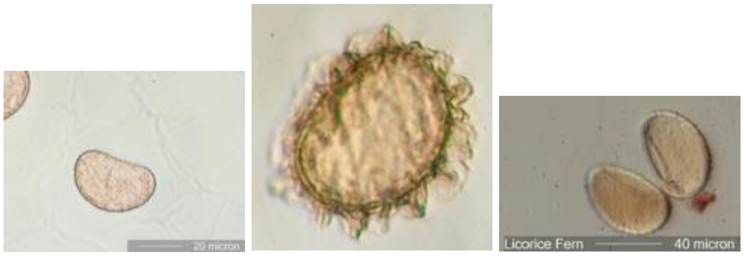


Fig 3.10 a, 3.10 b and 3.10 c: Monolete

Monocolpate

Monocolpate: Pollens with one furrow and without an associated pore or transverse furrow.

Monocolpate pollens are found in the Liliaceae (Lily Family) primarily.

Fig 3.11 a, 3.11 b and 3.11 c: Monocolpate pollens

Dicolpate: Pollens with two furrows and without associated pores or transverse furrows.

Fig 3.12 a, 3.12 b and 3.12 c: Monocolpate pollens

Tricolpate

Tricolpate: Pollens with three furrows and without associated pores or transverse furrows.

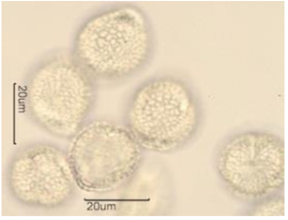


Fig 3.13: Tricolpate Pollens

Polycolpate: Pollens with more than three furrows and without associated pores or transverse furrows.

Stephanocolpate

Stephanocolpate: Pollens as above and all the furrows are oriented meridionally

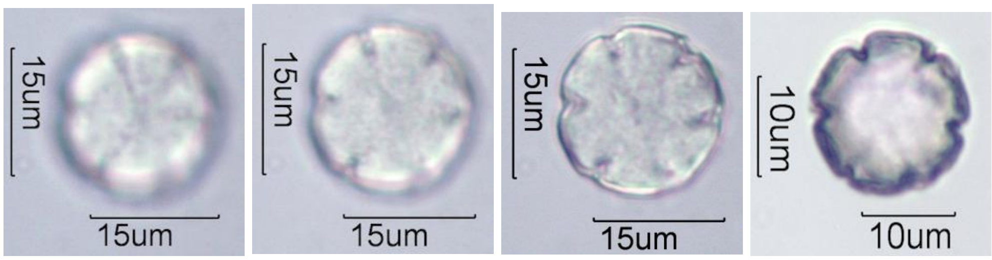


Fig 3.14 a, 3.14 b, 3.14 c and 3.14 d: Stephanocolpate Pollens

Pericolpate: Pollens as above but all the furrows are not oriented meridionally

Heterocolpate

Heterocolpate: Pollens with multiple furrows, some with pores.

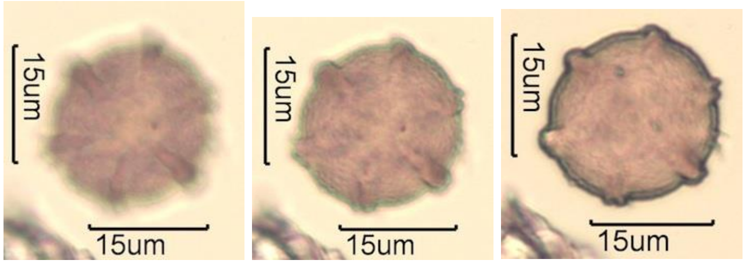


Fig 3.15 a, 3.15 b and 3.15 c: Heterocolpate: Pollens

Syncolpate

Syncolpate: Pollens with fused furrows.

Syncolpate pollens are found in the Primulaceae (Primrose Family), Eucalyptus (Eucalyptus), and Berberidaceae (Barberry and Oregon grape).

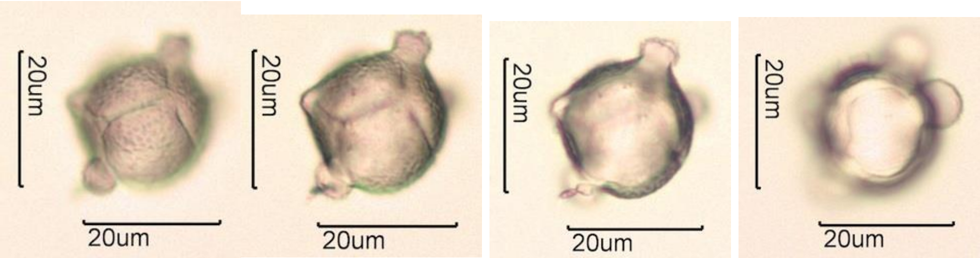


Fig 3.16 a, 3.16 b, 3.16 c and 3.16 d: Syncolpate pollens

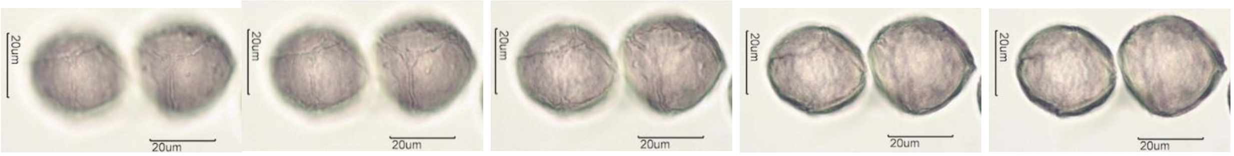


Fig 3.17 a, 3.17 b, 3.17 c, 3.17 d and 3.17 e: Syncolpate pollens

Monoporate

Monoporate: Pollens with one pore and without an associated furrow.

Monoporate pollens are found in the Gramineae (Grasses) primarily but also in the Taxodiaceae (Redwood and Cypress).

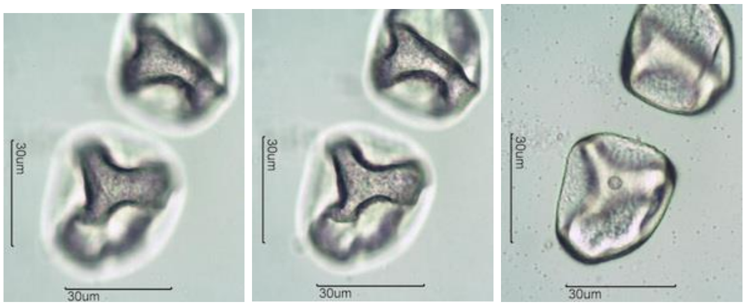


Fig 3.18 a, 3.18 b and 3.18 c: Syncolpate pollens

Diporate: Pollens with two pores and without associated furrows.

Triporate

Triporate: Pollens with three pores and without associated furrows.

Triporate pollens are very common so they will be sub-divided by surface ornimentation or other Dominant feature. Some species than normally have triporate pollens may show four pores.

Triporate, Echinate pollens

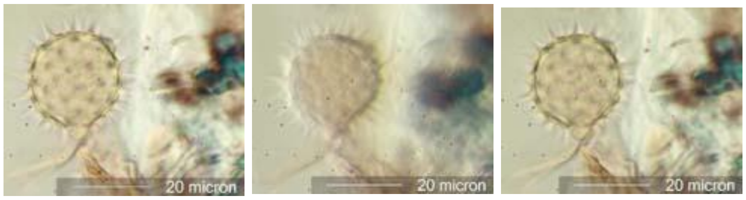


Fig 3.19 a, 3.19 b, 3.19 c Triporate, psilate (smooth) pollens

Triporate, with Vetibulum (Pore Cavity) pollens

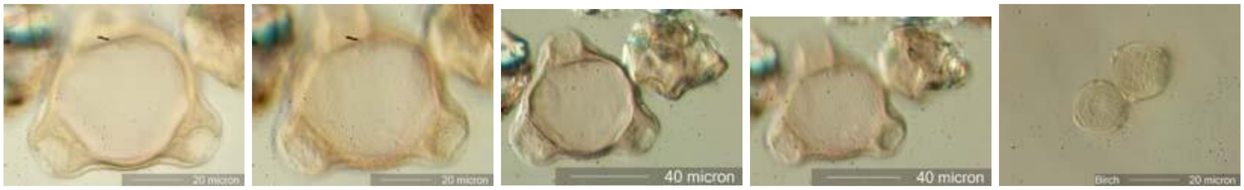


Fig 3.20 a, 3.20 b, 3.20 c, 3.20 d and 3.20 e: Triporate, with Vetibulum (Pore Cavity) pollens

Triporate, baculate and clavate, them forming reticulum pollens

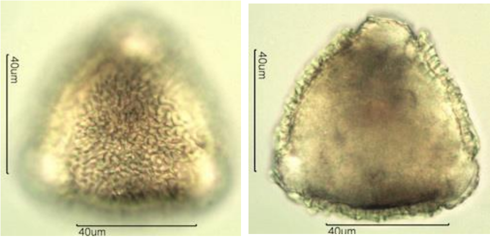


Fig 3.21 a, 3.21 b: Triporate, baculate and clavate, them forming reticulum pollens

Stephanoporate

Stephanoporate: Pollens with more than three pores and all pores are located equatorially.

Stephanoporate pollens are found in the Campanulaceae (Colorado Bluebells), Corylaceae (Alder),Onagraceae, and in Ulmaceae (Elm).

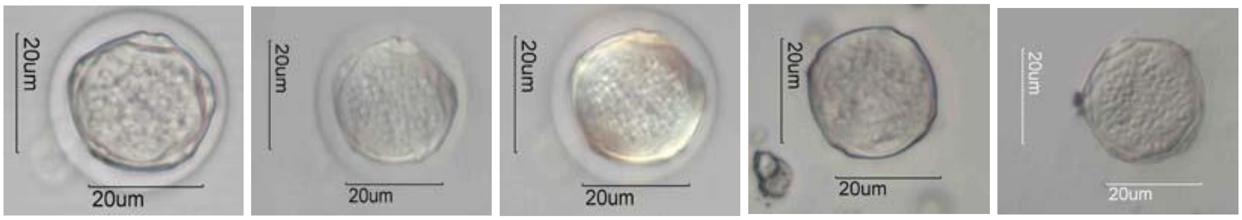


Fig 3.22 a, 3.22 b: Stephanoporate pollens

Periporate

Periporate: Pollens as above but the pores are not located just equatorially.

Periporate pollens are very common so they will be sub-divided by surface ornamentation or other Dominant feature.

Periporate, psilate (smooth) pollens are found in the Boraginaceae (Lithodora)

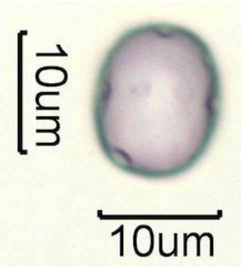


Fig 3.23: Periporate pollens

Periporate, scabrate (scab-like) pollens are found in the Plantaginaceae (Plantain).

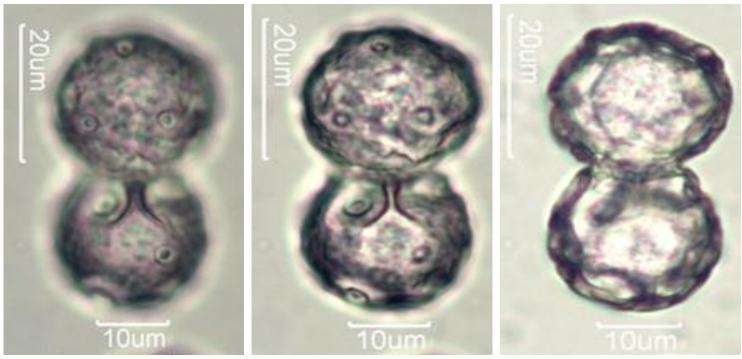


Fig 3.24 a, 3.24 b and 3.24 c: Periporate, scabrate (scab-like) pollens

Periporate, echinate pollens are found in the Polygonaceae.

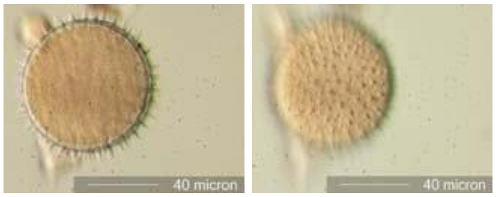


Fig 3.25 a and3.25 b: Periporate, echinate pollens

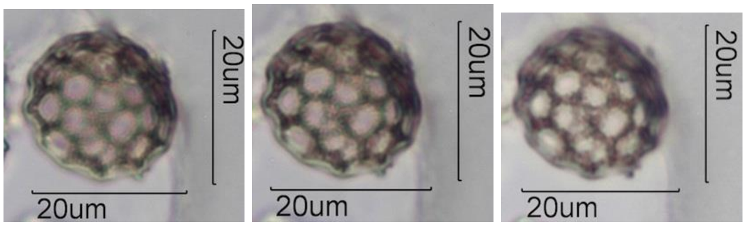


Fig 3.26 a, 3.26 b and 3.26 c: Periporate, echinate pollens

Tricolporate or Trizonocolporate

Tricolporate: Pollen three furrows, each with a pore.

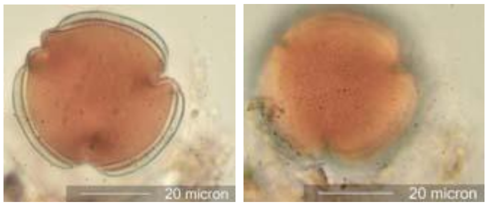


Fig 3.27 a and 3.27 b: Tricolporate Pollen

ECHINATE

(Spikes) Trizonocolporate

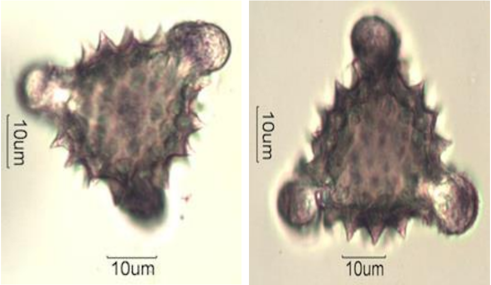


Fig 3.28 a and 3.28 b: (Spikes) Trizonocolporate

RETICULATE (Cavities) Trizonocolporate

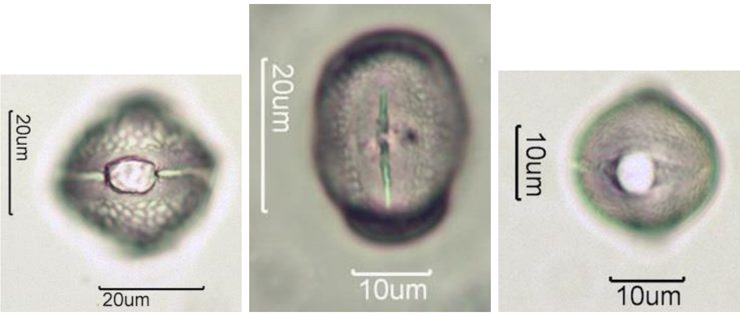


Fig 3.29 a, 3.29 b and 3.29 c: RETICULATE (Cavities) Trizonocolporate

SCABRATE (No distinct surface structure) Trizonocolporate

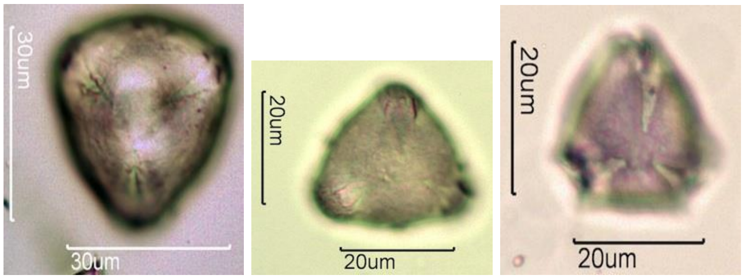


Fig 3.30 a, 3.30 b and 3.30 c: SCABRATE (No distinct surface structure) Trizonocolporate

Striate (Roughly Parallel Elongation) Trizonocolporate

Fig 3.31 a, 3.31 b and 3.31 c: Striate (Roughly Parallel Elongation) Trizonocolporate

Polycolporate: Pollen with more than three furrows, each with a pore.

Stephanocolporate

Stephanocolporate: Pollens as above and all the furrows are oriented meridionally

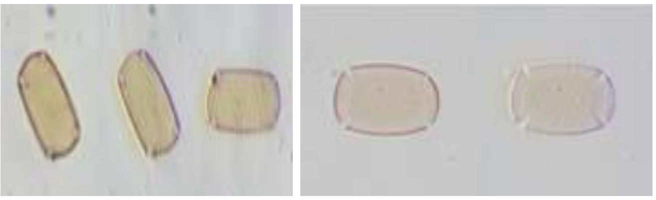


Fig 3.32 a and 3.32 b: Stephanocolporate Pollens

Pericolporate: Pollens as above but all the furrows are not oriented meridionally.

Echinolophate (Fenestrate)

Echinolophate (Fenestrate): Pollen with geometrically positioned large openings in the "tectum", some with pores.

Fenestrate pollens are found in the Lactuceae (Dandelion) primarily.

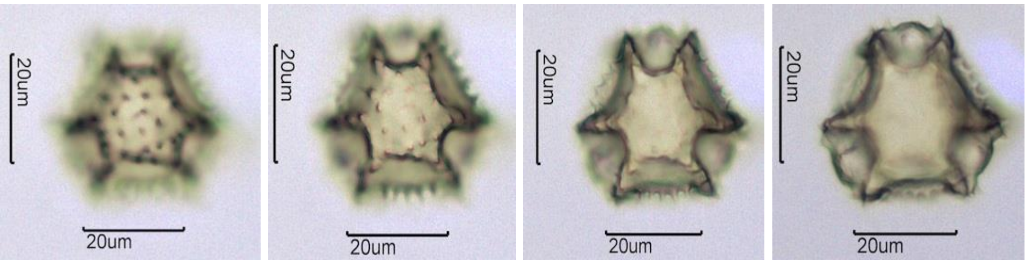


Fig 3.33 a, 3.33 b, 3.33 c and 3.33 d: Fenestrate pollens

Polyad

Polyad: Pollen consisting of more than one grain.

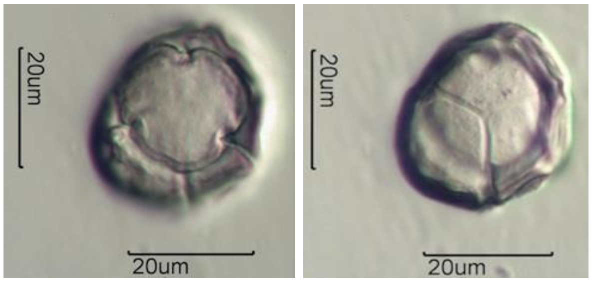


Fig 3.34 a and 3.34 b: Polyad: Pollen

Applications and uses of Palynology

Palynology is used for a diverse range of applications, related to many scientific disciplines:

- **Biostratigraphy and geochronology.** Geologists use palynological studies in biostratigraphy to correlate strata and determine the relative age of a given bed, horizon, formation or stratigraphical sequence.

- **Palaeoecology and climate change.** Palynology can be used to reconstruct past vegetation (land plants) and marine and freshwater phytoplankton communities, and so infer past environmental (palaeoenvironmental) and palaeoclimaticconditions.
- **Organic palynofacies studies,** which examine the preservation of the particulate organic matter and palynomorphsprovides information on the depositional environment of sediments and depositional palaeoenvironments of sedimentary rocks.

- **Geothermal alteration studies,** examine the colour of palynomorphs extracted from rocks to give the thermal alteration and maturation of sedimentary sequences, which provides estimates of maximum palaeotemperatures.

- **Limnology studies.** Freshwater palynomorphs and animal and plant fragments, including the prasinophytes and desmids (green algae) can be used to study past lake levels and long term climate change.

- **Taxonomy and evolutionary studies.**

- **Forensic palynology:** the study of pollen and other palynomorphs for evidence at a crime scene.

- **Allergy studies.** Studies of the geographic distribution and seasonal production of pollen can help sufferers of allergies such as hay fever.

- **Melissopalynology:** the study of pollen and spores found in honey.

- **Archaeological palynology,** examines human uses of plants in the past. This can help determine seasonality of site occupation, presence or absence of agricultural practices or products, and 'plant-related activity areas' within an archaeological context. Bonfire Shelter is one such example of this application.

Because the distribution of acritarchs, chitinozoans, dinoflagellate cysts, pollen and spores provides evidence of stratigraphical correlation through biostratigraphy and palaeoenvironmental reconstruction, one common and lucrative application of palynology is in oil and gas exploration.

Palynology also allows scientists to infer the climatic conditions from the vegetation present in an area thousands or millions of years ago. This is a fundamental part of research into climate change (Faegri and Knut 1973: 5-12).

Palynological Archaeology

Definition:

Archaeological palynology is the study of pollen, the virtually indestructible, microscopic, but easily identifiable plant parts in archaeological sites. Pollen is one of several types of plant residues which have been retrieved from archaeological sites, either clinging to the inside of pots, on stone tools or within archaeological features such as storage pits or living floors.

Palynology is the science that studies fossil pollen and other palynomorphs (tiny organic-walled micro-fossils). Archeological palynology examines human use of plants in the past. Pollen analysts study pollen grains preserved in soil sediments, peat bogs, on rocks and even on artifacts. By studying fossil pollen we can correlate climatic change and archaeological evidence to help us to understand Maryland’s environmental history.

When identified to species, archaeological pollen can be used to identify clues to prehistoric climate (what kind of plants grew in the neighborhood of a given site) and diet (what kind of plants were consumed at a given site). Recent studies have shown that caution should be taken with regard to pollen, because like many microscopic archaeological remains, natural and cultural behavior may both account for the presence of pollen (Bryant, Vaughn, and Holloway 1983: 191-195).

Using Palynology as an archaeological tool. Archaeological Palynology has developed somewhat independently in different nations during the mid- twentieth century, so terminologies and emphases vary. Its various aspects are summarized below as:

Archaeological Palynology is a branch of Archaeobotany applying botanical and paleo-botanical techniques to archaeological investigations.

1. Quaternary Palynology

This branch of archaeological palynology focuses on the **influence of vegetation and climate change on human behavior and demographic patterns** in addition to the effect of humans on the environment. Archaeological mitigation of large construction projects often includes environmental reconstruction as a background for the chronology for human occupation of the area. A Southwestern example is the palynological reconstructions of precipitation and temperature for the Dolores Colorado region by Petersen (1988). Intensive Anasazi occupation of the area was permitted by a longer growing season and greater summer precipitation during the Medieval Warm Period (AD 1000 - 1350).
In the mid- twentieth century, pollen analysis of European Paleolithic sites often utilized cave sediments. Leroi- Gouran and Miskovski analyzed the pollen from burials, living floors, and cave fill and interpreted the pollen percentages in terms of the regional climatic chronology (Bryson and Swain 1981: 135-137).

2. Archaeopalynology

This term, used in Faegri, Kaland, and Krzywinski (1989), primarily refers to the palynological study of **human impact on the environment**. Pollen analysis of lakes and bogs may be used to study humans as agents of vegetation change rather than causes such as climate. Firbas (1934) and Iversen (1954) lead the development of this technique in northern Europe. The human caused changes in pollen diagrams may be difficult to detect because the archaeological sites are small and the effects on the pollen rain to not extend far. Indicator taxa, such as cultigens (Wheat) or weeds (*Plantago*) are useful.
J. Iversen experimentally investigated the relationship between humans and the pollen rain by clearing a mature forest with stone-age tools, and following the development of weeds on the forest floor. These same weeds accompany the earliest wheat pollen in pollen diagrams dating to the Atlantic / Sub Boreal transition

of the European Climatic Sequence. In contrast to these local effects, in the American Midwest, regional vegetation patterns were shaped by Indian caused fires, which ceased after settlement (Grimm 1983). The degree of vegetation disturbance reflected in the pollen rain can be used as a measure of population density or duration (annual vs. seasonal) of occupation (Bakker 1951: 1-5).

3. Environmental Archaeology

As used here, this term refers to the **study of sediments of archeological sites**, particularly soils. In Britain, it is a general term for the application of palynology and other geological methods to archaeological settings. **Geoffrey Dimbleby** pioneered environmental archaeology in Britain in the 1950s, particularly the pollen analysis of soil samples. He demonstrated that pollen was preserved in certain soils, and he interpreted the pollen percentages in terms of human-caused environmental change. His analyses were characterized by close interval sampling and tens of samples per site standards that are seldom surpassed in contemporary studies of archaeological open sites (Hall 1981: 193).

4. Archaeological Palynology

This North American term includes the previously-mentioned topics, and some unique applications. It is characterized by the analysis of **artifacts, features, and coprolites from archeological sites** as well as stratigraphic study of its sediments. Archaeological palynology in North America was heavily influenced by **Paul Martin** and his colleagues during the 1950's and 1960's. Although his interests primarily were in the effects of climate change on the North American mega fauna, his connection with the Geochronology Laboratory of the University of Arizona led to the pollen analysis of many archaeological sites in the American Southwest. The aridity of Southwest produces excellent pollen preservation in open archaeological sites and in alluvial settings. Martin recognized the power of archaeological palynology to trace the history of the domestication and cultivation of plants.

Artifact Sourcing: Martin and his students (Bohrer, Hevly) also pioneered the pollen analysis of archaeological artifacts with the "pollen wash" of ground-stone artifacts. This technique is frequently applied, but has never been rigorously investigated. It consists of analyzing the the pollen from material imbeded in an artifact (Arendt 2004).

Human Coprolites The superb preservation provided by southwestern aridity has allowed the detailed analysis of human dietary preferences. (Ibid).

History of Plant Domestication: Paul Martin (Martin and Schoenwetter 1960; Schoenwetter 1974) and his students were the first to apply palynology to the study of plant domestication in North America. Corn (*Zea mays*) is the most commonly found pollen of a cultigen, squash and cotton (but not bean) also occur - as do “incipient cultigens“ such as *Agave, Cleome, Opuntia*, and the abundant pollen of various “weeds.“ The foods and fibers upon which civilization is based were first selected and cultivated by humans in the early Holocene. Early examples are wheat in the Near East and squash in Central America. Cotton remains an abominable mystery (Arendt 2004).

The Role of Palynology in Archaeology

Introduction

A primary objective of archaeological investigation is to reconstruct and explain as fully as possible mechanisms and directions of prehistoric culture change. To accomplish this task, the archaeologist must look beyond the recovery and identification of cultural materials such as lithic debris, points, grinding stones, perishables, and pottery. Through the careful analysis of other sources of information such as plant macrofossils (seeds, leaves, bark, flowers, and wood), animal remains (bones, hair, tooth, and shells), soil chemistry, charcoal identification, and pollen the archaeologist is able to speak more confidently about many aspects of past cultures. Once these analyses are completed, the archaeologist also is afforded an opportunity to test hypotheses about the paleoenvironment, diet, subsistence, disease, and the level of prehistoric technology and trade. One of these formerly peripheral areas of archaeological study now being investigated with increased regularity is the recovery and analysis of fossil pollen. Although most archaeologists are aware of the basics of palynology, many of them are still not aware of the wide range of data that palynology can provide, they are not familiar with new sampling techniques that yield these data, nor are they aware of the importance of asking for the advice of a palynologist prior to conducting actual field investigations.

As pollen analysts working primarily in the field of archaeology, we have often been asked to explain how one should collect pollen samples and to outline the various ways that pollen data are useful in archaeology. This research is our attempt to answer those questions.

History of Palynological Applications to Archaeology

The microscope

The invention of the microscope initiated several different areas of scholarship, including the field of palynology. Although precursors to the microscope occur before the 1600's, the basic microscope begins with Anton von Leeuwenhoek**.** He found that when glass is polished in a certain way it results in a curvature allowing for increased magnification. Robert Hooke working with Leeuwenhoeks design made changes and improved it. As a result of these early microscope pioneers, research at the microscopic level began in earnest. Two names are known to be associated with the earliest applications of microscopy to botany and specifically to palynology. Nehemiah Grew of England and Marcello Malpighi from Italy are considered the co-founders of pollen morphology and the initiators of the study of pollen (Wodehouse 1935). Nevertheless, it was not until the late 1800’s that routine studies in botany and pollen begin.

History: Archaeological Applications of Pollen in Europe

The earliest applications for the study of pollen found in sediments were to date geologic deposits. It was soon realized that pollen could be utilized for other purposes as well (Davis 1976). The earliest known application of palynology to archaeology is the study of a Swedish archaeological site by Lennart von Post et al. (1925). Von Post was not the first to identify and study pollen, nor was he the first to establish the basic principles of pollen research; however, he was the first to realize the potential importance of pollen studies to archaeological research. Von Post, a geologist by professions, would, occasionally analyze pollen samples in conjunction with archaeological samples to determine relative dates. However, he would only look at samples from Sweden. The first and best known of these sites is the dating of a Bronze Age mantle found at Västergötland (Von Post et al. 1925). Essentially von Post used palynological evidence to date a woven cloak found in a bog near Gerumsberg, in Västergötland. "The cloak was found in a small bog near the eastern shore of the Hjortmossen swamp in the foothills of Västergötland" (Ibids: 2). Von Post attempted to use palynological evidence to date the stratigraphic layers within the swamp. He was, unfortunately, not entirely successful. He states that the analysis was conducted according to the following research plan: "1) Integration of the environment into the layering series of the location in which the cloak was found, 2) Connection of the layering series with a stratigraphically significant layering series within the Hjortmossen [Swamp], 3) Attempt to create a meaningful time line based on pollen spectra from bogs in the region, [and] 4) Discover a temporal connection between the regional stratigraphy and the stratigraphy of the discovery location" (Post 1925:10).

At no point did von Post attempt any type of environmental reconstruction, paleodiet determination or any other analysis not directly linked to determining a time sequence of the stratigraphic layers. Nevertheless, he did succeed in correlating some of the pollen he found with the natural flora for the Hjortmossen Swamp. He suggested that, "The ability to date the various layers of the bog to specific time periods is somewhat limited" (Ibid).

Von Post and most palynologists of the early 20th century utilized pollen data exclusively as a technique for dating strata. However, in a later publication (Von Post et al. 1939), archaeological information regarding everyday life is discussed. The major difference between the Västergötland study (1925) and this later study is the discovery of *Humulus* (hops) pollen. Von Post never considered any pollen other than arboreal or tree pollen important. As a result, pollen applications to archaeology came later than would have been expected, especially with the later research emphasis on cultigens. Additional studies conducted in Europe advanced the study of pollen in archaeological settings. Some of the most important ones include: 1) the introduction of pollen staining (Faegri 1936), which enabled finer details of exine morphology to be examined and a distinction between pollen grains to be established; 2) Erdtman's acetolysis processing procedure, which aided in pollen identification and removed more organic debris in samples [Erdtman and Erdtman 1933]; 3) the application of the Assarson Granlund [1924] HF procedure to removes silicates, 4) the availability of more technologically sophisticated microscopes; and 5) the development of the electric centrifuge.

Before 1940, with the exception of von Post's study in 1925, few attempts to examine samples in an archaeological context using pollen data were conducted until the landmark study by Johs. Iversen (1941). Iversen was a Danish geologist who is best well known for dating the introduction of agriculture in northern European, but he also found evidence of plants introduced to the study area and the effects of land clearing due to human intervention (Iversen 1941). Iversen is one of the first to correlate palynological data to cultural events revealed in archaeological setting. Although Firbas (1934) first emphasized the importance of non-arboreal pollen (NAP) or pollen from plants other than trees, Iversen used both arboreal and non-arboreal pollen data to interpret: 1) climate, 2) cultural events, and 3) the introduction of cultigens into Denmark. Iversen used data to determine the native flora at the time of deposition. He then inferred the climatic conditions by classifying these plants as either warm vs cold weather and wet vs dry tolerant weather species. The pollen types that Iversen identified as indicators of culture include Chenopodiaceae (goosefoot), cereal pollen types from the Poaceae/Gramineae family (grass family) such as wheat and barley, and *Ulmus* (Elm). As a result of these investigations Iversen successfully dated introduction of the Neolithic into Denmark.

History: archaeological applications of pollen in the Near East

Initial applications of palynology applied to archaeological sites began with von Post in Sweden in the 1920's; however, archaeological applications of pollen data in the Middle East did not begin until the 1950's. According to Warnock (1998), the Near East is an area consisting of three regions, Syro-Palestine or the Levant (now including Israel); Anatolia or most of Asian Turkey; and Mesopotamia including the western slopes of the Zagros Mountains or what Braidwood refers to as the "Hilly Flanks" of the Fertile Crescent (Warnock 1998; Braidwood and Braidwood 1950).

The Fertile Crescent is an area defined by the founder of the Oriental Institute and Egyptologist James Breasted and includes the plains of the Tigris, the Euphrates and the Nile (Braidwood 1952). Braidwood expanded this definition to include the slopes of the surrounding mountains as these areas did not require irrigation as the winter rains would result in a crop in the spring (Ibid). To some scholars the term palaeothnobotany is synonymous with palynology, having grouped palynology with macrobotanical plant remains, charcoal and wood remains, seeds, and phytoliths, all under the heading of palaoethonobotany. The original definition for palaeoethnobotany is by Hans Helbaek, who first coined the term in 1959, stating that any domesticated plant is a product of human manipulation (Helbaek 1959).

Today areas of plant studies from the past are so numerous as to require separate terms and definitions to be able to determine which aspect of plant research is being explored. Historically, in the Near East palynology, as it is applied to archaeology, lagged significantly behind Europe and the United States. Although Warnock states (1998) that palynological studies parallel paleoethnobotanical studies as applied to archaeology, I have found no indications that pollen analysis in the Near East began as early as the palaeoethnobotany studies in the area. In the early days of botanical analysis from archaeological remains, especially in the Near East, studies routinely included vegetation history, climate changes, and the impact of humans to the vegetation. Although these three aspects were not applied anthropologically, as Warnock states, I believe that the question of domestication is anthropological by its very nature. The domestication question has been and is being intensely studied. The best known early researcher to investigate this question was Gordon V. Childe, followed by Robert Braidwood and his “hilly flanks” of the fertile crescent. Nevertheless, Gordon Childe’s Oasis Theory may be traced back to Raphael Pumpelly (Pumpelly 1904, 1908) and to C.E.P. Brooks in his Climactic Determinism theory (Brooks 1936).

In his 1928 book “*The Most Ancient Near-East*” Gordon V. Childe postulates the Oasis Theory or what has also been termed the Propinquity Theory or the Desiccation Theory (Phillips 1979). This theory attempts to explain how and why people initially grouped together and ultimately domesticated animals and plants. In his explanation as the climate became drier, people and animals grouped together in areas that could sustain food. Animals became domesticated by the humans inhabiting these oases and people domesticated plants to feed themselves and their domesticated animals. This Oasis Theory or the theory of environmental determinism (climatic determinism) may be traced back to Raphael Pumpelly, a geologist by training. When Pumpelly was working at the site of Anau in 1904, he postulated that as a result of the climate and Physiography, animals became domesticated because they sought refuge on the oases, during the dry times, before human settlement (Pumpelly 1908).

Pumpelly was not an academically trained archaeologist but he had the foresight to self-educate himself and to realize his limitations. His initial interest in archaeology stemmed from a curiosity regarding the origins of the Aryan language and people (what is today Indo European). Although not successful in this venture, he did organize and execute the first multidisciplinary archaeological expedition and excavation which included archaeologists (Hubert Schmidt and Langdon Warner), a geographer (Ellsworth Huntington), a physical geographer (William Davis -who pioneered the field of geomorphology), and Pumpelly himself as geologist. Another aspect of his excavations, which was considered unusual for the time, was his willingness to excavate a site but not keep any of the artifacts found (Ibid).

Unfortunately, as so often happens in academia it is the prolific writers, not always the originators who are associated with new innovations. In this instance it was Gordon V. Child who developed and popularized the idea of environmental determinism through the synthesis of the available ideas and theories of plant and animal domestication. In *The Most Ancient East*, Childe had followed Brooke's speculations on climate as a force resulting in domestication of plants and animals (Braidwood 1958). Brooks was a climatologist whose main concern was changes in glacier levels, ocean circulation patterns, sun radiation, temperatures cloudiness, mountains and other geological features that affected the climate and ultimately the weather, however, he also appreciated the consequences of climactic shifts to prehistoric and historic peoples. From his *Climate through the ages* (1926) Brooks states that he believed that even variations in rainfall amounts from one century to the next would determine where people would settle (Brooks 1936; Childe 1928). With regards to Childe’s theory Braidwood found a gap or hiatus in his time sequence between the first settlements and the first evidence for domestication.

In 1945 Braidwood produced “the gap chart.” This was a chronological diagram demonstrating a significant gap in the time between the last mobile Paleolithic hunter-gatherers, and the appearance of the earliest agropastoral villages (Braidwood 1949; Watson 2006). This discovery directly refutes Childe’s post-Pleistocene revolution and fuels further research into the domestication question. All of these theories have in common the original research completed by J.R. Mucke in 1898 in which he concludes that the peoples that originally domesticated animals could not be nomadic hunters but agriculturalists who first domesticated plants (Mucke 1898).

These early agriculturalists, he theorized, attracted ruminants in search of food due to the change in climate that resulted in the scarcity of food and this resulted in the domestication of animals. The earliest publication of cultivation centers lies with Alphonse de Candolle’s in his1882 book *Origine de Plantes Cultivées*. This book describes those areas or regions where plant domestication may have occurred. Candolle’s potential domestication centers included, China, Southwest Asia including Egypt, and Tropical Asia. Later Vavilov (1935) in his book *The Phytogeographical Basis for Plant Breeding*, identifies eight centers of potential domestication zones based on the number of varieties of domesticated plants found.
What these early expeditions and theories lacked was accurate plant data in an archaeological context. While many of these early excavations report plant remains and some even attempt to interpret the findings, in reality the botanical remains found were accidental rather than planned attempts. As a result these plant remains do not represent all of the possible information available, making any reliable interpretation impossible except for ubiquity studies. In many cases food cultivation was inferred from tools (i.e., sickles and axes), and botanical remains considered “nonartifactual” (Braidwood and Braidwood 1952).

In the Middle East as in Europe the traditional pollen expert was botanically trained and utilized the data primarily for environmental reconstructions (Warnock 1998; Bottema and van Zeist 1981; van Zeist and Bottema 1982; van Zeist and Wright 1963; van Zeist and Bottema 1977; Bottema 1986; Baruch and Bottema 1991; Leroi-Gourhan and Darmon 1991; Zohary 1935).

Pollen analyses were completed and dated absolutely after the introduction of carbon-14 dating in the late 1940’s and early 1950’s, yet these pollen data continued to be utilized for climate reconstructions, as they had been prior to this time (Libby 1947, 1949, 1955; Arnold and Libby 1951). In fact it wasn’t until the 1950’s that Robert Braidwood invited Hans Helbaek and his flotation methodologies to study macro remains such as carbonized seeds, which were explored as an independent potential methodology for additional cultural information (Braidwood 1952, Braidwood and Braidwood 1953; Hopf 1969; Miller 1991; Bottema 1995, Frey 1955; Jarman et al. 1972; Pearsall 2000). By the 1990’s palynological investigations of Near East archaeological sites became more equal in research goals found earlier in Europe and the New World. Topics such as human impact on the vegetation (Barach 1991) and anthropogenic indicators (Bottema and Woldring 1991) began appearing with Near East sites. The greatest challenge to palynology in the Near East has been and still is the preservation of pollen. While some success in extracting sufficient concentrations of pollen from fossil samples has been reported in Israel
(Schoenwetter and Geyer 2000), many early attempts to extract pollen from archaeological sediments

proved unsuccessful. Although dry conditions do tend to preserve artifacts, arid lands also tend to have alkaline soils which may result in a decrease of pollen preservation. There is still controversy surrounding different processing methodologies and whether or not all pollen records from sites, such as those found in Israel, may be considered valid (Bryant and Hall 1993; Schoenwetter and Geyer2000).

One of the earliest attempts to use pollen data from an archaeological site in the Near East for a cultural interpretation comes from the site of Shanidar Cave in Iraq. It was at this site that sediments associated with a Neanderthal burial were analyzed and found to contain high concentrations of insect-pollinated flower pollen (Leroi-Gourhan 1975). This was interpreted to indicate cultural, if not religious, burial practices and was further evidence suggesting that Neanderthals were intelligent, and capable of abstract thinking. Prior to the 1970's the only other reference found regarding pollen analysis of an archaeological site in the Near East is found in Echegary (1966).

In this publication the botanist van Zeist attempts a pollen analysis from the sediments of a terrace at El Khaim in the Judean Desert (Horowitz 1979). Although this attempt was not successful due to a lack of preserved pollen, it still remains a turning point in ethnopalynology.

History: archaeological applications of pollen in North America

The earliest uses of in North America were for dating strata and were conducted in 1927 by the Finnish Palynologist Väinö Auer. Auer studied the bogs of southeastern Canada and, although this study was not archaeological in nature it marks the introduction of palynology to the New World. The earliest palynological study by an American was conducted by several years later Patricia Draper (1929). Davis (2004) lists other early studies including: Ivey F. Lewis and E. C. Cocke (1929), Paul B. Sears (1930, 1931), Lane (1931), Bowman (1931) and John E. Potzger (1932). The first Ph.D. dissertation on Quaternary palynology was that of Leonard Richard Wilson (University of Wisconsin - Madison) (1935). Although these initial studies did not apply directly to archaeology, they set the framework for other studies to follow.

The first palynological application to archaeological sites in North America is a study completed by Paul B. Sears (1931). In his 1931 article Sears reviewed the pollen analyses being conducted throughout North America at the time, (Auer 1930, Huntington 1922, Lewis and Cocke 1929) and suggested that the human settlement patterns fall along what he called the "corn belt of post-glacial times." Although antiquated and misinterpreted, Sears's theories about the rise and fall of the Hopewell civilization are based on the integration and application of palynological data to archaeology. In a 1932 article Sears attempts to explain the movement of native peoples as a result of climatic shifts. Although this 1932 study and his subsequent study in 1939 yielded limited success, he and others (i.e., Deevey 1944, Sears and Clisby 1952, Clisby and Sears 1956, Anderson 1955) conducted some of the first New World archaeological studies utilizing palynology.

Most of these studies were conducted on sites in the Southwest United States. The American Southwest has always intrigued travelers who visit the many abandoned pueblos. Even during the colonization period many detailed descriptions of these pueblos may be found as these early settlers began to wonder who had create these vast structures. As time progressed and the area became influenced more by the invading “anglos”, replacing the earlier Mexican occupation by the 1830's and 1840's new interests in the area, combined with the newly formed and government controlled, Smithsonian Institute, resulted in funded exploration parties to the region (Dupree 1957).

According to Wissler (an American anthropologist associated with the American Museum of Natural History from 1902-1942) the period that ran from 1860 to 1900 was the "Museum Period," which saw the growth of eastern institutions, under such leaders as Frederick W. Putnam, that sent out collecting expeditions to areas like the Southwest”(Schuyler 1971). As a result of the increased interest from the museums and the government, both money and archaeologists infused into the American Southwest. Paul Schultz Martin, historically a prominent scientist working in the Southwest, was a herpetologist by training, but became interested in pollen data as a way to explain how certain plant and animal species could be found in Mexico and southwestern United States but were absent from in between Years earlier researchers such as Lucy Braun hypothesized that the southeastern forests of the United States once extended through Texas and parts of the Southwest in a continuous area down as far as the highland of Mexico. Unfortunately, Braun (1955) had no data to support her theory other than the presence of identical species of plants in both areas but not inbetween. Her ideas were rebuked by other scientists namely Frey (1955), a geologist working with pollen data. Other studies at this time in the American southwest were also trying to find the answer to the disparate placement of plants and animals. Martin learned palynology and began a long career studying palynological applications in the American Southwest and archaeology.

By the first half of the 20th century the archaeology in the American Southwest was in the middle of a renaissance and many archaeological projects were carried out in the ensuing years. Because of good preservation created by the dry conditions, the American southwest represented a unique environment that resulted in the remarkable preservation of many different types of artifacts. Because of the initial efforts of Paul Schultz Martin and others, palynological applications to archaeology in the United States began in earnest in the American Southwest. There are two Paul S. Martins who spent their careers working in Southwestern archaeology. The first, already mentioned is Paul Schultz Martin; the other is Paul Sidney Martin. The latter was an archaeologist who worked for the Chicago Field Museum and spent his career working on the Anasazi and Mogollan complexes. Palynological applications to archaeology in the American Southwest were not the only ones. Applications elsewhere included pollen studies at sites such as the Boyles Street Fishweir (Benninghoff 1942; Knox 1942a). Because of ideal preservation, this study demonstrated the capabilities of pollen data and by 1944 was considered the only reliable evidence of early humans in the eastern United States (Deevey 1944).

In addition to the initial “museum effect”, the later antiquity laws and the implementation of federal legislation requiring extensive reports of archaeological sites on federal lands fueled the application of palynology to archaeology. Unfortunately, many of these early palynological investigations during the 1960s, 1970s, and 1980s became simply appendices added out of legal neccessity rather than being integrated into the overall archaeological site study. Many archaeologists were not trained to understand the implications of palynological research; a problem that is reflected in the initial lack of pollen studies and the location of these studies being relegated to appendices (Hall 1983).

The right word: history of the word palynology

Until the early 1940's there was a lack of consensus among researchers as to what the discipline, which ultimately became known as palynology, should be called. Ernest Antevs, known for his work in the development of the field of geomorphology and his work with his mentor Gerard De Geer, the creator of the Swedish varve chronologies, posed the question, “The Right Word?.” As written in the March 15, 1944, issue of P. B. Sears' Pollen Analysis Circular.

Antevs states: Is pollen analysis' the proper name for the study of pollen and its applications? The word ‘pollen analysis’ (meaning, I suppose, analysis of peat for pollen) was from the beginning used in Sweden to signify the identification and percentage-determination of the pollen grains of the principal forest trees in peat bogs and lake beds. However, its inadequacy was soon obvious, as shown for instance by Gunnar Erdtman's titles ‘Literature on pollen-statistics...’ and, beginning in 1932, ‘Literature on pollen-statistics and related topics’. Even the combination ‘statistical pollen analysis’, refer only to the *method* of getting certain data which in itself has little purpose and which does not apply to or cover all the branches of the pollen studies, much less the application of the direct results to climatic conclusions, etc. It is the *knowledge* gained from the pollen studies, be these statistical of morphological, or be they concerned with pollen-induced diseases as hay fever, etc., that has purpose and significance. In this case the international combining form -*logy* (English spelling) can hardly be used to denote this science, for the name would be, I suppose, “pollinilogy” (cf. polliniferous, pollinization), which is bad. To me “pollen science” (Swedish, “pollenvetenskap’”; German “Pollenwissenschaft” and “pollen scientific” sound better. Would “pollen science” be preferable to “pollen analysis”? (Ernst Antevs Feb. 18, 1944).

It is in a rebuttal to this publication that the term palynology was first coined. In the Pollen Science Circular. 1944. no. 8, p. 6, Hyde and Williams proposed: **THE RIGHT WORD**. The question rose by Dr. Antevs: “Is pollen analysis the proper name for the study of pollen and its applications?” and his suggestion to replace it by “pollen science” interests us very much. We entirely agree that a new term is needed but in view of the fact that pollen analysts normally include in their counts the spores of such plants as ferns and mosses we think that some word carrying a wider connotation than pollen seems to be called for. We should therefore suggest *palynology* from Greek A"80 (*paluno*), to strew or sprinkle; cf. An”8b<T (*pal*-), fine meal; cognate with Latin *pollen*, flour, dust): the study of pollen and other spores and their dispersal, and applications thereof. We venture to hope that the sequence of consonants p-l-n (suggesting pollen, but with a difference) and the general euphony of the new word may commend it to our fellow workers in this field. We have been assisted in the coining of this new word by Mr. L. J. D. Richardson, M.A., and

University College, Cardiff (Hyde and Williams July 15, 1944.).

Paul Sears (who was responsible for this circular) obviously found the term “Pollen Science” satisfactory since the title of his circular soon changed from “Pollen Analysis Circular” to “Pollen Science Circular.” However, it is the term palynology that has become widely accepted.

History of the processing methodology

In the early years of palynology, pollen samples were collected exclusively from bog environments. Bogs are ideal for pollen preservation; however, bog samples also contain a high concentration of organic matter. The greatest challenge to palynology during the early 1900's was (and continues to be) the separation and ultimate concentration of pollen grains from the surrounding matrix.

This problem is solved by a series of processing methodologies that focus on the destruction and dissolution of matrix materials (i.e., carbonates, silicates, cellulose, hemicellulose, etc.) using acids and bases, which, when used appropriately, will leave the fossil pollen undamaged. Early experiments with the use of aqueous KOH (potassium hydroxide) show that it is useful for removing humic acids, especially from bog samples. Nevertheless, an application of this technique, which employs a strong base, is not always practical for archaeological samples because of the susceptibility of partially degraded pollen to further degradation by KOH.

Holm (1890, 1898) discovered that aqueous hydrofluoric acid (HF) could be used to digest silicates (quartz or sand). In 1924 Assarson and Granlund (1924) introduced HF digestion to palynological processing as a way to remove the sand, which tended to occlude pollen grains, from bog samples. In 1934, Gunnar Erdtman (1934) introduced the acetolysis processing procedure to remove cellulose and lipids from the surface and interior of the pollen grains exposing the acid-resistant wall. This technique involves mixing two acids (acetic anhydride and sulfuric acid) to produce an exothermic (heat creating) reaction that dissolves cellulose. An additional procedure to remove remaining silicates and other inorganic materials takes advantage of the relatively high density of these materials with respect to pollen.

The theory behind the use of heavy liquids is fairly simple. Water has a specific gravity of 1.0, the pollen wall has a specific gravity of around 1.4 (Traverse 2007). The ideal heavy liquid is one in which all particles heavier than pollen sink, and pollen, and other material with a lighter density similar to pollen floats. The first mention of a differential heavy liquid separation technique, as it is applied to pollen, is found in Knox (1942). Although the heavy density material mentioned is an acetone/bromoform solution with a specific gravity of 2.3 rather than the current zinc chloride or zinc bromide solution in use today, it was effective in separating the heavy particles from pollen. An earlier article that describes a similar technique was written by F. Hustedt (1927).

In this publication the author discusses a separation methodology that employs Thoulet solution (a combination of mercuric iodide and potassium iodide), as the heavy liquid solution. Although this solution has an acceptable specific gravity, it is also described as being extremely poisonous and corrosive (Knox 1942). Knox also states that he did not find any other reference to the use of heavy density liquids for separation; nevertheless another publication does exist espousing the uses of Thoulet solution to separate out minerals. As a result to an intensive geological study of the native copper deposits of the Keweenaw Peninsula, in Michigan, two methods were used to separate minerals for study (Palache and Vasser 1925).

The first consisted of screening samples and the second consisted of using Thoulet solution because fluorite floated and was used to remove quartz and calcite (Palache and Vasser 1925). Later articles that mention heavy density separation include Deevey (1944) and Waterbolk (1954), in which bromoform is recommended as the heavy liquid solution. An article by Funkhauser and Evitt (1959) makes mention of a heavy density methodology using aqueous zinc chloride. Currently, zinc bromide is the solution of choice for many pollen labs although the cost can often be prohibitive. When evaluating the proper processing procedure for a given sample it is generally best to select the procedure with the fewest steps required to remove the majority of the matrix material because any procedure has the potential to lose pollen. The ideal processing procedure is one that is tailored to the matrix material.

Today, processing methodologies are varied and require the use of acids, bases, and alcohols in various strengths combined with a myriad of other procedures including heating, settling, deflocculation, screening, heavy density and suspension steps; all with the purpose of separating the pollen from its surrounding debris. In addition, some report differences in pollen recovery depending on the order in which different extraction procedures are performed (Smith 1998).

Pattern of Pollen Analysis

Pollen collected from an archeological site can provide insights into what the overall environment was like at the time the site was occupied and how area vegetation changed through time. Samples can be derived both from cultural and non-cultural settings when reconstructing plant communities.

Before Fieldwork Guide the sampling techniques

This guide is designed to provide advice on sampling techniques, to standardize field methods for collecting pollen, starch, phytolith, and macrofloral samples, and to provide a standard format for reporting field data to us.

When collecting pollen/starch, phytolith, and macrofloral samples it is important to remember that the purpose in sampling an archaeological site is to obtain specific information from various levels and/or features to address questions within the research design. To accomplish this, one must take care to sample only one specific level at a time. Do not mix levels or include surface material with soil from lower levels. The techniques outlined here are a guide to achieving thorough sampling with a minimum of contamination.

Pollen. Pollen may be transported by wind and form part of a record of local and regional vegetation. Some plants are pollinated by insects or other small animals and do not contribute much pollen to records of vegetation or human activity. Finally, pollen may be transported more selectively by humans in the course of working with plants. Pollen analysis can focus on interpretation of the past environment, for which stratigraphic samples are recommended. Pollen analysis also is a good tool for interpreting human exploitation of plants as foods, construction materials, or for a variety of utilitarian purposes. Pollen is surprisingly rugged and survives in sediments that many suppose would not be conducive to pollen preservation. We have developed methods for coaxing pollen from the sediments with which they are mixed. We find that making small changes in lab procedures improves recovery of pollen in geographic areas that have been difficult in the past.

Starch. Starch grains are white, tasteless, odorless, granular, solid complex carbohydrates (C6 H10 O5). They occur in starchy foods or foods high in carbohydrates, such as corn, grass seeds, cultivated and wild potatoes, biscuit root (Lomatium), acorns, etc. Any food that can be ground into flour is a good candidate for yielding starches. Starch grains can be present in sediment samples from cultural contexts and stratigraphic samples, in vessel and in ground stone washes, and in dental calculus. Starch grains survive the normal processing of pollen and phytolith samples in this institute; therefore, any sample collected for pollen or phytolith analysis is a candidate for yielding starch grains.

Phytoliths. Phytoliths are silica bodies accumulated by plants when soluble silica in the ground water is absorbed by the plant roots and is carried up to the plant via the vascular system. Evaporation and metabolism of this water result in precipitation of the silica in and around the cell walls in plants that accumulate silica. The general term phytoliths, while strictly applied to opal phytoliths, can also be used to refer to calcium oxalate crystals produced by plants such as agave, prickly pear cactus, cattail, mesquite pods and other legumes, and in some other plants. Calcium oxalate crystals appear to be more susceptible to degradation and/or dissolution in sediments than opal phytoliths. Opal phytoliths, which are distinct and decay-resistant plant remains, are deposited in the soil as the plant or plant parts die and break down. They are, however, subject to mechanical breakage and erosion and deterioration in high pH soils. Phytoliths are usually introduced directly into the soils in which the plants decay. Transportation of phytoliths occurs primarily by animal consumption, man's gathering of plants or by erosion or transportation of the soil by wind, water, or ice.

Contamination

Contamination. Contamination comes primarily from four sources at most sites: **Wind, Plants, Soil, and People.**

The **wind** is a constant source of pollen contamination at the site, carrying pollen from both nearby plants and vegetation farther away. It also moves dirt and remains contained in the local dirt, such as pollen and phytolith. It is preferable to sample for pollen on calm days to minimize contamination by modern pollen carried on the wind. If you must sample on windy days, try to shelter the area to be sampled during the sampling process, and conduct the sampling as quickly as possible. This might be accomplished by enlisting a crew member to serve as a windbreak for the period required cleaning the surface and removing the pollen sample. Pollen samples must be collected immediately upon exposure of the feature or level to be sampled, since the surface will become thoroughly contaminated within 10-30 minutes (or less) of exposure. If immediate sampling is not possible, a small block of earth (1-2 cm thick) may be left in place over the area to be sampled. Note: this is not sufficient to protect the sample for long periods of time, or in case of rain.

Plants near the site also are a source of modern pollen, which can contaminate samples. Surface samples (modern control) always should be collected at each site prior to removal of vegetation for excavation.
As excavation proceeds, the **soil** that is removed becomes a potential source of contamination for both the modern surface and archaeological surfaces as they are exposed. The back dirt can introduce pollen from levels of occupation into the modern surface sediments.

People. Smoking or chewing tobacco on site: Handling cigarettes, cigars, or chewing tobacco contaminates your hands. Your hands then contaminate the area in which you are working and any samples that you collect. You can introduce tobacco pollen into your samples, resulting in an interpretation of the presence and possible use of wild tobacco by occupants of the site. You can introduce pollen from weedy plants from the southeastern US, confusing the pollen record and interpretation. These weedy plants are found in many other parts of North America, as well. Dogs can contaminate a record. Their fur constantly accumulates pollen that is shed, along with hair, while dogs are at the site. Analysis of animal fibers recovered in samples will be hindered by the presence of dogs at the site, either permanently or as visitors. Notation of dogs at the site or back at camp should be made and a specimen of dog hair saved in an envelope for reference and submitted with the samples. The presence of fields or piles of corn or other cultivated crops in the vicinity of the site also should be noted.

Sampling Methods

Surface Samples. A surface sample should be collected at every site to be excavated before clearing or excavation begins. This will insure that the surface sample will not become contaminated by the activities of the archaeologists and by the soil from the occupation levels of the site. Every site that is tested, and might be a candidate for pollen sampling, should be sampled at the surface to provide data for comparison of the modern environment with that of the past. Soil samples from the surface should be collected by the modified pinch technique, i.e., a spoonful of sediment from various places within a diameter of approximately 100 feet (30 meters) around the site. Attention should be paid to local conditions such as leeward areas of rocks and plants and areas where the surface sediments are relatively finer, as these make excellent modern sampling loci. Surface samples collected in connection with a stratigraphic column, however, should be collected as the top 1 centimeter of the column. Sites that appear to be shallow (10 cm or less in depth) lithic concentrations do not need to be sampled.

Stratigraphic Columns. Sampling stratigraphic columns at archaeological sites accomplishes many purposes. A closely-sampled stratigraphic column provides information concerning vegetation change through time. The closer the sampling interval, the better the interpretation. Collecting samples at 2 cm vertical intervals is recommended from most sites. This yields an individual pollen sample each 2 vertical cm they are contiguous. If you are collecting stratigraphic samples at intervals greater than 2 cm, please do not lump more than 2 vertical cm of sediment into any one sample bag. This simply averages too much time in a single sample. Stratigraphic samples provide an excellent control at archaeological sites for interpreting the pollen record of economic activities. Pollen recovered in samples from features may be compared with the pollen record from the stratigraphic column particularly that from the cultural levels identified in the column, to identify anomalies that might represent cultural activity. In this way, stratigraphic sampling strengthens interpretations of cultural activity.

Types of Archaeological Samples:

- Stratigraphic columns
- Middens
- Features
- Living surfaces
- Ground stone (manos, metates, mortars, pestles, etc.) surfaces

- Ceramic vessels (Dr. Linda Scott Cummings, 2010).

Sampling

Sampling techniques utilized at archaeological sites are extremely varied. Which methodologies are used will be determined in part by:

(1) The type and size of the archaeological site;
(2) The geographical locality of the site;
(3) The specific focus of the investigation;
(4) The degree of pollen preservation, or lack of it, within the archaeological site.

At this point, we feel it is important to present some generalized procedures that can be utilized for sampling most types of sites. The following suggestions represent basic concepts that should alleviate many of the potential contamination problems commonly encountered during sampling:

1. Clean the outer surface of the excavation pit profile prior to sampling.

2. Always use a clean trowel or other type of digging implement.
3. Collect between /2 and 1 liter of material. This insures sufficient sample size for a second analysis, if necessary.
4. Carefully clean the sampling tool before collecting each new sample.

Fig 3.35: Cleaning the trowel between samples

Fig 3.36: Preparing to the samples; note and labeled whirl packs.

5. Always use a sterile, uncontaminated, leak-proof container for each soil sample. If the sample is damp, add a few drops of fungicide or 100GbE TOH to prevent microbial activity, which may destroy pollen in the sample.
6. Correctly label each sample with a permanent ink pen.
7. When collecting samples from a profile, sample within one stratum (whenever possible), rather than mixing strata in a single sample.
8. Sample a profile starting at the bottom and work towards the top. This will insure that material falling from the upper samples will not contaminate the collection of lower samples.
9. Movement of the trowel should be lateral, following the plane of the stratum. Again, this prevents any contamination between strata.
10. Avoid taking samples from hearths or any archaeological features that appear to have been burned or that contain large amounts of ash and charcoal. Avoiding these charcoal-rich areas is important since charcoal is often impossible to remove from samples during laboratory processing and pollen is often destroyed in areas that have been subjected to intense heating.

Fig 3.37: collection of soil sample from Archaeological site

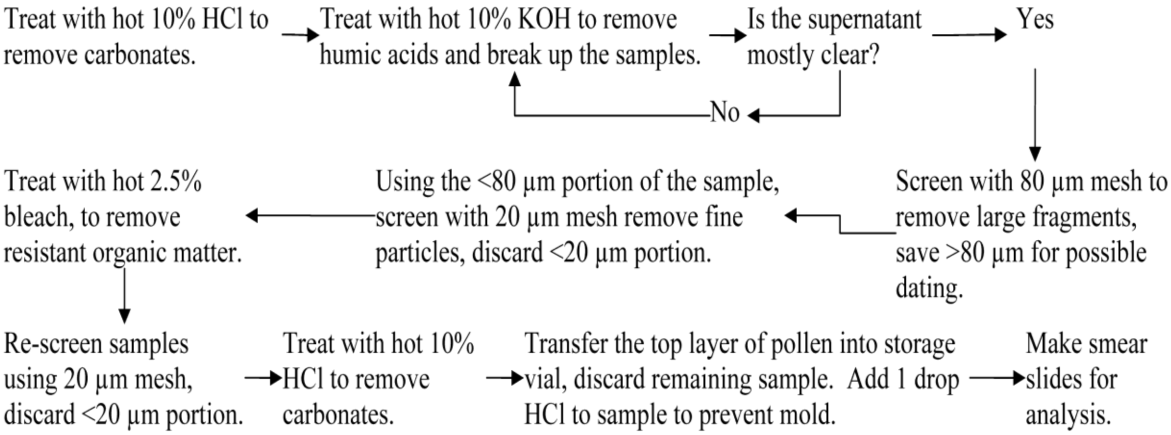
When sampling sediments from archaeological sites, the palynologist must assume that man's cultural activities have influenced the types and amounts of pollen that were introduced into the site and later incorporated into the fossil pollen assemblage. For that reason, no single pollen sample from an archaeological site is, by itself, characteristic of a given temporal horizon or a valid clue to natural paleoecological conditions. The keys to an accurate interpretation of archaeological pollen data are replication and controls. Analysis of many samples collected at various locales from a single horizon at a site allows for later statistical evaluation. However, paleoenvironmental reconstructions ideally must be based on samples recovered from relatively undisturbed sediments beyond the main area of a site. In this way, past cultural modifications of the local site environment will not bias the reconstruction of a regional environment. The collection and analysis of external samples from adjacent, non-site areas are important since check for successional patterns existing on the site after its abandonment by human populations.

The most important concern in any type of sampling is to collect samples that will insure a valid statistical treatment of the pollen data. For this reason, consultation between the archaeologist and palynologist is highly recommended prior to excavations. In that way, a total research design can be implemented that includes ample and correct sampling for botanical remains (Heusser 1978; Mack and Bryant 1974; Mack et al. 1978).

Data Analysis

Prior to the identification and interpretation of palynological material, the fossil pollen must be removed from their sedimentary matrix and concentrated. Techniques used in laboratory extraction of fossil pollen consist of two basic steps. First, the unwanted inorganic and organic matrices must be removed so that the fossil pollen can be concentrated. Second, the concentrated fossil pollen must be analyzed. Many existing publications have outlined ways to successfully remove fossil pollen from different parent matrices since each sediment type generally requires its own unique laboratory extraction procedure. However, for the purposes of this discussion, we shall try to summarize some of the most commonly used techniques.

Fig 3.38 a and 3.38 b: Palynological Laboratory



Treat with hot 10% HCl to remove carbonates.

Treat with hot 10% KOH to remove humic acids and break up the samples.

Is the supernatant mostly clear?

Yes

No

Screen with 80 µm mesh to remove large fragments, save >80 µm for possible dating.

Using the <80 µm portion of the sample, screen with 20 µm mesh remove fine particles, discard <20 µm portion.

Treat with hot 2.5% bleach, to remove resistant organic matter.

Re-screen samples using 20 µm mesh, discard <20 µm portion.

Treat with hot 10% HCl to remove carbonates.

Transfer the top layer of pollen into storage vial, discard remaining sample. Add 1 drop HCl to sample to prevent mold.

Make smear slides for analysis.

Table 3.1: Flow chat of Pollen Analysis

Anhydrous carbonates of the calcite group are the most common type of carbonates found in archaeological sediment samples. These carbonates generally can be removed with concentrated hydrochloric acid (HCI, approximately 35%) or, in some cases, with glacial acetic acid. Fine-sand and coarse-grained silicates are another common element present in almost all archaeological samples. The larger and coarser grained silicates can be initially separated and removed using a modified swirling or heavy-density separation techniques (Funkhouser and Evict 1959).

Fig 3.39: chemicals for Extraction of Pollens

Most pollen has a specific gravity of between 1.45 and 1.52. In a concentrated solution of zinc chloride (ZnCl2, sp. gr. 1.95-2.00), the organic fraction containing the pollen remain suspended at the surface, whereas the silicates and other heavy particles sink and thus can be easily removed. Solutions of zinc bromide also produce effective heavy-density separation results, but the cost is often prohibitive. During the use of these extraction techniques, we have not observed any destruction of pollen by either of these heavy-density chemicals. There is, however, a danger that some pollen grains may become trapped and thus sink with the heavier inorganic material. By checking the sediments that sink, the processor can determine if pollen loss is occurring. If so, it may be necessary to repeat this procedure until no pollen loss is observed.

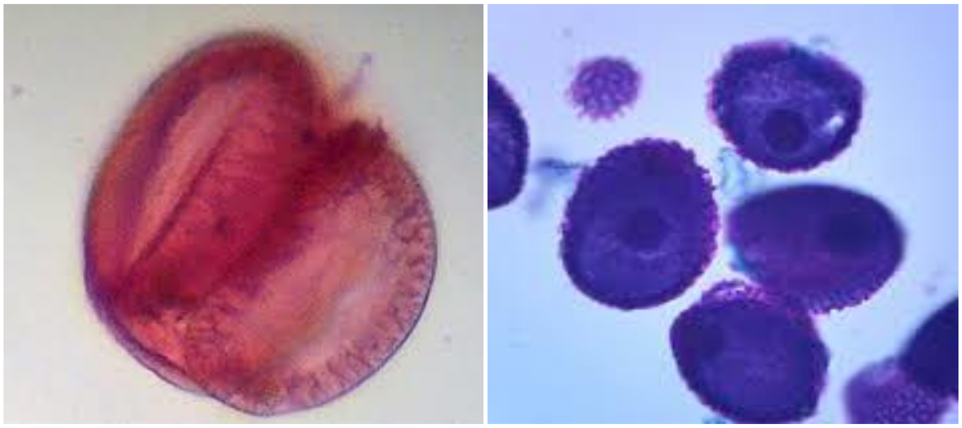


Fig 3.40 a and 3.40 b: Microscopic Pollen by extraction techniques

Another method of removing silicates involves the use of hydrofluoric (HF) acid. Although most commercially available HF is sold in concentration of 44 to 45%, we have found that the best results are obtained when an HF concentration of 70%o is used. The higher HF concentration removes more silicates and accelerates the removal process, yet tests have shown that it does not harm pollen grains. Swirling, in combination with HF, has been recommended as a technique to reduce large volumes of silicates in pollen samples (Funkhouser and Evitt 1959). Thus, some researchers prefer to use a procedure involving only HCl, HF, and swirling (Woosley 1978).

A small quantity of sodium hexametaphosphate is added to each sample once it reaches neutrality, then the samples are allowed to settle according to Stoke's Law in settling columns. This process is repeated with ethylenediaminetetraacetic acid (EDTA). These steps remove clay prior to heavy liquid separation. The samples are then freeze dried. Once that process is completed, a small vial of liquid sample lifted which has the same look and consistency as muddy water.

Fig 3.41: Sodium Hexametaphosphate and Ethylenediaminetetraacetic acid (EDTA).

Sodium polytungstate (SPT), with a density 1.8, is used for the flotation process. The samples are mixed with SPT and centrifuged at 1500 rpm for 10 minutes to separate organic from inorganic remains. The supernatant containing pollen and organic remains is decanted. Sodium polytungstate is again added to the inorganic fraction to repeat the separation process. The supernatant is decanted into the same tube as the supernatant from the first separation. This supernatant is then centrifuged at 1500 rpm for 10 minutes to allow any silica remaining to be separated from the organics. Following this, the supernatant is decanted into a 50 ml conical tube and diluted with distilled water. These samples are centrifuged at 3000 rpm to concentrate the organic fraction in the bottom of the tube. After rinsing the pollen-rich organic fraction obtained by this separation, all samples receive a short (20-30 minute) treatment in hot hydrofluoric acid to remove any remaining inorganic particles. The samples are then acetylated for 3-5 minutes to remove any extraneous organic matter.

Fig 3.42 a and 3.42 b: Sodium polytungstate (SPT), and acetylated used for the flotation process

On the other hand, our experience has been that the best results are obtained when we use sanitation and heavy-density separation (without swirling), followed by the use of HCl and HF. Clays often present a removal problem in samples since clay is resistant to deflocculating. Sometimes clays can be dispersed by treatment with HF, but this is a costly method since it often requires a large quantity of this chemical simply to deflocculated the clays. Thus, for clay sediments, we use dimethyl sulfoxide (DMSO) since it has recently proven to be an excellent deflocculating agent. Shane and Clark (1981) originally reported their use of DMSO on polymerized samples of Pre-Quaternary-age sediments. However, we have found that DMSO also works well as a reagent in deflocculating clay sediments of more recent age. Using DMSO, our best results are produced when the sediment samples are placed in a solution of 99% DMSO that is then heated in a hot water bath for a period of from 1 to 1.5 hours. This procedure quickly deflocculates the clay-rich sediment samples, yet it does not appear to have any detrimental effect on the pollen grains. One drawback to its use, however, is that in addition to its deflocculating property, DMSO also has the ability to quickly enter the bloodstream through contact with the skin (i.e., accidental spillage). Therefore, extreme caution should be exercised when using this chemical. Residues of DMSO also should be removed completely before any other chemical reagent is added since DMSO is a universal solvent and acts as a carrier for other hazardous chemicals that could cause lethal results upon entry into the blood stream.

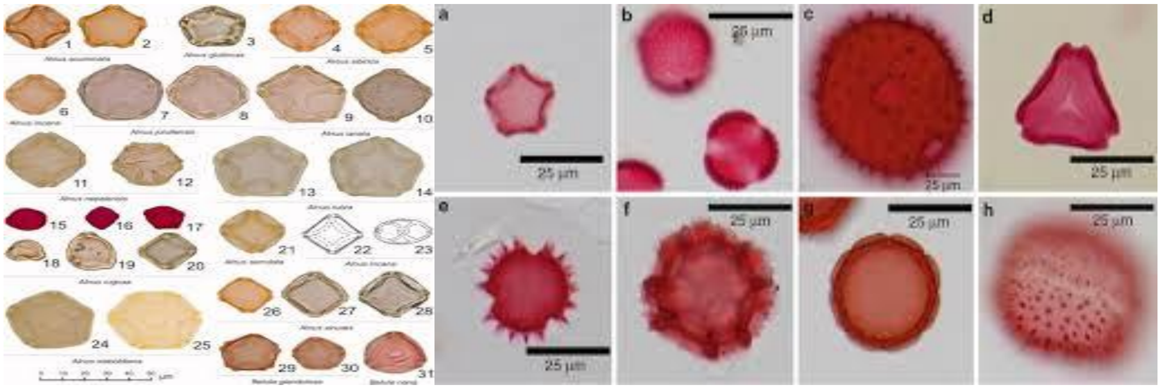
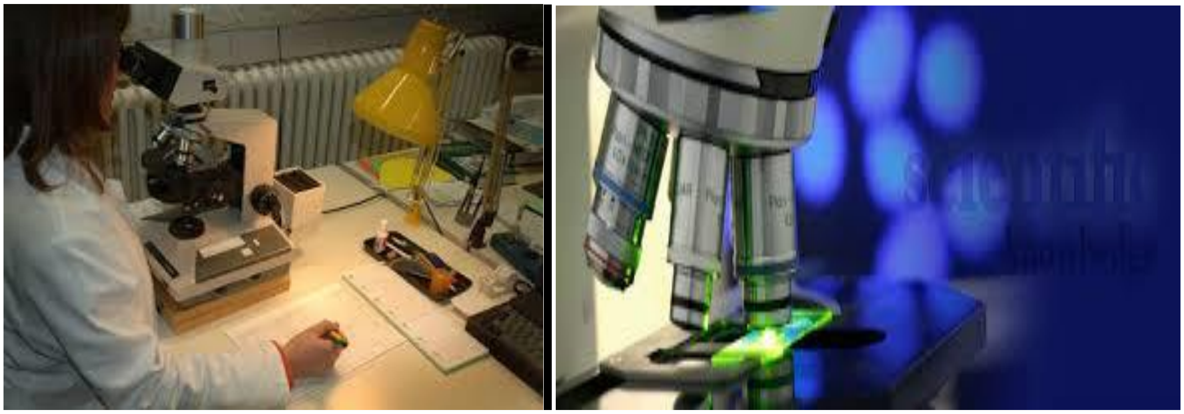


Fig 3.43 a and 3.43 b: Different Pollen Species under Microscope

Observation under Microscope

Once the extraneous materials have been removed and the original sample has been reduced to concentrated residue containing mostly fossil pollen, it is ready to be mounted on slides for microscopic analysis. There are many types of pollen mounting media, and their usage will vary with the type and age of sediments and/or with the personal preferences of the palynologist (Anderson 1965). Three of the most widely used types of mounting media in clued glycerin jelly, silicon oil, and castellated.



Fig, 3.44 a and 3.44 b: Microscopic analysis of Pollen slides

Now that the sample has been processed it can be scanned for pollen grains. A drop of sample solution is placed on a microscope slide with a drop of glycerol, covered with a cover slip and scanned under a 400x dissecting microscope. The glycerol allows the pollen grains to “swim” on the sample so that a gentle tap on the slide will roll the grains and give the scanner a different view of the pollen in question to help aid in identification.

Once mounted, slides are generally examined at magnifications between 400xs and 1000x, and the fossil pollen grains are counted until a statistically significant number has been recorded. The number of pollen grains counted per sample will vary, but under most circumstances, palynologists feel that a minimum of at least 200 fossil grains (excluding spores) per sample should be counted (Barkley 1934; Godwin 1934).

As the slide is scanned pollen grains are identified as specifically as possible and counted until the total number of pollen reaches at least 300. A light microscope is used to count the pollen to a total of approximately 30 to 100 pollen grains at a magnification of 500 xs.

Fig 3.45: Counting technique

Typically, although with several exceptions, most pollen can only be confidently identified to the Family level. The three pictures of Rosaceous pollen below should give you a hint as to why that’s the case. All three represent very different Genus within the same family, and all three look very similar. Could you tell them apart if you saw them all together on the same slide? Remember also, that individual pollen grains vary in size and appearance and that the pollen grains from soil samples are often broken or degraded in some way.

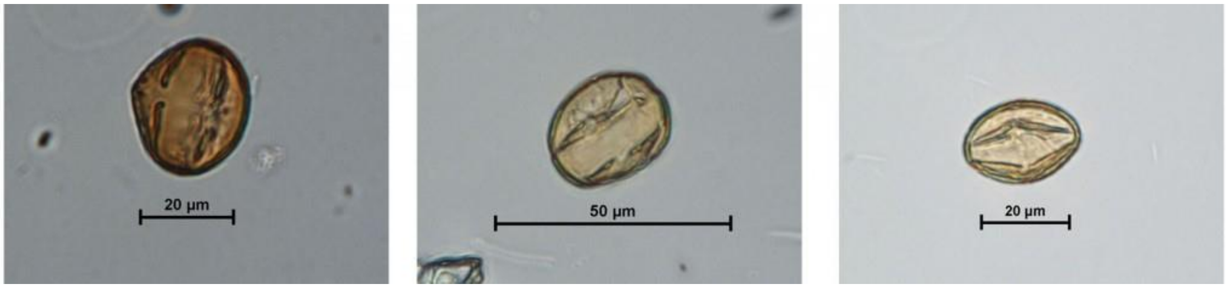


Fig 3.46 a, 3.46 b and 3.46 c: Different Genus size of Pollen within the same family

Thus the results of pollen analysis are often rather general identifications. Even general Family identifications can be extremely valuable as they give us a list of possible plants which can be narrowed down through documentary research.

Previous Studies about Archaeological Palynology

- **PALYNOLOGICAL STUDY OF SOIL SAMPLE COLLECTED FROM AN ARCHAEOLOGICAL SITE (GULABI BAGH) IN LAHORE, PAKISTAN (G. Khola and U. Hanif).**

Soil samples collected from an archaeological site Gulabi Bagh Lahore to evaluate pollen morphology and type of pollen present in the surface soil or their origin either they belong to vegetation of the same area or somewhat migrated. For that purpose soil was collected from 2 feet deep of the ground on 17th November 2008. Standard methods were used for the treatment of soil samples and slides were prepared. The results indicated total 10 pollen taxa in the soil sample belonging to 9 families and 10 genera. Among them nine were introduced or cultivated and only one belonging to the natural vegetation. The shapes of pollen were mostly prolate and spheroidal. Polyporate number of aperture and porate type of aperture was characteric in all the pollen taxa except one in *Jatropha curcas* Linn. Which was non aperturate? It was also observed that maximum pollen size was recorded in *Murraya koenigii* (Linn.) Spreng. And the minimum pollen size was observed in *Imperata cylindrica* (Linn.) P. Beauv**.**

Introduction

Palynology is the science that studies contemporary and fossil palynomorphs, including pollen, spores, orbicules, dinoflagellate cysts, acritarchs, chitinozoans and scolecodonts, together with particulate organic matter (POM) found in sedimentary rocks and sediments (Jansonius and McGregor 1996). Major conceptual development was occurred when it was realized that the spores/pollen could be utilized to reconstruct the sequence of past vegetation changes and hence environmental and climatic alterations (Erdmann, 1943). Nair (1979) reported that pollen grains and spores constitute an important morphological entity, reflecting the facts and facets of pollen evolution. Among the various characters of exine, the aperture is considered to be the most conservative.

Lee (1990) explains the significance of pollen diversity in pollen size, exine, thickness, aperture type and number, and wall stratification. Yildiz *et al.,* (2009) worked on palynological investigations of endemic taxa from Northern Cyperus collected from soil. In Pakistan, the research dates back to early sixties. Malik *et al*., 1964; Bhutta, 1968; Ashraf 1973; Zahur *et al*., 1978; Meo *et al*., 1988 (ab); 1999; Hafiz and Baig, 1989; Nasreen and Khan 1998; Mumtaz *et al*., 2000 and Dawar *et al*., 2002 have provided a commendable quantity of basic and applied information in palynology. Moreover, at international level there has been an explosion of information published on many aspects of pollen and spores. This study is based on the hypothesis that what type of pollen present in soil or either they belong to vegetation of the same area or somewhat migrated. Because palynological studies have played a vital role in the identification and delimitation of various taxa. This variation would prove as taxonomic criteria in the classification of plant species (Khola and Hanif 2012: 1113-1117).

- ## Khan Rass Masood (Dr.) work on Field Excursions

Higher ad Lesser Himalayas

During the past fifteen years he conducting field study tours as a team leader/member to the Higher and Lesser Himalayas, Northern Pakistan to collect botanical material and rock samples. This also included imparting training to the students and other professionals to measure sections of sedimentary rocks and use of latest scientific instruments e.g., Clinometer, Compass Prismatic, Map reading, Lithological description of sedimentary outcrops, Procurement and Cataloguing of rock samples.

Archaeological Sites

Since 1997 in collaboration with the members (Dr. S. Weber) of the Department of Anthropology, Washington State University, Vancouver, USA he was regularly visiting "Harappa", an important archeological site of the Indus Valley civilization to collect paleoethnobotanical samples. Initialprocessing of samples has produced encouraging results, which shall be regularly published.

Ph.D. – 1979-83

The field of investigation was “Sedimentary and Stratigraphical Palynology. More than six hundred rock samples from the Paleozoic (Early Permian - Amb, Warchha and Dandot Formations) and Mesozoic (Early Jurassic - Datta Formation) sediments of the Salt Range, Pakistan were studied palynologically. These rock samples were collected during more than twenty field study tours at six different localities from the Eastern, Western and Central Salt Range, during which time each Formation was carefully measured. Relevant held data including lithological description of Formations and their finer subdivisions (e.g., members, units, beds etc.), mutual contacts, faults and other details were recorded. Two hundred and twenty-five species of palynomorph belonging to eighty-five genera wet-c recorded and systematically described Palynological data was interpreted in terms of:

1. Palynostratigraphy:

Detailed Biostratigraphy of the sediments was carried out based on fine resolution Palynology and stratigraphic analysis of microfossils.

In each geological formation several Assemblage Zones and subzones (Cenozones) were recognized.

2. Correlation:

These zones were used for lateral correlation at local, regional and global levels. Several index palynomorphs (markers) were established for each formation.

3. Geochronology:

Exact age of each of the investigated formation was determined based on the occurrence of cosmopolitan marker palynomorphs.

4. Reconstruction of Past Plant Communities:

Vegetational complexion of the past plant communities (including ecosystems) were reconstructed based on the trend(s) of relative dominance of various palynomorph assemblages at different stratigraphic levels.

5. Gondwana Sequence:

Palynological results supported the existence of the Gondwana land. Paleozoic and Mesozoic sediments of the Salts Range Were correlated with the remaining Gondwana sequence of the world.

POSTDOCTORAL FELLOWSHIP

1992-93 - University Grants Commission Award

A postdoctoral fellowship by the said organization provided an opportunity to work in the Bryd Polar Research Centre, Department of Plant Biology, Ohio State University, and Columbus, Ohio, USA. One of the projects that was involved with and directed concerns the discovery, extraction and description of numerous palynomorphs from a stratigraphically important section of rocks in Antarctica.

The Mackellar Format urn lacked any evidence of microfossils, and thus could not be accurately positioned geologically and correlated with other sediments from other Gondwana continents. He was the first person to extract palynomorphs from these sediments using some different techniques. This contribution made it possible to accurately date these rocks. This was major contribution to better understanding the stratigraphy of Antarctica that will be used by scholars in numerous fields.

He also employed some different techniques and knowledge of Permian palynomorphs in examining sediments from another formation in Antarctica i.e., Buckley Formation. Studies concerning Buckley Formation will also contribute to a better biostratigraphic analysis of these sediments, as he was able to extract a rich palynoflora here as well.

RESEARCH PROJECTS

Background

In spite of the long history of research, the detailed litho and biostratigraphies of the continental and Marine Permian and Lower Triassic Strata in the Sail Range and the Trans-Indus ranges of Pakistan have not been thoroughly clarified, although these areas are important reference areas especially of the Upper Permian and Lower Triassic of the world. We, therefore, strongly felt the need to undertake series of research projects focusing mainly on the palynology of the Permian and Triassic system of the Salt Range, Pakistan. It was further decided to undertake these projects stepwise, firstly on Permiancontinental outcrops (Nilawahan Group) and then on Permian Marine Sediments (ZaluchGroup) followed by the Triassic system.

1. Completed

1.1 Award of a research project from the University of the Punjab (1996-97)

A research project entitled “Palynology of the Permian Strata (Tobra and Dandot Formations), Salt Range, and Pakistan” was submitted to the University of the Punjab. The scheme was approved for a period of one year. Under this Contract work on palynological analysis of the rock samples of Tobra and

Dandot Formations was undertaken. These Formations are of continental origin and represent Lower Permian (Asselian) Gondwana sequence of the Salt Range, and Pakistan. Tobra Formation was deposited in a Fluvio-glacial environment whereas Dandot Formation had a dominantly lacustrine or partly localized fluvial environment of deposition. Rich palynoflora was obtained from these Formations. Palynological data was interpreted in terms of Geochronology, Correlation and Stratigraphy. Detailed technical report was submitted to the University.

Punjab (1997-98)

A project entitled “Palynology of the Permian Strata (Warchha and Sardhai Formations) Salt Range, Pakistan” on the pattern of previous project was submitted to the University of the Punjab. The project was subsequently approved and fully geared during 1997-98. Purpose and scope of this work was detailed palynological analysis of the rock samples of the Warchha and Sardhai Formations. Warchha and Sardhai Formations overlies the Tobra and Dandot Formations and share many common features viz., Early Permian age, Gondwana and continental origin. Another feature of interest is that these four Formations collectively constitute the “Nilawahan Group” of the Permian system of Pakistan (Upper Indus Basin) comprising predominantly of continental rocks.

Warchha Formation was deposited in a strong to medium hydrodynamic (fluvial) conditions, whereas Sardhai Formation represents calm and quite lacustrine conditions. These facts were confirmed by palynological findings. Successional changes in plant communities, climate and environment of deposition were studied based on palynological data.

Detailed technical report was submitted to the University of the Punjab. Completion of this project also completed palynological studies on the “Nilawahan Group” of the Permian of Pakistan. Sonic part of this project has already been accepted for publication.

Award of research project from the UNESCO (2001-2002)

Research Project entitled “Palynology of Soil Samples from Shalamar Garden, Lahore, Pakistan” was awarded by UNESCO through the courtesy of the department of Archaeology, Government of Pakistan. The present study deals with the palynological analysis of twenty-five soil samples obtained from Shalamar Garden, Lahore, Pakistan. The samples were collected from a trench along the southwestern lawn at the middle point of the southern walkway.

The prime objective of the investigation was to elucidate periodic changes in the vegetational pattern since pre Shalimar to the present period. Pollen belonging to six Angiospermic families (Poaceae, Chenopodiaceae, Asteraceae, Anacardiaceae, Fabaceae and Euphorbiaceae) was isolated and identified. Based on pollen analytical results it was concluded that the original vegetation prior to the construction of Shalimar Garden mainly consisted of kikar (Acacia sp.) and Grasses (Poaceae), which was subsequently, replaced by other plants belonging to the families viz. Rosaceae (Rose and Plum family) Anacardiaceae (Mango family), Chenopodiaceae (Batho family), Fabaceae (Pulses family) and Asteraceae (Orange, Lemon family).

1.4 Award of research project entitled "Palynology of Permian Strata (Amb, Wargal and Chhidru Formations), Salt Range, Pakistan", by The University of the Punjab (2000—2001) completed.

Successful completion of the previous two projects opened new vistas and generated wealth of data useful not only for plant or Geoscientists but especially to stratigraphers and other professionals engaged in exploratory work of earth's resources. In order to obtain a comprehensive picture of Permian system of the Salt Range, Pakistan (also called field Geological Museum of the World) it was decided to further expand palynological research to include Permian rocks overlying Nilawahan Group i.e., Amb, Wargal and Chhidru Formations, respectively constituting "Zaluch Group" of the Permian of Pakistan (Upper Indus Basin) containing rocks which were deposited in predominantly marine environment. The above-cited project was submitted to the University of the Punjab, which after being thoroughly evaluated was duly approved. The investigation is in full swing and we intend to undertake series of field study tours starting in September 2000 to explore these formations in detail, to collect rock samples and relevant field information.

1.5 Award of the project entitled "Seeds of Urbanism: Paleoethnobotany At Harappa", by the National Science Foundation, USA as Senior Research Associate along with Dr. Ste A. Weber of the Department of Anthropology, Washington State University, Vancover, USA, as Principal Investigator. Completed.

At about 2600 B.C., a highly organized, economically centralized and culturally integrated civilization had emerged along the floodplains of the ancient Indus and Saraswati rivers in Northwest South Asia. Large, well-planned and walled cities like Harappa evolved from independent village farming communities, urbanization being a result of a successful food producing economy and the control of several trade routes. By the beginning of the second millennium B.C., this period of integration and centralization came to an end. With disruptions in trading networks and food supply, distinct local cultures once again began to dominate the region.

If we accept this model, as most scholars do, then agricultural production was variable throughout the evolution of the Indus Civilization. If agricultural change is so closely related to culture change, then shifts in the agricultural strategy should be identifiable as village farming communities became large centralized cities and again as these cities gave way to independent localized communities. This project will attempt to critically examine this model at a single site, that of Harappa. Its size, length of occupation (c.3300-1900 BC), large horizontal exposures, the detailed archaeological documentation and quality of organic preservation, mean it is one of the few prehistoric urban centers in South Asia were the relationship of agricultural change and culture change can he intricately addressed.

The proposed project will fully implement the study of archaeobotanical remains from Harappa, and wholly integrate paleoethnobotanical research into the interpretation of the origins, evolution and character of the sites. Based on preliminary analysis of 76 flotation samples from Harappa, archaeobotanical potential is extensive and the project objectives achieve-able. No South Asian urban site from the third millennium B.C. has demonstrated its suitability for these kinds of paleoethnobotanical studies as Harappa. Well-preserved seeds have been recovered from over ninety percent of the samples, yielding 26,240 seeds representing 33 different edible taxa. Because of the highly organized and standardized nature of the settlements and artifacts of the Indus Civilization, models drawn from Harappa data should he applicable, and certainly testable, at other sites within this civilization.

The primary objective of this project will be to determine what shifts in plant occurrence, use and resulting agricultural strategy occurred at Harappa and how these relate to other indications of culture change. The principal focus of the study will be upon seeds and other identifiable plant parts recovered from the soil through flotation. First to be analyzed will be selected samples from among those collected and floated over the last 13 years of excavation. New samples will be collected and analyzed over the following two field seasons, producing a database that will represent all periods of occupation. The variation in the types of plants recovered, their distribution and abundance in a given sample can be attributed to a number of natural and cultural processes. Using information about the stratigraphic, architectural and artifactual contexts of recovery, together with proven methods of quantitative analysis, plant occurrence can be explained and a model for the evolution of plant use at Harappa constructed.

The project will generate the data necessary to address historical, procession and environmental questions regarding the appearance and use of plants at the site of Harappa, contribute to the understanding of cultural change in the Indus Civilization, and provide a fresh model of the relationship between agricultural practices and culture change. In so doing, the project will place paleoethnobotanical studies of the Indus Civilization on a pal- with other early urban civilizations around the world (Curriculum Vitae of Khan Rass Masood).

CHAPTER: 4

Pollen Analysis from Archaeological Perspective

Generally, most archaeologists associate fossil pollen research with the reconstruction of a paleoenvironmental framework. However, such reconstruction is not an easy task for the palynologist because there are many types of data that must be considered and then correctly interpreted before an accurate reconstruction can be proposed. In addition, the palynologist must be able to successfully separate those pollen data that reflect the paleoenvironment from those data that reflect cultural activities. For example, does a high percentage of pine pollen in an archaeological deposit reflect the one-time widespread distribution of a pine forest, or does it instead reflect the ceremonial use of pine pollen that was carried into the site by man from some distant forest?

Once the paleo vegetational conditions have been reconstructed, ideally from sediments outside the actual archaeological site environs, the palynologist then can utilize those data to infer certain aspects concerning the paleo climatic conditions that may have existed in the past. It is important to remember that the palynologist is able only to reconstruct one aspect of the paleoenvironment: the paleovegetation. Therefore, additional interpretations concerning climate or other aspects must reflect inferences based on that original reconstruction (Bryant 1978).

By comparing the recovered palynological data with additional related studies-such as the archaeological record, dendro climatology, macrobotanical analyses, faunal analyses, and limn logical analyses-a more nearly precise interpretation of the paleovegetation and the inferred paleoclimate can be obtained. Once these data have been subjected to the rigors of statistical analysis, they can provide a general chronology of climate and environment against which other data recovered from archaeological sites can be compared.

Researcher Field Work

Collection of Soil Sample from Gandhara Site

Overview of Gandhara Regions

Country of ancient Gandhara, situated on the west bank of the Indus River, comprises Peshawar valley, Swat, Buner and Bajaur remained a stronghold of Buddhism from 3rd century BCE to 5th Century CE. It was thickly dotted with myriads of Buddhist sanctuaries. History of the discovery of ancient Gandhara goes hands in hands with the annexation of the Indian subcontinent in British Empire. A large number of British explorers contributed in discovery of this magnificent chapter of the history of Buddhist India. Systematic archaeological research on the Buddhist archaeological sites of Gandhara started after establishment of the Archaeological Survey of India in 1861. After creation of Pakistan the Federal Department of Archaeology and Museums, its sisterly organizations and foreign archaeological missions further broadened the spectrum of Gandharan archaeology. This field work provides an overview of the archaeological research has so far been conducted in this region.

The name “Gandhara”, literary meaning the land of fragrance, is of Sanskirat origin which “met for the first time in Rig-Veda, a collection of old Indian hymns going back to the second millennium BCE (Ingolt 1957: 13)” was “the ancient name of the tract of country on the west bank of the Indus River which comprises the Peshawar valley and the modern Swat, Buner Bajaur. It was a country with rich, well-watered valleys, clear-cut hills and a pleasant climate (Marshall 1973: 1).Being a borderland between the high lands of Central Asia and alluvium plains of the Indus and Ganga River systems its ancient history belonged as much and as little to the one as to the other. Now the land of Gandhara forms part of the North Western Frontier Province of Pakistan.

The nature has beautifully defined the boundaries of Gandhara. From north-eastern and western side the lands of Gandhara are walled by the high ranges of Hindukush and Karakrum, while to the south its hilly tracts gradually merge in the flat Indus Valley, providing access to Afghanistan and Central Asia through narrow passes. These passes served as caravan trade routes and played an important role in commercial and cultural exchange between Sub-continent, China and the Western World.

Badalpur Site in Taxila

Badalpur Gandharan monastery, (near) Taxila, Punjab, PK.

The monastery of Badalpur is situated in a village locally called as Bhera, District Haripur, between 35 46’ 56” North and 72 52’ 09” East and it is located 10 km north-east of Taxila Museum and 2.5 km north-west of Julian monastery, on the left bank of river Haro.

Taxila (also known as Taksh-shila), was an ancient Buddhist seat of learning, connected across the Khujerab pass to the Silk Road. It was also called Takshashila in Sanskrit in ancient India (Marshall 1945: 1). Taxila Valley lies north Latitude 33 42’ 30” and 33’ 50 and east longitudes 72 53’ 45’ and 72 59’ (Khan et al 2007: 39). Average height of the valley from sea level is 530 m which spreads over an area of about 375 square km (Dani 1986: 2). The valley derives its name from the historic city of Takshasila or Taxila. The present spelling Taxila was the abbreviated form used by Greeks and Romans and since then commonly adopted by European writers (Khan et al 2007: 39). Ancient Takshasila is one of the most important points of cultural diffusion. The innumerable ancient remains scattered all over area testimony its greatness.

The earliest known settlement of the Taxila Valley is Sarai-Khola which yielded a cultural sequence from late Neolithic to Iron Age i.e. Neolithic period (4000 to 2800 BC), Early Bronze Age Culture

(2800- 2600 BC), and late Bronze Age and Early Iron Age Culture (1000 BC). This history pushed back the history of the region from 6th century BC to the 4th millennium BC. Early Historic period of the Taxila begins with the conquest of the region by the Achamenians of Persia during the reign of Cyrus the Great (558-528 BC). Greek King, Alexander from Maccedonia captured the region in c. 326 BC. In 305 BC; Greek were kicked out by Chandra Gupta, founder of Mauryan Dynasty of Ancient India. Ashoka, the grandson of Chander Gupta Maurya (272-232 BC) was converted to Buddhism and made Taxila the prominent center of Buddhism.

The historic period ruins of Taxila contain buildings, Buddhist Stupas, cities. Three major cities were Bhir mound, belong to Achaeminian age (6th century BCE), Sirkapo belongs to Indo Greeks (2nd BCE) and Sirsukh belongs to Kushan period (1st century ACE) (Marshall 1960: 2-3).

Location of the Site

The monastery of Badalpur is situated in a village locally called as Bhera, District Haripur, between 35 46’ 55.41” North and 72 52’ 06.15” East and elevation 527.9136 m. It is located 10 km north-east of Taxila Museum and 2.5 km north-west of Julian monastery, on the left bank of river Haro.

Present Status

The monastery of Badalpur is a protected archaeological site and owned by the Government of KPK.

Plan of the Site

The site is rectangular in plan and covers an area of 2.9 acres (khan et al 2007: 41). The site has an imposing rectangular main stupa on the west which measures 71 meters north-west and 60 m east-west. The dome of the stupa is missing but its drum is added to the base which is about 6.09 m high. Two votive stupas in front of the main stupa at its eastern side, enclosure around the stupa courtyard comprising of chapels of different sizes (Ibid: 42).

There is a huge monastery with 38 monk cells with two openings, one at its western and other one at its southern side, which measures 81 m north-south by 78 m east-west, kitchen, store and assembly hall is situated on the southern side of the monastery. Additional small monastery is situated on the wet of assembly hall area. The stupa is made up with lime stones and built up in semi-ashlar and semi-diaper style with mud mortar inside and Kanjur stone has been used in moldings.

Previous Investigations on the Site

The site of Badalpur was first time mentioned by Sir Alexander Cunningham, the then Director General of Archaeological Survey of India, in report of 1863-64. He reported that the facing stones of the stupa were badly damaged (Curnningham 1864). After him the site was visited by Mr. Natisa Aiyar, superintendent of Frontier Circle. He exposed the stupa from all the sides and also exposed several chapels to the north and south and found 10 copper coins, 43 sealings and lot of potsherds from the stupa courtyard (Aiyar 1917). After this the site remained neglected. Federal Department of Archaeology and Museums planned to excavate the site and assign this task to Exploration and Excavation branch, which conducted excavations at the site for consecutive five periods i.e. from 2005 to 2008 which were led by M.Asharf Khan, M. Arif and Shakir Ali of the Federal Department of Archaeology and Museums. The important antiquities recovered during the excavation are gold and copper coins, seals and sealings, terracotta beads, potteries, Buddha in red sand stone of Mathura style, sculpture of Bodhisattva Maitrya and relic casket type in black schist stone.

Taxila Institute of Asian Civilizations, Quaid-i-Azam University Islamabad conducted Archaeological excavation on the remaining in-exposed area of the site from 2011 to 2014 (Khan et al 2014).

Recent Excavation in Badalpur Site

Taxila institute of Asian civilizations Quaid-i-Azam University has started archaeological excavations on the Buddhist monastery of Badalpur with the collaboration of Directorate of Archaeology and museums, Government of Khyber Pakhtoonkhwa under the leadership of Dr. Muhammad Ashraf Khan, Director, Taxila Institute of Asian Civilizations, Quaid-i-Azam University, and Islamabad. In this excavation the faculty and students of the Quaid-i-Azam University, Islamabad is also participating. During the current excavation the remains of assembly hall, kitchen, stores and steward rooms have been exposed and a good number of antiquities were discovered during excavation dated 1st century to 4th century CE.

Fig 4.1: Recent Excavation in Badalpur Site

Our study trip, the team consisting of scholars and students was headed by TIAC director Prof Dr. Mohammad Ashraf Khan. The newly discovered objects mostly stamped pottery parts of terracota, iron pieces and lamp which according to initial study belong to Kushan period.The TIAC Director while talking to the researcher at the site said that so far main assembly hall of the stupa and kitchen area of the monastery had been excavated.

Fig 4.2 a, 4.2 b: Recent Excavation in Badalpur Monastery (Different Trenches)

He said they had made good progress and with the passage of time more discoveries were expected although the site had been ruined by illegal treasurer hunter.

He said since the site had the potential of holding ancient treasures, TIAC in collaboration with Khyber Pakhtunkhwa's department of Archaeology and Museums initiated the excavations and preservation of this Buddhist Stupa and monastery.

The intensive study and observation of the site area focused on south of the main monastery and west of assembly hall which showed the traces of structural remains beneath. In order to expose the structures and their association with other features of the Badalpur complex, several square measuring 5 x 5 m were marked, following the grid plan. To control the measurement during excavation, a reference point was fixed at south- eastern corner of the area, presently under excavation. The area under the process of excavation encompassing squares i.e. BP-AA 13 to 16, BP-Z 13 to 16, BP- Y 14 to 16, BP-X 14 to 16, BP-W 15 to 16 and BP V-15 and V-16 revealed the presence eight cells (five cells were exposed in the previous season 2013 up to limited depth). These cells have been named on temporary basis as Cell # -1, Cell # 0, Cell #1, Cell #2 running west to eastwards and Cell #3, Cell #4, Cell #5 and Cell #6, running north to southwards. These cells will be renamed accordingly after the complete exposure of the plan of the area.

Stratigraphy

As for the stratigraphy of the Badalpur site is concerned, three layers, comprising two phases i.e. phase I which is the permanent Buddhist establishment and phase II which is the temporary alignment of the re-used of regular and irregular stones of phase I. Phase I is composed of two layer i.e. 2 and 3. The texture of the layer 2 is slightly dark brownish in color and is a combination of fine as well as coarse grains, consists of irregular and regular shaped boulder, chips, rubbles and gravels. The texture of the layer 1 is also light brownish in color and soft grained up to an extent, but boulders were also recovered from deepest excavated floor levels, on some of the areas of the site.

Phase II is composed of one strata I.e. 1, blackish in color, mostly comprising humus and coarse grained. As it is mentioned earlier, the site has experienced erosion from east to west, so that why the layers have different position in the cells, moving up to downward from east to west direction. Layer 1 has revealed the presence of three hearths, one in square BP- Z 13, and one in BP-Y 15 and one in BP-Z16, Layer 1 has revealed the uniform presence of ashes, faunal remains, charcoal and burnt pottery i.e. mostly cooking pots in fragments from all over the exposed area. This suggests that the area under excavation must have been used for kitchen purpose on large scale in later period. Layer 2 and 3 has revealed presence of charred wood pieces and charcoal along the normal red ware pottery, iron nails, clamps, burnt mud plaster and fallen wall debris uniformly from all the exposed area.

This suggests that the phase I must have experienced an abrupt firing and after that slowly and gradually, the site has been deposited and buried. The pieces and preserved mud plaster on the site is turned in to terracotta and close observation of the mud plaster has revealed the blackish core, which clearly indicate an abrupt fire. One more important aspect of the stratigraphy is that, there is a probability of the intermingling of the layers because of erosion and other factors, as animal bones have also been reported from layers, where they have moved down towards western boundary wall of this small monastery.

Chronology

The chronology of the site has been designed on the vases of numismatic evidence, which were previously reported from the site, by Ashraf Khan and Gul Rahim Khan. On numismatic basis, the site belongs to 1st century CE i.e. Kushana period and on the bases of masonry i.e. semi-ashar and diaper, site dates to late second century CE. Pottery analysis have shown resembles to common types reported from Sirkap level-II, III and IV, and recently absolute dating i.e. C-14 dates of charcoal samples from the deepest levels of the site revealed its existence back to 300 BCE. All these need to testify through thorough examination of the site and it is strongly suggested to draw a vertical trench on some suitable area, so that it’s clear chronological framework may come out properly.

After Excavation: Pollen Analysis

The study trip was scheduled during the excavation of Badalpur site in Taxila in the month of April 29, 2015. After the excavation, I collected over 15 soil samples for pollen analysis from various locations across the site in the hope that they could tell us agriculture evolution in Gandhara.

Fig 4.3 a, 4.3 b: Researcher collecting pollen sample.

Pollen can be a tricky artifact to deal with archaeologically, because modern pollen and archaeological pollen are indistinguishable from one another. That's because pollen doesn't degrade in the same highly visible and obvious way that say a metal artifact rusts when it decays. Hence, pollen samples must be handled very deliberately.

In the field, pollen samples must be taken carefully to avoid contamination from modern pollen rain. Pollen rain is the cloud of airborne pollen that showers down from modern plant life. The yellow-green film of pollen which covers car windshields and pools of water when pine trees pollinate is one of the most obvious examples of pollen rain. To avoid getting that modern pollen rains in our soil samples several precautions must be taken when gathering pollen samples.

Some Precautions during Sampling

The first is to never sample when it's windy. The second is to maintain as sterile an environment as possible while sampling.

The first step of pollen sampling is to use a trowel to clean off the surface of the wall or floor that you will be sampling from. This scrapes off most of the modern pollen which has fallen on the surface since it has been exposed. The second step is to clean the trowel using distilled water and sterile wipes in order to wipe off the modern pollen on your tool and get as sterile a surface a possible for collection. The third step is to use your freshly cleaned trowel to collect your sample. To process a pollen sample you need at least 30 grams of soil which is collected and placed in a whirlpak bag. Whirlpaks are specially-made collection bags which are completely sterile on the inside and sealed until opened by the archaeologist taking the sample.

Once the bag is filled with the sample it is sealed and labeled with the location and number of the sample.

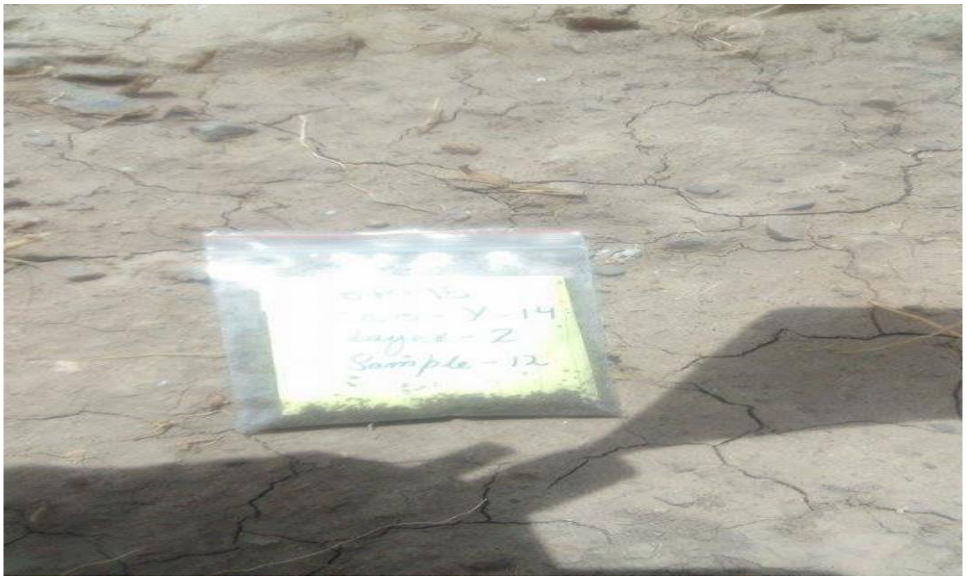


Fig 4.4: Sealed and labeled whirlpak bag

Pollen samples are best taken from closed archaeological features like buried floors and pits. Pollen samples can also be taken at set increments along the wall of an excavation unit. When taking samples this way it is important to start at the bottom and work your way up so that lower samples are not contaminated from the material above. Though we did not use this method at Gore Place, pollen samples can also be taken from large soil cores driven into the ground.

Collection of soil sample from different Trenches across the Badalpur site

Fig 4.5 a, 4.5 b: Two samples from BP -15, T.No.Y- 15, and Layer- 1

Fig 4.6 a, 4.6 b: Two samples from BP -15, T.No.Y- 16, and Layer- 1

Fig 4.7 a, 4.7 b: Three samples from BP -15, T.No. Z-15, Layer- 1 Three samples from BP -15, T.No.Z- 15, Layer- 2

Fig 4.8 a, 4.8 b: One sample from BP -15, T.No.Z- 16, Layer- 1

Fig 4.9 a, 4.9 b: Two samples from BP -15, T.No.Y- 14, Layer- 2

Fig 4.10 a, 4.10 b: One sample from BP -15, T.No.X- 15, Layer-1 and One from Layer-2

Once a group of soil samples have been collected, they are refrigerated until they can be processed. Refrigeration prevents the pollen from further decomposing. This is an important step since pollen processing is time consuming and only a maximum of eight samples can be processed at a time.

Table of the Soil Samples from Different Trenches of Badalpur site

Sample	Trench	Layer
1-2	T.No.Y-15	One
3-4	T.No.Y-16	One
5-10	T.No.Z-15	One and Two
11	T.No.Z-16	One
12-13	T.No.Y-14	Two
14-15	T.No.X-15	One and Two

By the Present Researcher

Table 4.1: Chart show the Soil Samples from Different Trenches of Badalpur site

Palynological Laboratory

Experimental Techniques for the Pollen Analysis from the Archaeological Soil

Abstract

Soil samples were collected from an archaeological Gandhara site Badalpur to evaluate pollen morphology and types of pollen present in soil. Strandards methods were used for the treatment of soil samples and slides were prepared. The result indicated total 47 pollen taxa in the soil sample belonging to 15 families and 12 genera.

Introduction

Palynology is the microscopic study of pollen grains and spores, the fine powdery material produced on the stamens and anthers of seed plants. The grains are minute in size, each ranging from 15 to 100 microns. To understand the scale, consider that the head of a pin is about 2mm (2000micron) in diameter. Just a pinch of pollen powder contains thousands of grains. Because each pollen type has a unique set of attributes (size, shape, and characteristics of the outer wall), analysis can usually identify the spores or plant family from which it originated.it is the most successful, of the biological techniques used in reconstructing past environments (Lowe and Walker 1997).

Pollens are typically preserved in a wide variety of wet and acidic sedimentary deposits in archaeological contexts (ditches, ponds, structural turves, plaggen soils etc). Pollen collected from such archaeological site can provide insight into what the overall environment was like at the time the site was occupied and how area vegetation changed through time (Fægri and Iversen 1989; Moore *et al.* 1991). However, pollen records within these materials can often be extremely difficult for palynologists to interpret, as there may be a problem of poor pollen preservation or mixing (Dimbleby 1985). Samples can be derived both from cultural and non-cultural settings when reconstructing plant communities. This picture allows secondary deduction about climate change and human disturbance to the environment after reconstructing plant communities.

The literature on pollen analysis in archaeological soil sample is not documented in Pakistan.

This study is based on the hypothesis that what type of pollen present in soil or either they belong to vegetation of the same area or somewhat migrated. Because palynological studies have played a vital role in the identification and delimitation of various taxa. This variation would prove as taxonomic criteria in the classification of plant species.

Data Analysis

A chemical extraction technique based on flotation is the standard preparation technique used in the laboratory for the removal of the pollen from the large volume of sand, silt, and clay with which they are mixed. This particular process was developed for extraction of pollen from soils where preservation has been less than ideal and pollen density is lower than in peat.

Materials and Methods

Chemical Extraction of pollen samples

1. Preparation of sample

Chemical extraction of pollen samples was conducted at the Plant Physiology Laboratory at Quaid-i-Azam University using a procedure as reported by Richard Holloway at Quaternary Services. Fifty gram of soil was sub-sampled from each sample submitted and is mixed with 250 ml of distilled water in a 500ml glass beaker. Two tablets of Lycopodium spores (marker grains) were added to each sub-sample. The addition of marker grains permits calculation of pollen concentration values and provides an indicator for accidental destruction of pollen during the laboratory procedure. The samples were kept overnight until the release of Lycopodium spores occurs from their matrix.

Fig 4.11 a, 4.11 b: Pollen Analysis in Laboratory

Techniques used in laboratory extraction of fossil pollen consist of two basic steps. First, the unwanted inorganic and organic matrices must be removed so that the fossil pollen can be concentrated. Second, the concentrated fossil pollen must be analyzed. Many existing publications have outlined ways to successfully remove fossil pollen from different parent matrices since each sediment type generally requires its own unique laboratory extraction procedure. However, for the purposes of this research, researcher try to summarize some of the most commonly used techniques.

2. Removal of Anhydrous carbonates

Anhydrous carbonates of he the calcite group are the most common type of carbonates found in archaeological sediment samples. These carbonates can be removed with 35% HCl or with glacial acetic acid. For this purpose, about 25 ml of 35% HCl was added and stirred slowly. This was continued until the material could be stirred vigorously with no further reaction. This step removed much of the carbonates and assured the release of pollen cemented in calcareous matrix (Anderson, 1955).

Fig 4.12 a, 4.12 b: Chemicals like hydrofluoric acid and hydrochloric acid

The researcher used chemicals to dissolve the soil are decanted off and the sample is washed to neutral. The samples are rinsed until neutral by adding water, letting the samples stand for 2 hours, and then pouring off the supernatant.

Fig 4.13 a, 4.13 b: Researcher used chemicals and water to neutral the sample

After neutralizing the acid with distilled water, the samples were allowed to settle for a period of at least three hours before the supernatant liquid was removed until the heavier fraction such as sand and gravel starts to settle out. Supernatant was collected in another 500 ml beaker and additional distilled water was added to the supernatant. The mixture was swirled and then allowed to settle for 50-60 sec. The suspended fine fraction was then decanted through a No. 100 very fine mesh screen into a second 500 ml beaker. Any sediment remaining on the screen was washed well with a strong jet of water from a plastic squeeze bottle and vertexed again and then allowed to stand less than two minutes. This procedure repeated at least three times to remove lighter materials including pollen grains from the heavier fractions. The fine material was concentrated by centrifuging at 2,000 rpm for 5 min in a 50 ml falcon tubes.

Fig 4.14: Laboratory Chemicals

3. Removal of silicates

Fine sand and coarse- grained silicates is another common element present in almost archaeological samples. The larger and coarser grained silicates initially separated and removed using a modified swirling or heavy density separation techniques (Funkhouser and Evitt 1959). Most pollen has a specific gravity of between 1.45 and 1.52. A concentrated solution of $ZnCl_2$ (sp. Gr. 1.95-2.00) was prepared and the sample mixture wad added to it. The organic fraction containing the pollen remains suspended at the surface, whereas silicates and other heavy particles sink and thus easily removed. The process was repeated until trapped pollens with heavier inorganic material were recovered. Best results were obtained when we use sonication and heavy- density separation (without swirling), followed by the use of HCl and HF.

4. Removal of clay

Clay often present a removal problem in samples since clay is resistant to deflocculation. DMSO is an excellent deflocculating agent (Shane and Clark, 1981). Sediments samples were placed in a solution of 99% DMSO and then heated in water bath for a period of from 1 to 1.5 hr. this procedure quickly deflocculate the clay-rich sediment samples.

5. Removal of organic compounds

Organic compounds generally found in the sediment of archaeological sites result from the incomplete deterioration of plant and animal remains. These materials consist of various types of resins, waxes, proteins, carbohydrates, derived carbohydrates (such as polysaccharides of cellulose and hemicellulose), lignin and fragments sporopollenin from the decomposing outer walls of degraded pollens and pore. It is necessary to remove this extraneous organic matter in order to concentrate the fossil pollen residue for microscopic examination. One method of destroying these unwanted organic residues is to use the acetolysis method, first perfected by Erdtman (1960). Other chemical agents such as HNO3, bleach (NaOCl), and NH4OH also remove these organic compounds but often cause damage to the pollen exine.

6. Removal of Charcoal

Charcoal is common component in most archaeological soils, is inert and not destroyed by the usual chemical treatment employed during the pollen extraction process. Therefore, most charcoal must be removed by mechanical methods. This is achieved by four-step removal process.

- The materials were screened through a 150-gm brass screen, which removes the larger charcoal fragments.
- The samples were sonicated in in a saturated solution of Darvan several times to free the remaining tiny charcoal fragments from other debris during the sample.
- A heavy density separation technique was applied, first at 1.9 sp. Gr. And then at 1.65 sp.gr. Which removed most of the remaining charcoal?
- Finally, the extracts were centrifuged in 1.15 sp.gr. Solution, which traps many of the smaller remaining charcoal fragments in suspension but allow s the heavier fossil pollen grains to fall to the bottom of the centrifuge tube.

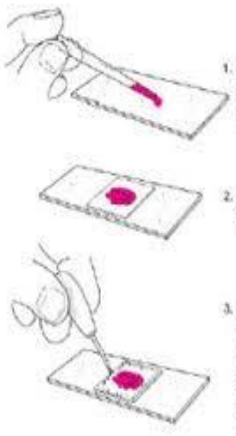
After the removal of extraneous material from original samples were concentrated to residue containing mostly fossil pollen.

Preservation of pollen sample

The resultant sample containing pollens were stored in the shell vials in a mixture of 2 parts glacial acetic acid, 2 parts glycerol, and 3 parts water and stored in refrigerator at 4°C.

Microscopic analysis

For microscopic analysis, crude glycerin jelly was used as mounting media. About 100ul of the sample was poured on slide, allow it to dry, then mounted in glycerine jelly and stained with safranine. Prepared slides were examined under a Nikon Type -2 microscope using 10x eye piece (between 400 x and 1000x) Fossil pollen grains were counted.



1. Using a capillary pipette, place a small drop of culture broth on the center of the slide.
2. Carefully place a clean coverslip over the drop, avoiding bubbles.
3. If no fluid has escaped from under the edges of the coverslip, seal the preparation with clear nail polish. Allow the polish to dry thoroughly before examining preparation under the microscope.

Fig 4.15: Steps of Slide Preparation

Fig 4.16 a, 4.16 b: Slide Preparation for Observation

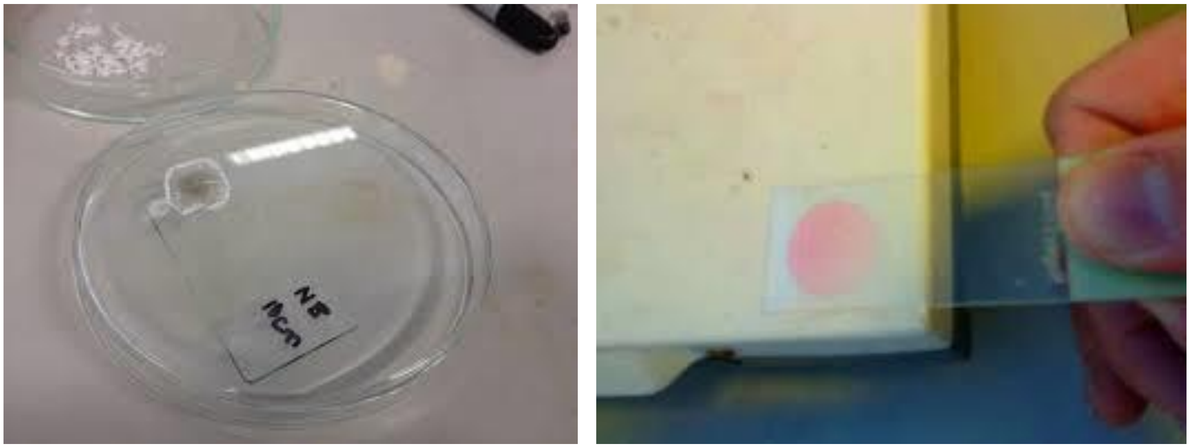


Fig 4.17: Scanned pollen slides

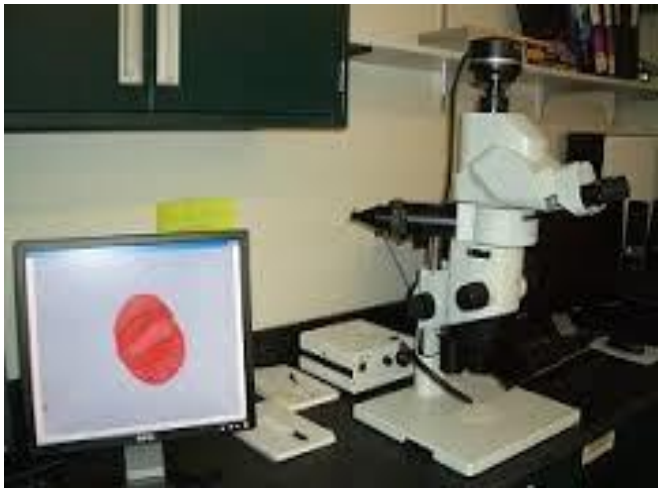


Fig 4.18: Scanned pollen grains under microscope

Pollen preservation in these samples varied from good to poor. Comparative reference material was used to identify the pollen to the family, genus, and species level, where possible.

Experimental Results

The Research work was conducted to analyze the palynomorphological data of ornamental plants collected from Gandhara site Badalpur. Soil samples were collected from an archaeological site Badalpur to evaluate pollen morphology and types of pollen present in soil. Standards methods were used for the treatment of soil samples and slides were prepared. The results compiled indicated that total 47 pollen taxa in the soil sample belonging to 15 families and 12 genera.

Sequence of ancient pollen grains/slide

1. Bp 15, T.No:x-15, layer- 2, sample 15, TAC-QAU
2. BP 15 , T.No:Y-15, layer-1 sample 1, TAC-QAU
3. BP 15, T.No:Y-14, layer-2, sample 13, TAC-QAU
4. BP 15, T.No:Y-14, layer-2, sample 12, TAC-QAU
5. Bp 15(i), T.No:Z-15, layer-1,sample 8, TAC-QAU
6. Bp 15(i) T.No: Z-15,layer-1 sample 10, TAC-QAU

7\.

Bp 15(i), T.No:Z-15, layer-1, sample 9, TAC-QAU

8\.

Bp 15(i),T.No:Z-15, layer-2, sample 7, TAC-QAU

9\.

Bp15, T.No:Z-15, layer-2, sample-6, TAC-QAU

10\.

Bp15, T.No:Z-16, layer-1,sample 11, TAC-QAU

11\.

Bp15, T.No:Z-15,layer-2, sample 5, TAC-QAU

12\.

Bp 15, T.No:Y-16, layer-I, sample 3, TAC-QAU

13\.

Bp15, T.No:Y-15, layer-2, sample 2, TAC-QAU

14\.

Bp-15,T.No:X-15, layer-1,sample 14, TAC-QAU

15\.

Bp 15, T.No:Y-16, layer-I, sample 4, TAC-QAU

A total of 47 pollen taxa were identified in soil sample collected from an archaeological site Badalpur. The pollen taxa belong to 15 families and 12 genera.

The identified families **Amaranthaceae, Caesalpiniaceae, Combretaceae, Euphorbiaceae, Lythraceae, Malvaceae, Mimosaceae, Poaceae, Plantaginaceae, Rosaceae, Rubiaceae, Rutaceae, Solanaceae, Violaceae and Zygophyllaceae.** The pollen identified belonging to the natural vegetation of the study area.

1. Family: Amaranthaceae

Botanical name: Achyranthus aspera L.

Fig 4.19 a, 4.19 b: Amaranthaceae (Achyranthus aspera L).

Palymorph: pollen grains apolar, spherical - polyhydral with obtuse angles. Diameter 13-16 -µm. Pollen grains polypantoporate (32 pores), each of about 2µm diameter and round. Exine 0.7-1 µm thick. Sexine as thick as nexine, minutely granulate. Tectum thin, supported by densely spaced bacula.

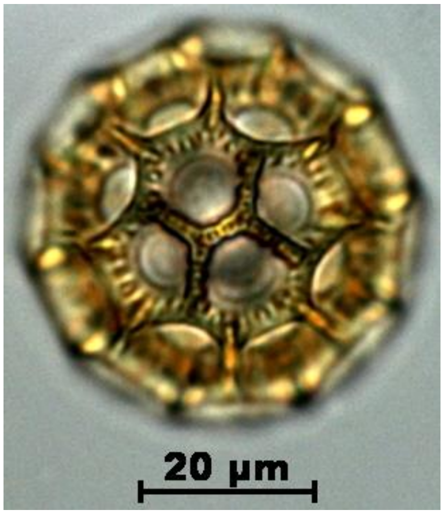


Fig 4.20**:** Achyranthus aspera L Linn pollen under Electron Microscope (Family Amaranthaceae).

2. Family: Caesalpiniaceae

Botanical name: Cassia fistula Linn.

Fig 4.21 a, 4.21 b: Caesalpiniaceae (Cassia fistula Linn).

Palynomorph: Tricolporate, non-angular, colpi length 21 µm and breadth 12.6µm. Pollen size is 264.6µm Mesocolpium 1.89µm. Apocolpium 8.4µm. Exine 1.05µm thick. Sexine thicker than nexine. Tectum reticulate-regulate. Grains prolate-spheroidal, contour sub-triangular, small to medium, granulate, testate, colpi and pores distant , colpi 2-7µm wide and more than the length of polar axis ,spherical , variable in diameter 3.6- 4.6µm and an gulo aperature. Isopolar.

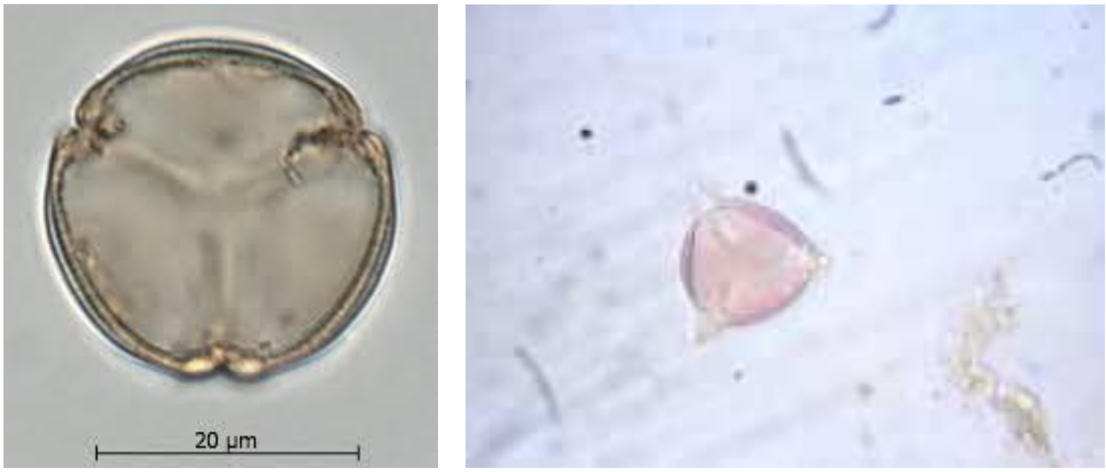


Fig 4.22 a, 4.22 b: Cassia fistula Linn pollen under Electron Microscope (Family Caesalpiniaceae)

3. Family: Combretaceae

Botanical name: Quisqualis indica Linn.

Fig 4.23 a, 4.23 b: Combretaceae (Quisqualis indica Linn).

Palynomorph: Grains tricolporate, prolate and granulate. Colpi alternating with pseudocolpoid thin walled areas which are contiguous at the poles. Size of the pollen is 23µm. Grains similar type and sometime with distinct pseudocolpi. Isopolar.

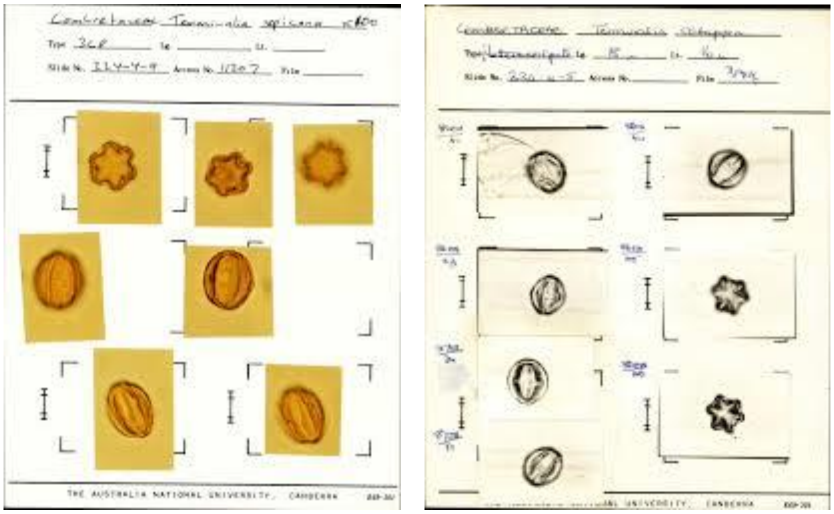


Fig 4.24 a, 4.24 b

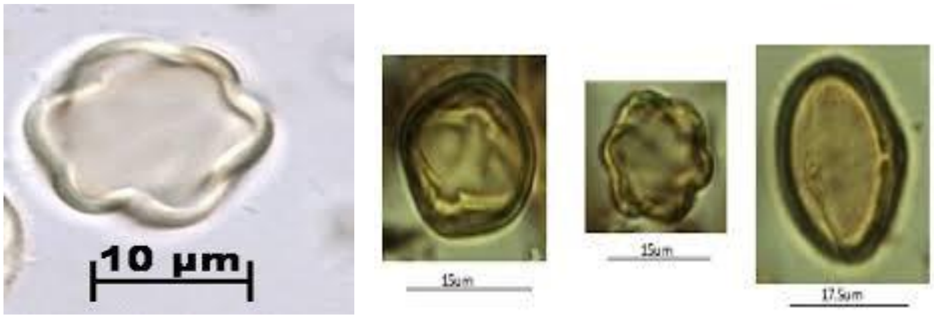


Fig 4.24 c, 4.24 d: Quisqualis indica Linn pollen under Electron Microscope (Family Combretaceae).

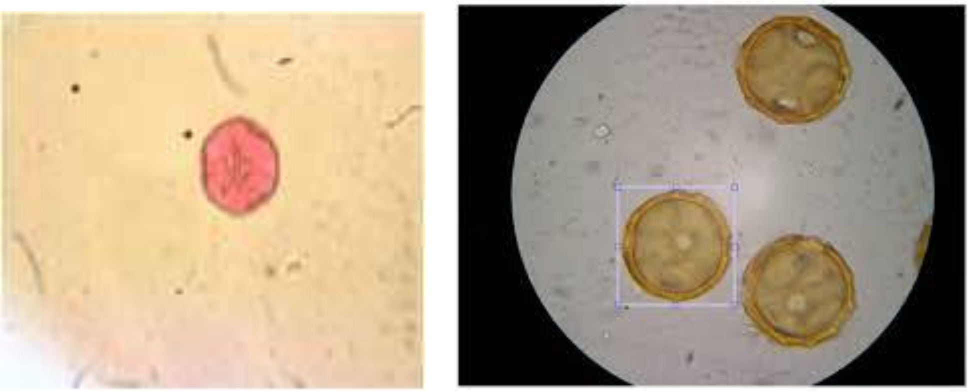


Fig 4.24 e, 4.24 f: Quisqualis indica Linn pollen under Electron Microscope

4. Family: Euphorbiaceae

Botanical name: Jatropha curcas Linn.

Fig 4.25 a, 4.25 b, 4.25 c: Euphorbiaceae (Jatropha curcas Linn).

Palynomorph: Oblong, nonaperturate, colpate, or colporate, or foraminate, or rugate; 2-celled. Size of the pollen was 31.1µm. Heteropolar.

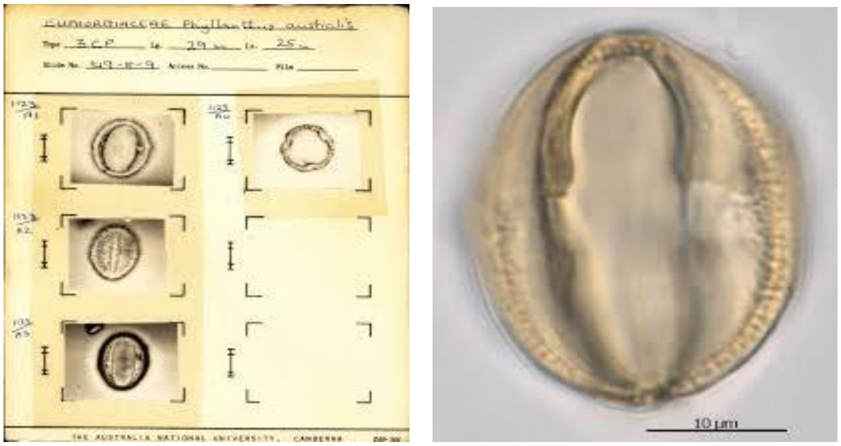


Fig 4.26 a, 4.26 b: Jatropha curcas Linn pollen under Electron Microscope (Family Euphorbiaceae).

Fig 4.26 c, 4.26 d: Jatropha curcas Linn pollen under Electron Microscope

5. Family: Lythraceae

Botanical name: Lagerstroemia indica Linn.

Fig 4.27 a, 4.27 b: Lythraceae (Lagerstroemia indica Linn).

Palynomorph: Tricolporate. Prolate-spheroidal. Aperature long elliptic, acute ends. Length 15µm long, breath 10µm, size of the pollen is 150µm, sexine thicker than nexine. Colpi 12µm long. Exine 3µm thick. Isopolar.

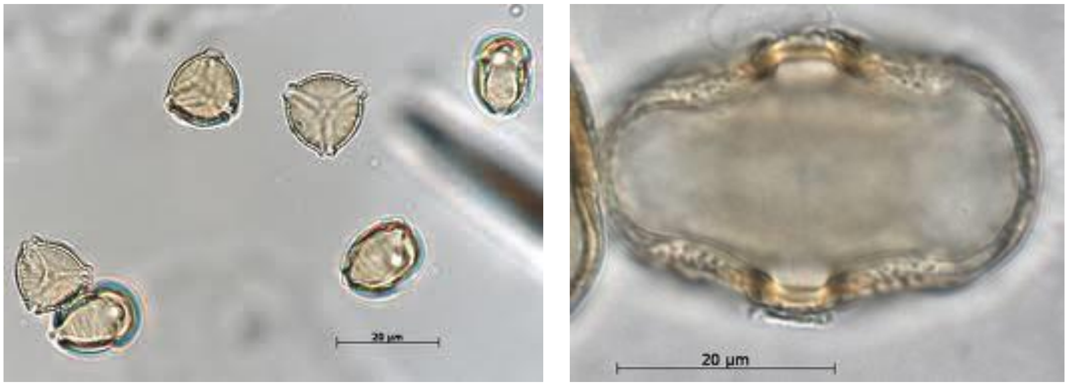


Fig 4.28 a, 4.28 b: Lagerstroemia indica Linn pollen under Electron Microscope (Family Lythraceae).

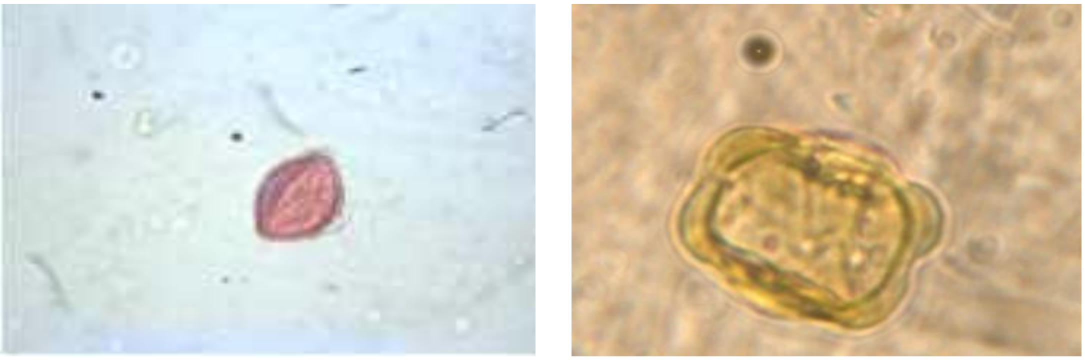


Fig 4.28 c, 4.28 d: Lagerstroemia indica Linn pollen under Electron Microscope

6. Family: Malvaceae

Botanical name: Hibiscus rosa-sinensis Linn.

Fig 4.29 a, 4.29 b: Malvaceae (Hibiscus rosa-sinensis Linn).

Palynomorph: Pantoporate, spherical to globose, isopolar, radial symmetry in polar view and bilateral in equatorial view, circular to oval. Pollen size is 143µm, exine 3.5µm thick, echini 9µm high, echini base 5µm wide, echini apexes 25.3µm apart, inter echini base distance 18µm, pore diameter 5µm. Number of spines are 24 and number of pores are 16. Pollen echinate and echini large in size and spaced widely, easy to count and distinct with blunt apex. Echini arranged regularly. Central spines which form a ring are somewhat different. Dimorphic with apex blunt, rounded and bifurcated. In some spines the apex is as much wide as base. Tectum is finely reticulate, perforated and densely granulated between spines. Aperture large and clear. Isopolar.

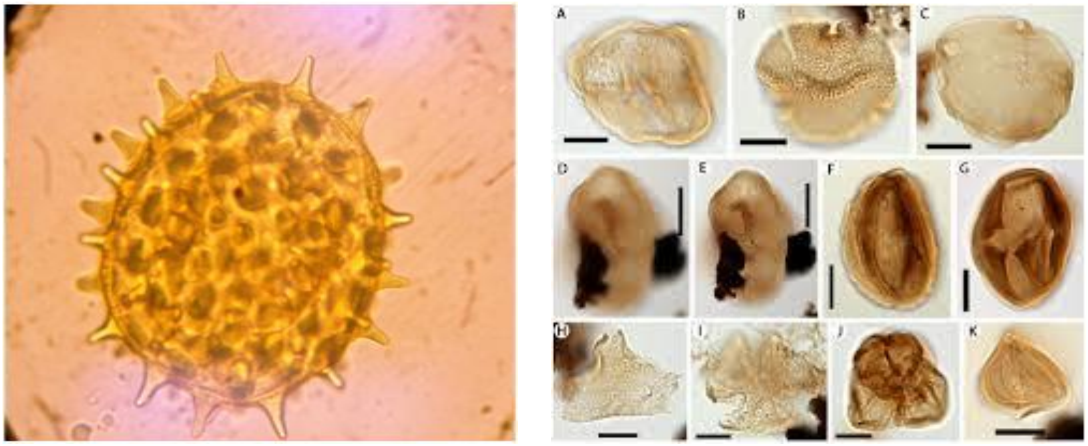


Fig 4.30 a, 4.30 b: Hibiscus rosa-sinensis Linn pollen under Electron Microscope (Family Malvaceae)

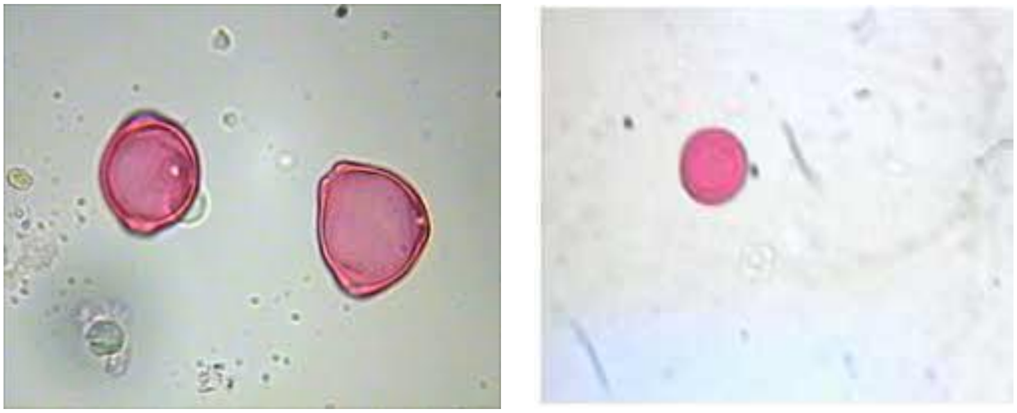


Fig 4.30 c, 4.30 d: Hibiscus rosa-sinensis Linn pollen under Electron Microscope

7. Family: Mimosaceae

Botanical name: Acacia nilotica (Linn.)Delile

Fig 4.31 a, 4.31 b: Mimosaceae (Acacia nilotica (Linn.)Delile)

Palynomorph: Polyads of 16 grained, 8 grains peripheral and 8 grains centrally placed in two groups, each group containing 4 grains, medium to large. Individual cell sub- globose in priphery and square in center, grain 3 porate, prolate to subspherical contour of peripheral grain circular. Prilate to finely granulate, testate, pores distinct, diameter of pores is 1.8µm, size of peripheral grain 8.4µm. Heteropolar, Exine 2.8µm thick.

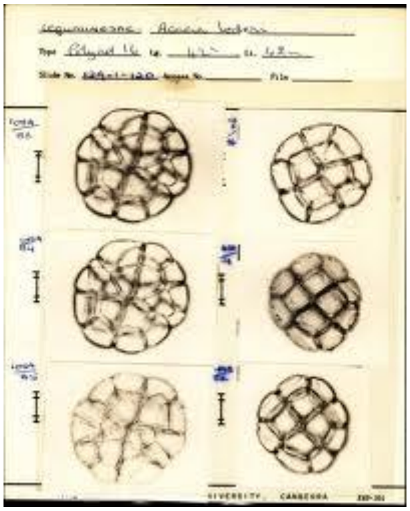


Fig 4.32 a:

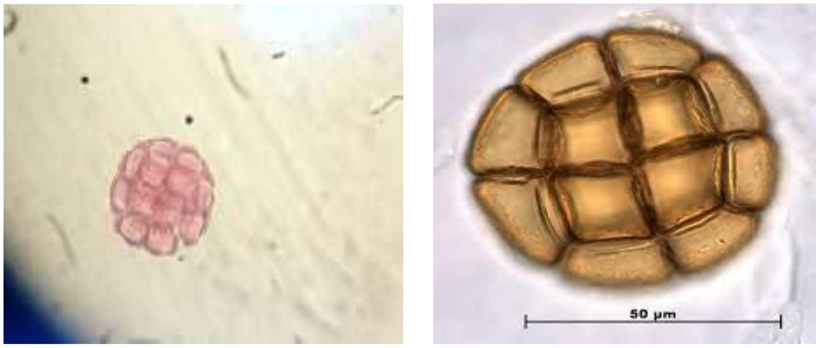


Fig 4.32 b, 4.32 c: Acacia nilotica (Linn.)Delile pollen (Family Mimosaceae)

8. Family: Poaceae

Botanical name: Imperata cylindrica (Linn.)

Fig 4.33 a, 4.33 b: Poaceae (Imperata cylindrica (Linn.))

Palynomorph: Areolate with medium scabrae-type, Spheroidal, Annulate, operculate, annulate, annulus reduced, annulus 3µm in diameter, 0.85µm thick, size of pollen is 2.5µm often slightly thicker pores. Exine 0.33µm thick, sexine slightly thicker or thinner than nexine. Tectum areolate, scabrae medium size in groups of 2-25, closely-widely distributed on small-large size regular or irregular areolae. Isopolar.

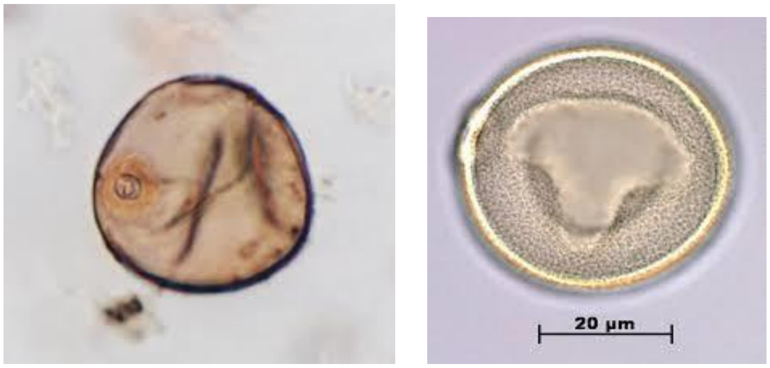


Fig 4.34 a, 4.34 b: Imperata cylindrica (Linn.) pollen under Electron Microscope (Family Poaceae).

Fig 4.34 c, 4.34 d: Imperata cylindrica (Linn.) pollen under Electron Microscope

9. Family: Plantaginaceae

Botanical name: Plantago lenceolata L.

Courtesy EcoPort
(http://www.ecoport.org):
P.L. Avenant

Fig 4.35 a, 4.35 b: Plantaginaceae (Plantago lenceolata L).

Palymorph: Pollen class: Pantoporate. Adaquate. Shape: Spheroidal. Aperture: Pori-small, circular with or without operculum. Exine: Sexine thicker than nexine. Ornamentation: Tectum areolate, scabrae coarse or fine. Outline: More or less circular. Measurements: Equatorial diameter 15.1 (16.1 ± 1.25) 30.0 µm, and pore more or less circular, diameter 0.75- (4.5 ± 0.31) 3.75 µm. operculate or non-operculate. Pore plate scabrate. Sexine thicker than nexine. Exine 0.75- (2.33) 2.47 um thick.

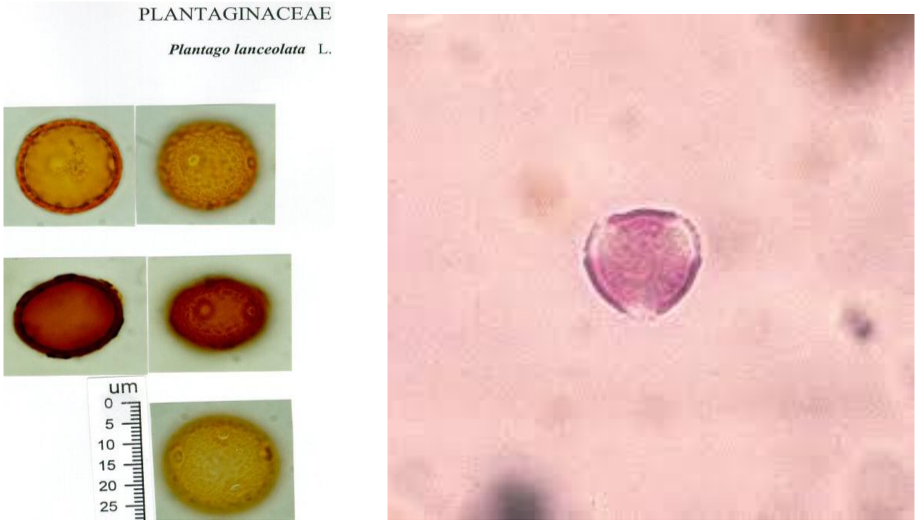


Fig 4.36 a, 4.36 b: Plantago lenceolata L pollen under Electron Microscope (: Plantaginaceae).

10. Family: Rosaceae

Botanical name: Rosa indica Linn.

Fig 4.37 a, 4.37 b: Rosacea (Rosa indica Linn).

Palynomorph: Tricolporate, prolate perforate, striate, and composed of muri and wide striae separating them. Striae are deep and run parallel. The sculpture of apocolpium and mesocolpium is striate. Length of pollen 6µm, breadth of pollen 4µm. Size of pollen 24µm, Shape of pollen: Elliptical. Isopolar.

Fig 4.38 a, 4.38 b: Rosa indica Linn pollen under Electron Microscope (Family Rosaceae).

11. Family: Rubiaceae

Botanical name: Ixora coccinea Linn.

Fig 4.39 a, 4.39 b: Rubiaceae (Ixora coccinea Linn).

Palynomorph: Grains isopolar, radially symmetrical, triangular, goniotreme, prolate, 3 zono-colpate, some grains show occasional para syncolpate furrows, bordered by distinct margins. Size of the pollen was 21.1µm. Exine 0.54µm thick, stratification distinct, crassimarginate, granula nexine, homogenous, psilate.

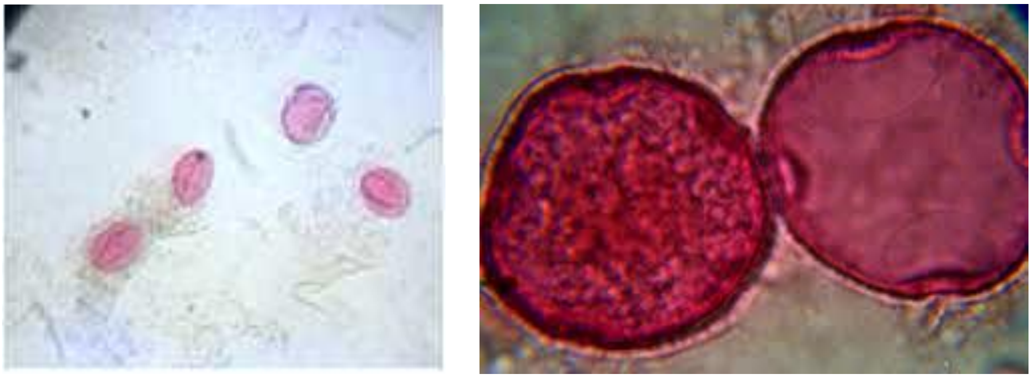


Fig 4.40 a, 4.40 b: Ixora coccinea Linn pollen under Electron Microscope (Family Rubiaceae).

12. Family: Rutaceae

Botanical name: Murraya koenigii (Linn.)

Fig 4.41 a, 4.41 b: Rutaceae (Murraya koenigii (Linn.).

Palynomorph: Tri-colporate, prolate aperature. Ectocolpus long narrow, small, more or less circula. Sexine thicker than nexine. Length 30.1µm, and breadth 12µm, size of the cell is 360µm, colpi 35.5µm long. Mesocolpium 32.5µm. Apocolpium 1.25µm. Exine 2.5µm thick. Tectum striate-foveolate. Isopolar.

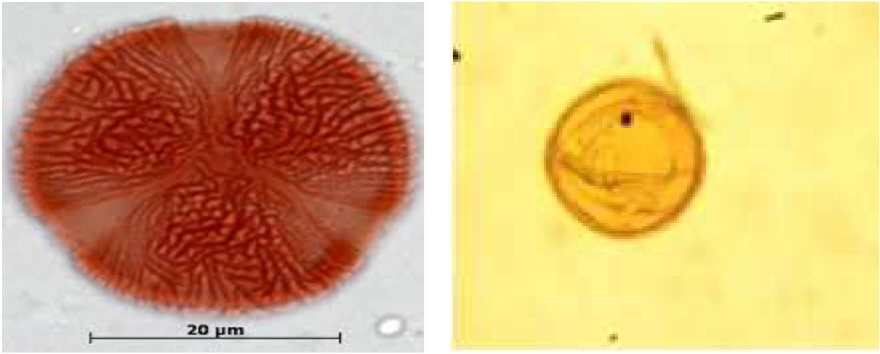


Fig 4.42 a, 4.42 b: Murraya koenigii (Linn.) pollen under Electron Microscope (Family Rutaceae).

13. Family: Solanaceae

Botanical name: *Solanum americanum* Mill.

Fig 4.43 a, 4.43 b: Solanaceae (Solanum americanum Mill).

Palymorph: 3-colporate, 3-zonocolporate. Apertures: Ectoapertures-colpus long, sunken, narrow, margins, sub-psilate end actue. Endoaperture circular. Exine: Sexine thicker or thinner than nexine. Ornamentation: Tectum scabrate. Outline: Equatorial view elliptic, Polar view trilobed with aperture on the angles of the outline of the grains in polar view. Measurements: Polar axis (P)14.3 (20.5±0.22)27.7 µm. Equatorial diameter 13.4 (20.5±0.22) 28.12 µm. Colpus length 14.5 (19.4±0.11) 25.5 µm. Mesocolpium 10 (15.5±0.11) 21.5µm. Apocolpium 0.75-5.55 µm. Exine 0.25 (1.75±0.11) 3.25 µm thick.

Fig 4.44: Solanum americanum Mill pollen under Electron Microscope (Family Solanaceae).

14. Family: Violaceae

Botanical name: ***Viola canescens* Wall.**

Fig 4.45: Violaceae (Viola canescens Wall)

Palymorph: Tricolporate, Prolate-spheroidal. Colpus short sunken with acute ends. Exine: Sexine thinner than nexine. Sub-psilate, densely punctate. Polar axis P (21.7-) 24.45 ± 0.54 (-29.41) µm and equatorial diameter E (19.61-) 23.01 ± 0.55 (-28.11) µm, tricolporate, triangular, with apertures on the sides of an angular grain in polar view, colpi (21.21-) 22.61 ± 0.68 (-28.13) µm long, with vestibuli, colpal membrane sparsely granulated. Mesocolpium (14.23-) 16.78 ± 0.55 (-19.61) µm. Apocolpium (0.70-) 1.26 ± 0.14 (-2.41) µm. Exine (1.26-) 1.33 ± 0.02 (-1.41) thick µm, sexine thinner than nexine. Tectum sub-psilate, densely punctate.

Fig 4.46: Viola canescens Wall pollen under Electron Microscope (Family Violaceae).

15. Family: Zygophyllaceae

Botanical name: *Tribulus terrestris* L. (Bhakra)

Fig 4.47: Zygophyllaceae (Tribulus terrestris L. (Bhakra).

Palymorph: In the Tribulus genus the sexine is thicker than or as thick as the nexine and the endexine is very thin, fibrillar with very small globular elements. T. terrestris pollen grains are spheroidal with a reticulate exine pattern with different sizes of the brochi and a big lumen, scaly inside. The sizes of the pollen grains range between 35 and 47.5 µm (43.5 µm at an average).

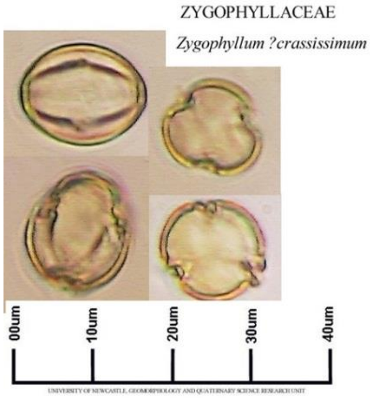


Fig 4.48: Tribulus terrestris L. (Bhakra) pollen under Electron Microscope (Family Zygophyllaceae).

List of Pollen Morphology of the Identified Species from Achaeological Gandhara site (Badalpur)

Sr. No.	Plant Species	Pollen apperture	No. of Apertures	Pollen Shape& Class	Polarity of Pollen	Family	Habbit	Site of Collection	Origin
1.	*Achyranthus aspera L.*	Porate	polypantoporate	spherical	apolar	Amaranthaceae	shrubby	BP	Native
2.				Prolate-					

	Cassia fistula Linn.	Tricolporate	Porate	spheroidal	Isopolar	Caesalpiniaceae	woody	BP	Native
3.	*Quisqualis indica* Linn.	Porate	Tricolporate	Prolate	Isopolar	Combretaceae	woody	BP	Native
4.	*Jatropha curcas* Linn.	Non-Porate	Non-aperturate	Prolate	Hetero Polar	Euphorbiaceae	shrubby	BP	Exotic
5.	*Lagerstroemia indica* Linn.	Porate	Tricolporate	Prolate-spheroidall	Isopolar	Lythraceae	Woody	BP	Exotic
6.	*Hibiscus rosa-sinensis* Linn.	Porate	Pantoporate	Spheroidal	Isopolar	Malvaceae	shrubby	BP	Exotic
7.	Acacia nilotica (Linn.)Delile	Porate	Tricolporate	Prolate	Hetero Polar	Mimosaceae	woody	BP	Native
8.	*Imperata cylindrica* (Linn.) P. Beauv	Porate	Annulate	Spheroidal	Isopolar	Poaceae	shrubby	BP	Native
9.	*Plantago lenceolata L.*	Porate	Pantoporate	Spheroidal	Isopolar	Plantaginaceae	shrubby	BP	Native
10.	*Rosa indica* Linn.	Porate	Tricolporate	Prolate	Isopolar	Rosaceae	woody	BP	Native
11.	*Ixora coccinea* Linn.	Porate	Zono-colpate	Prolate	Isopolar	Rubiaceae	woody	BP	Native
12.	*Murraya koenigii* (Linn.) Spreng.	Porate	Tricolporate	Prolate	Isopolar	Rutaceae	woody	BP	Native
13.	*Solanum americanum Mill.*	Ectoapertures	colporate	spherical	Polar	Solanaceae	shrubby	BP	Native
14.	*Viola canescens Wall.*	Tricolporate	Tricolporate	Prolate-spheroidal.	Polar	Violaceae	shrubby	BP	Native
15.	*Tribulus terrestris L. (Bhakra)*	Porate	reticulate	spheroidal	Isopolar	Zygophyllaceae	shrubby	BP	Native

Table 4.2: List of Pollen Morphology of the Identified Species from Achaeological Gandhara site (Badalpur)

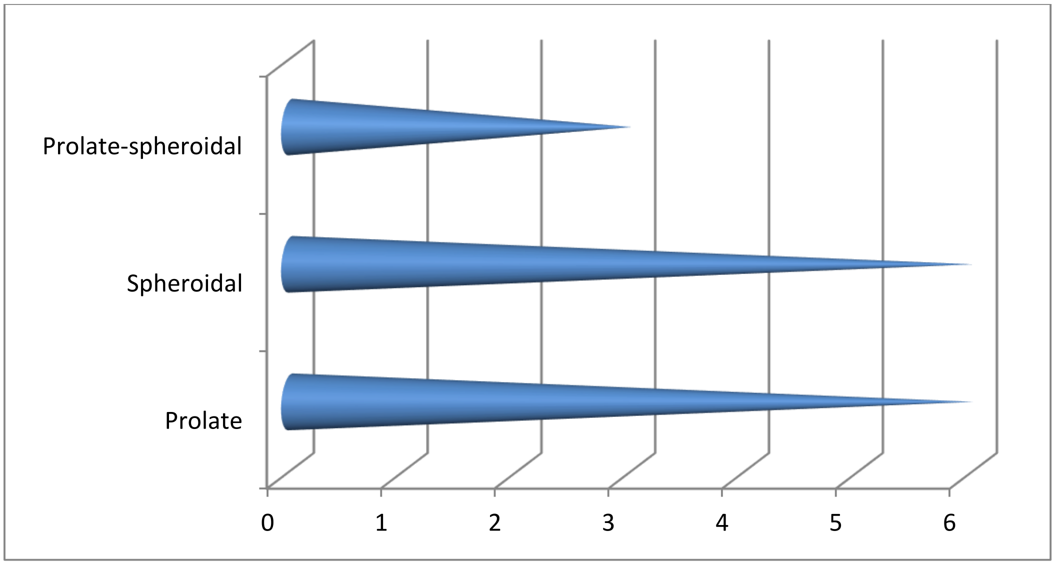


Table 4.3: Flow Chart of Pollen Morphology (Shapes and Class) of Plants Species

CHAPTER: 5

Discussion

This research purpose is basically investigate the features of pollen grains from ancient Gandhara site (Badalpur) and Comparison of Gandhara period plants with present existing plant and investigate the agriculture evolution in Gandhara. The change of climate patterns often can be determined by pollen analyses of the soil, especially the soil of Badalpur Gandhara sites. The investigational palynological research will contribute in the meadow of archaeology and towards the conversion of traditional archaeology into “Experimental Archaeology”.

Present existing cultivated plants in Taxila, Punjab

The flora of taxila is Mediterranean type of flora. Because of long dry seasons the flora of the plains is distinctly arid. Grasses are also very numerous, no less than 185 are collected (Stewart, 1957). In the plains, ferns, mosses, lichens and liverworts are not common because of the long dry seasons but these groups are better represented in the hills as the rainfall increases. Occasional reserves or graveyards in the plains give some idea of what the plant cover of the district would be like if it were given a fair chance.

Palynology is the science devoted to the study of pollen, spores and other microfossils of similar size and composition. Hyde and William (1945) used the term “palynology” for the first time for pollen analysis. Pollen grains are an outrageous invention of the seed plants, which first appeared over 300 million years ago. Pollen is produced by the seed plants, which include the gymnosperms (conifers and related groups) and the angiosperms (flowering plants).

Agricultural activities in Recent Taxila

Main Crops

Wheat, Maize, Jawar and Ground Nut are the main crops grown in the district.

Main Fruits

Apple, Citrus and Guavas are main fruits grown in the district.

Main Vegetables

Potatoes and Onion are main vegetables grown in the district.

Taxila valley is rich in the variety of its flora due to its varied Geo-climatic feature. The flora differing at different elevations. There are many closely related disciplines which have specific application such as in identification, differentiation of Taxa in systematic and taxonomic decision. Among these discipline palynology is one of the most important and applicable tool in taxonomic studies of flora of particular geography. Pollen morphology and fertility is closely related to its function because many of the features present in pollen grains have helped the species of plants to which it belongs to adapt to life on particular geography, be able to disperse its pollen and fertilize the female eggs to produce new seeds that would give rise to new plants. In light of this research application on pollen morphology and taxonomic description of some important weeds from flora of taxila was investigated to highlight the diagnostic pollen characters of flora used in taxonomic decision and also provide pollen inventory for future research in related disciplines.

Palynomorph and Morphology of the recent cultivated plants in Taxila valley

Pollen studies of flora of Rawalpindi were carried out. In total of 8 species belonging to 8 genera of 6 families were investigated for Taxonomic description and Palynomorph features. Palynomorph inventory represents the finding in alphabetic order of botanical name followed by local name, English name, Morphology, Phytogeography, flower color & season and Palynomorph features.

1. ***Allium jacquemontii*** **Regel ex Kunth (Alliaceae)**

Syn: ***A. przewalskianum*** **Regel, Allior. Monogr**.

Local Name	:	Jangli Thoom
English Name	:	Wild garlic
Morphology	:	Or sub-globose, pedicels shorter or longer than the lilac campanulate flowers, sepals oblong-lanceolate obtuse or subacute, filaments exserted subulate inner with a dilated 2-toothed base. Bulbs tufted, cylindric, elongae; fibrous coats very finely reticulate, rusty brown. The sepals, shortly exserted, inner obscurely toothed at the base. Capsule globosely ovoid, style very long. Filaments inserted much above the bases of the sepals, shortly exserted, inner obscurely toothed at the base. Capsule globosely ovoid. The inflorescence is umbel.

Phytogeography : Central Asia, Afghanistan, India and Western Tibet. In Pakistan; Ziarat, Shokor Shal, Ladakh, Shushal, Rupshu, Da-Hanle, Shyok and Rawalpindi. Flower Color & Season Pale & March-April

Palynomorph : Exoporate. Shape in polar view is perprolate to prolate and in equatorial view it is rectangular. Polar diameter is 14.6 µm (11-15 µm) and equatorial is 20.05 µm 20-20.5 µm). P/E ratio is 0.728 µm. Exine thickness is 0.5 µm.

2. *Ageratum conyzoides* L. (Asteraceae)

***A. houstonianum* Mill. Gard.**

Local Name : Neeli Booti

English Name : Goat weed

Morphology : Erect herb; young stems pubescent; leaves ovate or rhombic- ovate, acute at apex, acute to obtuse or subcordately rounded at base, pubescent on both surfaces, glandular dorsally, 2-10 cm long, 1-56 cm wide, on petiole 1-5 cm long; heads corymbose 4-6mm long; involucre subglabrous, bracts acute- acuminate, 3 mm long; florets about 75 per head; corolla about 1 mm long, white or blue-purplish, included in the involucre; style-branches exserted, achenes 1.5-2 mm long, nearly glabrous

Phytogeography : Pantropical, Central and South America. Widespread weed. In Pakistan; Islamabad and Rawalpindi.

Flower Color & Season : Pruplish pink & February-April.

Palynomorph : Pollen is monad, tricolporate. Shape of pollen in polar and equatorial view is circular. Polar diameter s 19.7 µm (15-20.5 µm). Equatorial diameter is 19 µm (16.5-20 µm). P/E ratio is 1.03 µm. The length f spine is 2.3 um (2-2.5 µm). Exine thickness is 1.2 µm (1-1.5 µm).

3. *Parthenium hysterophorus* L. (Asteraceae)

Syn: *Parthenium lobatum* Buckl.

Local Name : Gandi Booti

English Name : Congress weed

Morphology An erect ephemeral herb known for its vigorous growth. It is light green with branching stems, finely lobed leaves and grows up to 1.5 meters, occasionally reaching 2 m in deep rich soils. Young plants form a basal rosette of strongly dissected leaves that are up to 30 cm in length. Once stem elongation is initiated, smaller leaves are produced and the plant becomes much-branched in its extremities.

Phytogeography : Native to Mexico, Central and South America, introduced into several countries including Australia, India, Taiwan and Ethiopia. In Pakistan; Islamabad, Chakwal, Talagang and Rawalpindi.

Flower Color & Season : Ceramic white & through out the year.

Palynomorph : Pollen is monad, tricolporate and echinate. Shape of pollen in polar and equatorial view is circular to semi-angular. Polar diameter is 15.58 µm (14-17.5 µm) and equatorial diameter is 16.37 µm (14-17.5 µm). P/E ratio is 0.95 µm. Number of spines between colpi are 6-7. Exine thickness is 1.75 µm (0.75-1 µm).

4. *Saussuria heteromala* (D.Don) Hand.-Mazz. (Asteraceae)

Syn: *S. candicans* (DC.) Sch.-Bip.

Local Name : Kali Ziri

English Name : Costus

Morphology : Erect herb up to 120 cm tall; stem branched above. Basal leaves lyrately lobed. Upper ones smaller, toothed. Flower heads pale purplish, many, 20-30 mm broad. Involucral bracts lanceolate. Pappus hairs white. The inflorescence is capitulum.

Phytogeography : Afghanistan and Kashmir to Bhutan. In Pakistan; Kurram, Chitral, Gilgit, Swat, Hazara, Salt range, Lahore, Murree, Kashmir, Jummu, Islamabad and Rawalpindi.

Flower Color & Season : Light purple & March-September

Palynomorph : The pollen is monad and dicolporate. The shape of pollen in polar view in both polar and equatorial view is prolate. The polar diameter is 36.66 µm (35-39 µm) and equatorial diameter is 37 µm (35.5- 39 µm). P/E ratio is 0.98 µm. Exine thickness is 5.16 µm (5-5.5 µm).

5. *Sisymbrium irio* L. (Brassicaceae)

Local Name : Khoob Kalan / Khakshi

English Name : London rocket

Morphology : Annual or biennial, tall, glabrous, leaves runcinate - pinnatifid, segments not auricled, flowers minute, pedicels slender, young pods overtopping the raceme, old 3-nerved, stigma sessile. Stem 1-3 ft., tall, quite glabrous, or slightly pubescent near the base. Leaves petioled, pinnatifid or pinnatipartite; segments remoste, spreading, toothed; terminal large, sometimes hastate. Pods slender, erect, glabrous, sub-torulose; valves 3-nerved; pedicels ascending, curved. The inflorescence is corymbose.

Phytogeography : India, Afghanishtan, Canary Islands. In Pakistan; Waziristan, Chitral, Swat, Hazara, Gilgit, Poonch, Kashmir and Rawalpindi.

Flower Color & Season : Yellow & January-April

Palynomorph : The pollen is monad and tricolporate. The shape of pollen in polar view is circular and in equatorial view is prolate. The polar diameter is 21.25 µm (20-24 µm) and equatorial diameter is 20 µm. P/E ratio is 0.96 µm. Exine thickness is 1 µm.

6. *Convolvulus arvensis* L. (Convolvulaceae)

Local Name : Lali Poli

English Name : Field Bindweed

Morphology : Glabrous or pubescent perennial; stem up triangular or ovate-oblong to linear, hastate to sagittate, more or less entire. Very variable in pubescence and leaf-shape. Plants with linear to oblong-lanceolate leaves. Peduncles axillary, often about as long as bracts, 1- to 2(3) flowered. Sepals obtuse to emarginated, and often apiculate. Corolla 10-25 mm, white to pink. Ovary glabrous. The inflorescence is solitary axillary.

Phytogeography : Temperate and Tropical regions of the world, South Europe. In Pakistan; Sind, Ladkh, Baltistan, Attock, Mianwali, Jhang, Talagang, Chakwal and Rawalpindi.

Flower Color & Season : Pale pink to pink or white & mostly throughout the year.

Palynomorph : Pollen is monad and tricolporate. The shape of pollen in polar view is circular to semi-circular and in equatorial view is prolate. The polar diameter is 62.25 µm (56-70 µm) and equatorial diameter is61.75 µm (57.5-66 µm). P/E ratio is 01 µm. The length of colpi is 14.25 µm (11-16 µm) the width of colpi is 15.25 µm (15-16 µm). Exine thickness is 6.25 µm (5-9 µm).

7. *Boerhaavia procumbens* Banks ex Roxb. (Nyctaginaceae)

Syn: *B. cocinea* mill. Gard.

: *B. diffusa* auct. Plur

Local Name : Biskhapra / Jangli Itsit

English Name : Spreading hogweed

Morphology Branches 2-3 ft., usually slender glabrous, leaves larger broader often rounded white beneath, more robust, branches long stout glabrous pubescent or viscous, leaves 1-2 in., ovate obtuse or acute usually cordate green beneath. Inflorescence panicled.

Phytogeography : India, Africa, and USA. In Pakistan; Sind, Baluchistan, NWFP, Thal to Kurram, Peshawar, Multan, Attock, Hazara and Rawalpindi.

Flower Color & Season : Purplish red & January-August

Palynomorph : The pollen is monad, periporate and echinate. The shape of pollen in polar and equatorial view is circular. The polar diameter with spine is 75.75 µm (72.5-79 µm). The length of spine is 3 µm (2.5-3.5 µm) and the size of pore is 6 µm (4.5-10 µm). Exine and entine are prominent but exine is broader than entine. Exine thickness is 4.8 µm (4.5-5 µm).

8. *Tribulus terrestris* L. (Zygophyllaceae)

Local Name : Bakhra

English Name : Puncture vine

Morphology : Annual or biennial, peduncle shorter than the leaves, cocci with 2 long and 2 short spines. Prostrate, hirsute or silky hairy, petals often not exceeding than the calyx. Cocci very variable, glabrous or hairy and mucronate. Stigmatic lobes longer than the diameter of the style. Fruit 5-angled or tuberculate in cocci. Seeds obliquely pendulous, testa membranous, embryo without albumen, cotyledons ovate, radicle short.

Phytogeography India, Western Tibet. In Pakistan; Gilgit, Astor, Baltistan, Salt Range, Attock, Jhelum, Kohat, Ladakh, Kahmir, Mianwali, Attock and Rawalpindi.

Flower Color & Season : Yellow & mostly throughout the year.

Palynomorph : The pollen is monad, periporate and echiate. The shape of pollen in polar view is circular. The polar diameter is 45.62 µm (45-46.5 µm). Exine thickness is 2.83 µm (2.5-3 µm).

Keeping in view, the importance and scope of application of palynology in taxonomy, in a total of 8 species belonging to 8 genera of 6 Angiosperm families were investigated for their general morphology and detailed pollen morphological characters. Out of these 6 families, one is monocot i.e. **Alliaceae** and 5 others are dicot families. On the basis of life form it was investigated that all species were herbs. Great diversity in taxonomic description and pollen morphology was found among the representative species of these families.

Out of these 8 species of present study, there were 3 species belonging to family **Asteraceae.** It is a eurypalynous family (Erdtman 1952) and most of its genera possess zonocolporate pollen (Sachdeva and Malik 1986). The present study showed that there is a great diversity in pollen morphology of Asteraceae, variation mostly found in size, shape, spine length, number and colpi morphology.

In *S. heteromala* the shapes of pollen were prolate whereas in rest of species of Asteraceae the shape almost circular to semi-angular. The character of pollen spine is significance in evolution and at specific and generic level in classification of this family. Spineless pollens were observed in *S. heteromala*where as rest of the species has spines in their pollen. These findings are in agreement with of Keeley and Jones (1977) who reports pinnate and spineless pollen in some *Veronica* species and observed that both pollen and vegetative character indicate a divergence due to independent line of evolution of spine isolation. Wodehouse (1935) outlined the principles of morphological evolution of spine form in Compositae and suggested the reduction series from long to minute spines. The spinate pollen character is considered as a primitive feature as compared to spineless pollen.

One of the interesting variations found in pollen of *A. jacquemontii,* in which the pollen was found to be tricolporate. This character is varied from the rest of the monocot and considered to be of evolutionary significance in primitive and advanced monocot families.

In case of **Convolvulaceae,** in *C. arvensis* pollen is found to be tricolporate and smooth. It indicates a great variation in pollen morphology which would be helpful to improve the classification of Convolvulaceae.

Zygophyllaceae is also one of the established and well represented families in flora of Rawalpindi and this group is easily differentiated taxonomically from rest of the other Angiospermic families. Further investigation is required to explore the pollen diversity in this greatly significant family. In *S. irio* **(Brassicaceae)** pollens are tricolporate and circular to prolate in polar and equatorial view respectively. In case of *B. procumbens* **(Nyctaginaceae)** pollen are periporate, echinate and circular both in polar and equatorial view. Perveen and Qaiser (2001) have also reported uniform and mostly spheroidal pentporate pollens in Nyctaginaceae.

It is concluded from this research that palynological data is very important not only for taxonomists but also for related disciplines of pure and applied sciences because this study provided some new dimensions towards further research in the disciplines of palynology.

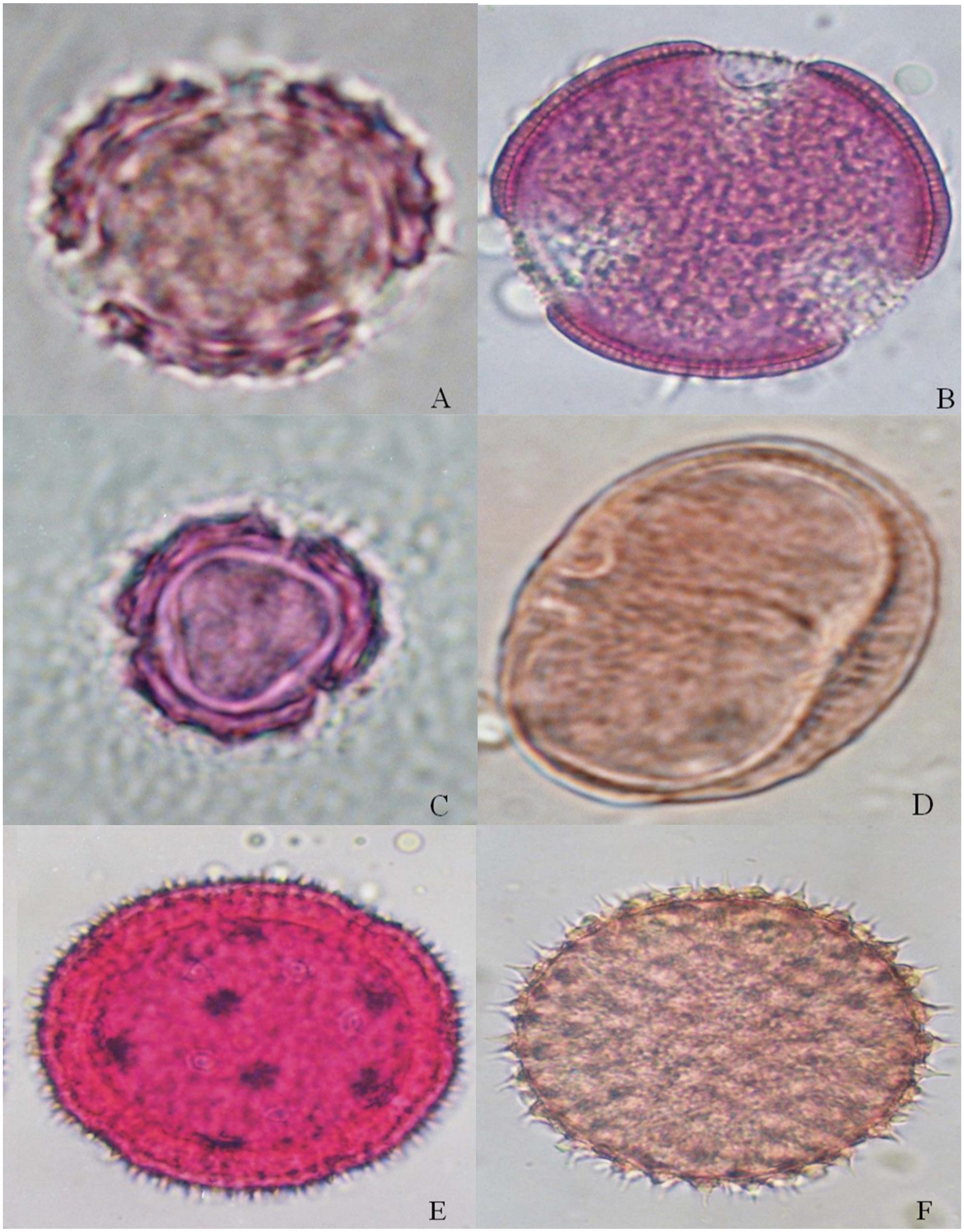


Fig 4.49 a, 4.49 b, 4.49 c, 4.49 d, 4.49 e, 4.49 f: A- *Ageratum conyzoides* (Polar view -1000x), B- *Convolvulus arvensis* (Polar view - 400x), C-*Parthenium hysterophorus* (Polar view – 1000x), D- *Saussuria heteromala* (Equatorial view – 400x), E- *Boerhaavia procumbens* (Polar view – 400x), F- *Tribulus terrestris* (Polar view – 400x)

Conclusion

This research discusses some of the applications of fossilized pollen data in Archaeology, thus, bringing Botany and Arcaheolgy in accordance with each other and offers suggestions and concerns about the course of the discipline in the years to come. This research considers archaeobotanical evidence for the evolutionary stages of domestication and the rates of evolution of the domestication syndrome for a selected number of the best archaeologically documented crops in the Old World.

This also explores the close links between Botany and Archaeology, using case study from the ancient Gandhara sites in Taxila. It is to find out whether the agriculture pattern were the same at that time or different plants were cultivated in Gandharan sites. It explains the kinds of palaeobotanical remains that the researcher recovered and the methods used to analyse them.

The aim of this research was to develop a relation of Botany and Archaeology. In this research, a modest attempt is made to initiate a debate on the current theory, methodology and objectives of the study of archaeological plant remains with special emphasis on issues relevant to archaeology and archaeological research on ancient plant remains. The results obtained from experiment include some suggestions (that are open to discussion) on prospective contribution of archaeobotanical research to applied science, and hence the need of the contemporary world.

In this research, the plant (archaeobotanical) remains is meant to denote all types of ancient plant remains which are recovered from archaeological sites or from other areas with the intention of studying human-plant interrelationship and the context (environment) in which they took place. Macro and microbotanical remains are deposited in or brought to archaeological sites by natural and /or cultural processes. They are preserved by carbonization, water logging, desiccation, and mineralization, as stomach contents and residues, e.g. coprolites, impressions in pottery. They are identified (on the basis of their external morphology) by comparing them with reference collections, manuals, and by sorting types, size, measurements, and shape and surface texture.

Experimental research on processing and preparation of (wild and domesticated) food plants is also generally lacking and the few projects done or running are uncoordinated and mostly access-restricted (Mason 2002c). Experimental studies contribute to our understanding of the archaeobotanical data in three main ways.

As Archaeoboatny is marginal between Botany and Archaeology, the ideal situation is to have a researcher trained in both Archaeology and Botany. Unfortunately, until now there are a very few specialists who have such qualifications and it still is a matter of debate whether it is better for Archaeobotanist to be first good botanist and then to learn about archaeology, or whether archaeologists can become good botanists. The current positive tendency towards interdisciplinary research work might motivate future archaeobotanists to acquire training in both disciplines.

In short, Archaeologists should carefully consider the value of fossilized pollen data when they conduct their excavations. In the past, palynologists have been able to help archaeologists determine past environmental changes, prehistoric diets, the use of native and cultivated plants, graveside rituals, intersite and intrasite dating, aboriginal use of certain categories of artifacts, utilization patterns for rooms at pueblo sites, and most recently, a method for pre testing sites to determine their archaeological potential. In addition, there are often instances where the fossilized pollen record will provide precise answers to questions that often cannot be answered by the artifact record alone.

The discussion in this research present an attempt to examine the archaeological palynology as it exists today and is not intended as a guide for the future. There are still many problems that exist in conducting archaeological palynology that we hope will be solved in the near future. As more research is completed and new techniques of sampling and analysis are perfected, this field of palynological research will become more precise.

Bibliography

Adams, D. P. and P. J. Mehringer 1975 *Modern pollen surface samples: and analysis of Sub samples* Journal of Research United States Geological Survey 3:733-736.

Addelson, Barbara (December 2003). *"Natural Science Institute in Botany and Ecology for Elementary Teachers* ".Botanical Gardens Conservation International.Retrieved June 8, 2013.
Aftab, R. & Perveen, A., 2006. A Palynological srudy of some cultivated trees from Karachi. *Pak. J. Bot.,* 38(1): 15-28.

Andersen, S. T. 1965 *Mounting media and mounting techniques. In Handbook of Paleontological tech niques,* edited by Kummel and Raup. New York: W. H. Freeman.

Anderson, R. Y. 1955 *Pollen analysis, a research tool for the study of cave deposits*. American Antiquity 21:84-85.

Anon. 1998. District Census Report of Rawalpindi, Population Census Organization Statistical Division GOP, Islamabad.1-19.

Barkley, F. A. 1934 *the statistical theory for pollen analysis*. Ecology 15:283-289.

Bhattacharya, K., Majumdar, M. R. & Bhattacharya. S. G., 2006. A Textbook of Palynology.New Central Book Agency (P) Ltd. Kolkata, India.

Bhutta, A.A. (1968). Palynology, the study of pollen and spores.*Horizon*, 10:47-49.

Bhutta, A.A. (1983). The science of Palynology *Ait.Bio.Spring-83.pp-30-36*.

Birks, H. J., T. Webb III, and A. A. Berti 1975 *Numerical analysis of pollen samples from central Canada: a comparison of methods.* Review of Paleobotany and Palynology 20:133-169.

Bohrer, V. L. 1968 *Paleocology of an archaeological site near Snow Flake Arizona.* Ph.D. disserta tion on file, Department of Biological Sciences. University of Arizona Library, Tucson.

Bryant, V. M., Jr. 1966 *Pollen analysis: its environmental and cultural implications in the Amistad reservoir area.* Masters thesis on fi'le, Department of Anthropology, University of Texas Library, Austin.

Bryant, Vaughn M., Jr., and Richard G. Holloway1983 "*The Role of Palynology in Archaeology"*. Advances in Archaeological Method and Theory 6:191-232. New York: Academic Press

Chaffey, Nigel (2007). "*Esau's Plant Anatomy, Meristems, Cells, and Tissues* of *the Plant Body: their Structure, Function, and Development*". Annals of Botany 99 (4): 785.

Davidson, D. A., S. Carter, B. Boag, D. Long, R. Tipping and A. Tyler. (1999) Analysis of pollen in soils: processes of incorporation and redistribution of pollen in five soil profile types. *Soil Biology and Biochemistry*, 31(5): 643-653.

D.F. Dinacauze, *Environmental Archaeology, Principles and Practice*, Cambridge University Press, 2000.

Dillon Brain. (1989) "*Introduction to Archaeology"*.The archaeological field vehicle.In practical archaeology field and laboratory techniques, Brain D Dillon Los Angeles; University of California.

Dumo, S. E. 1965 *Pollen analytical evidence of "Landnam" from two scottish sites.* Transactions of the Botanical Society of Edinburgh. 40:13-19.

Ehrhardt, D.W, Frommer, W. B. (February 2012). *"New Technologies for 21st Century Plant Science"* (PDF). The Plant Cell 24 (2): 374-94.

Erdtman, G. (1943). *An introduction to pollen analysis.Verdoon*, New Ser. Pl. Sci. Books 12. Waltham, Mass. ChronicaBotanica Co. U.S.A. pp-239.

Erdtman, G. 1952. Pollen and spore morphology/plant taxonomy (An introduction to palynology, II. Gymnospermae, Pteridophyta, Bryophyta) Almqvist and Wicksell, Stockholm.

Erdtman, G. (1963).*Palynology: Advances in Botanical Research,* Edited by Preston, R.D. Academy Press London. Pp-149-208.Ereshefsky, Marc (1997). "*The Evolution of the Linnaean Hierarchy"*. Biology and Philosophy (Kluwer Academic Publishers) 12 (4): 493.

Faegri, Knut and Johs.Iversen.1989 .*Textbook of Pollen Analysis*.Fourth edition.Chichester: John Wiley & Sons.

Ferguson, I. K. 1981. The pollen morphology of genus *Ceratonia* (Leguminasae: Caesalpiniaceae).
Funkhouser, J. W., and W. R. Evitt 1959 *Preparation techniques for acid insoluble microfossils.* Micropaleontology 5:369 375.

Godwin, H. 1934 *Pollen analysis: an outline of problems and potentialities of the method.* New Phytologist 33:278-305.

Gordon, A. D., and H. J. Birks 1974 *Numerical methods in Quaternary paleoecology*. New Phytologist 73:221-249.

Hastorf, Christine A. 1999. *Recent Research in Paleoethnobotany*. Journal of Archaeological Research 7(1):55-103.

Hevly, R. H. 1964 *Pollen analysis of Quarternary archaeological and lacustrine sediments from the Colorado Plateau. Ph.D. dissertation on file,* Department of Biological Sciences, University of Arizona Library, Tucson.

Holloway, R. G. 1981 *Preservation and experimental diagenesis of pollen exine.* Ph.D. dissertation on file, Department of Biology, Texas A & M University Library, College Station.

Horrocks, M., Coulson, S. & Walsh, K., 1998. Forensic palynology: variation in the pollen content of soil surface samples. *J. Forensic Sci.,* **43**: 320-323.

Hyde, H.A. and D.A.William. 1945. “Palynology” Nature, London, pp. 155-265.

J. Evans and T. O’Connor.2001.*Environmental Archaeology, Principles and Method, Sutton, Stroud.*

Jansonius, J., D.C. McGregor (1996) Introduction, Palynology: Principles and Applications. *AASP Foundation,* 1: 1–10.
Jorgensen, S. 1967 *A method of absolute pollen counting.* New Phytologist 66:489-493.

Kapp, Ronald O., HOW TO KNOW POLLEN AND SPORES, Wm. C. Brown Company, 1969.

Keeley, S.C. & Jones, S.B. JR. 1977. Taxonomic implications of external pollen morphology to *Vernonia* (Compositae) in the West Indies. Amer. J. Bot. 64(5): 576-584.

Khola, G. & Hanif, U. 2012 .Palynological study of Soil samples collected from an Archaeological site (GULABI BAGH) in Lahore, Pakistan. *J. Anim. Plant Sci,* **22**(**4**): 1113-1117.

King, J. E., et al. 1975 *Pollen preservation and archaeology in eastern North America.* American Antiquity 40:180-190.

Lee, S. L. (1990) some functional Aspects of Angiosperm Pollen. Korean J. Pl. Taxon, 19(4): 289-302.
Meo, A. A. (1999) Impact of Pollen and intergeneric crosses between Graminaceous (Poaceae) plants. Pakistan J. Biological Sci., 2(3): 809 –812.
Mildenhall, D. C., Wiltshire, P. E. J. & Bryant, V. M., 2006. Forensic Palynology: Why do it and how it works. *Forensic Sci Int.,* **163**: 163-172.
Mildenhall, D. C., 2006. An unusual appearance of a common pollen type indicates the scene of the crime. *Forensic Sci Int.,* **163**: 236-240.
Mittre, V., 1961. Contacts of Palynology. *Bull. Nat. Inst. Sci.* India. **19**:2-14.
Moore, P. B., and J. A. Webb 1978 *An Illustrated Guide to Pollen Analysis.* London: Hodder and Stoughton.

Moore, P.D., J. A. Webb, and M. E. Collinson, POLLEN ANALYSIS, Blackwell Scientific Publications, 1991.

Morrison, M. E. S. 1959 *Evidence and interpretation of Landam in the southeast of Ireland*. Sar tryck ur Postaniska Notiser 112 Fax 2.

Nasreen, U. and M. A. Khan (1998) PalynologicalStudies of *Matricaria chamomilla* L.(Babuna)and its related genera. Hamdard Medicus 4: 94-97.
Perveen, A.and M. Qaiser. 2001. Pollen flora of Pakistan. XXVII. Nayctaginaceae. Turk. J.Bot. 25:385-88.

Ronald, O. K. 2000. Pollen and spores. 2nd ed. American Association of Stratographic Palynologists, 13-21.

Sachdeva, S.K. and C.P. Malik 1986. Experimental plant taxonomy. Kalyani Publications, New Delhi.

Sangster, A. G., and H. M. Dale 1961 *A preliminary study of differential pollen grain preservation*. Canadian Journal of Botany 39:35-43.

Schoenwetter, J. 1962. *The pollen analysis of eighteen archaeological sites in Arizona and New Mexico.* In: Chapters in the Prehistory of Eastern Arizona, edited by P. S. Martin. Chicago Natural History Museum Fieldiana (Anthropology) 43:168-209.

Schoenwetter, J., and F. W. Eddy 1964 *Alluvial and palynological reconstruction of environments:* Navajo reservoir district. Museum of New Mexico Papers in Anthropology 13:1-115.

Shackley, M. (1981) Environmental Archaeology. Allen and Unwin, London.

Smith, E. Grant, SAMPLING AND IDENTIFYING ALLERGENIC POLLENS AND MOLDS, Blewstone Press, San Antonio,

Stanley, R. G., and H. F. Linskens 1974 *Pollen biology, biochemistry and management.* New York: Springer Verlag.

Srivastava, S. K. 1962. Palynolgy-A gift of flowers. Sci. Cult., **28**: 265-269.

Van an Zeist, W. 1967 *Archaeology and palynology in the Netherlands.* Review of Paleobotany and Palynology 4:45-65.

Van Campo, M., S. Nilsson and A.J.M. Leeuwenberg. 1979. Palynotaxonomic studies in Tabernae Montana L. sensu lato (Apocynaceae). *Grana palynologica*, 18.5-14.

Walker, J.W. and J.A. Doyle. 1976. The basis of Angiosperm phylogeny: Palynology. *Ann. Mo. Bot. Gard*., 62: 666-723.

Wodehouse, R.P. (1935). *Pollen Grains.Their structure, identification and significance in science and medicine*.Hafner Publishing Co. New York and London.Pp-574.

Zahur, M. S., A. A. Bhutta and M. Ashraf (1978) Palynological studies of the Plants growing in Punjab. Seasonal variation in the frequencies of air-borne pollen and spores which cause allergies and asthma with special reference to “Central Punjab”. Pakistan Science Foundation (PSF). Final Research Report.

(http://en.wikipedia.org/2015)w/index.php?title=Archaeological_sub disciplines & oldid = 648829387).