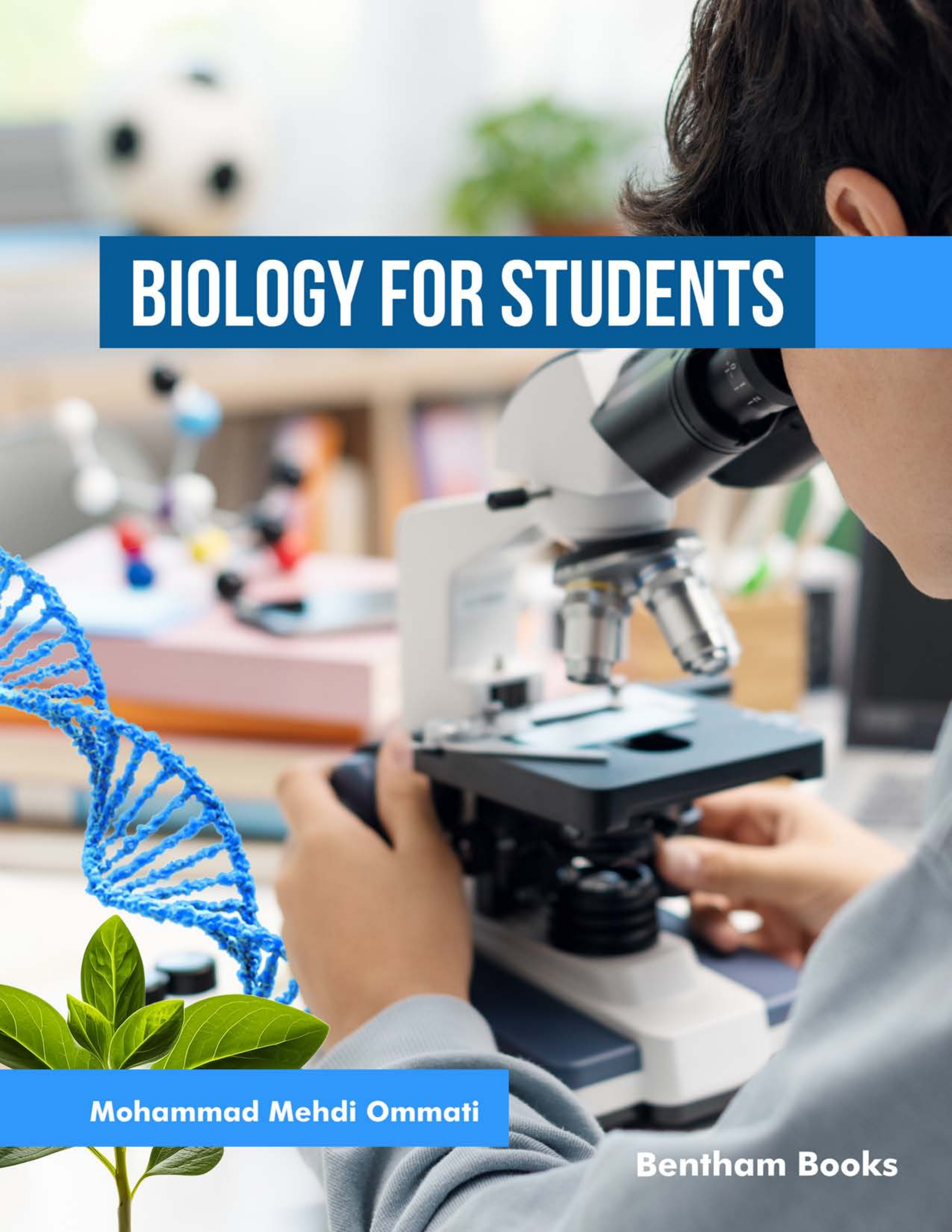
BIOLOGY FOR STUDENTS



Mohammad Mehdi Ommati

Bentham Books

Biology for Students

Authored by

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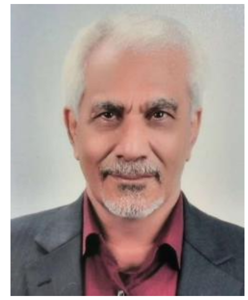
CONTENTS

FOREWORD I



Dr. Mohammad Mehdi Ommati obtained his M.Sc. and Ph.D. degrees under my supervision in the Department of Animal Science, College of Agriculture, Shiraz University, Shiraz, Iran. I was fortunate to guide such a talented and highly enthusiastic student in his desire to be trained in reproductive physiology. He was a top student amongst his peers throughout his graduate and undergraduate studies, simultaneously being chosen as a member of the National Elites Foundation (INEF), Iran. After successfully completing his sabbatical studies at Shanxi Agricultural University (SXAU), where he served as an assistant professor for about five years, Dr. Ommati joined the College of Animal Science and Technology at Henan University of Science and Technology, China, where he is currently an associate professor. Believing in quality research, Dr. Ommati has always carried out his research with utmost diligence and meticulously. This is borne by the fact that his research findings have been published in many reputable periodicals, and books, and presented at international scientific meetings, as well as receiving several international awards. He is currently on the editorial boards of several reputable journals and is also a visiting professor at the Shiraz University of Medical Sciences, Shiraz, Iran. His recent endeavor is the current book aimed at presenting the basic knowledge and current advancements in biological sciences, making it a useful source for students of general biology, animal science, medicine, and veterinary science. I believe he has all the essential qualities for writing this book. I wish him the best in pursuing his future scientific activities.

M. J. Zamiri
Department of Animal Science,
Shiraz University,
Shiraz, Iran

FOREWORD II

After obtaining his degree in Animal Sciences in 2009, Professor M. Mehdi Ommati initiated a successful career in reproductive physiology. He is a highly qualified researcher, teacher, editorial member, and reviewer in several journals, with very important research in reproductive toxicology. His articles have a high citation index, and he has received awards and recognition in countries such as China, India, Mexico, *etc*. Professor Ommati is an outstanding example of a young researcher who, with great effort, dedication, and commitment, has managed to position himself as one of the most outstanding researchers at an international level, with recognized prestige. His achievements reflect his great capabilities, making him a great motivation for new generation of young researchers. Despite his achievements, Professor Ommati continues to work with great dedication and enthusiasm, inspiring his undergraduate and graduate students to pursue distinguished careers in the biological sciences. In addition, Professor Ommati has always shown the best willingness and ability to establish international collaborations with his academic peers, with a great vision for research. This book is intended for postgraduate students, but it can also be useful for students in biology, animal sciences, and related medical disciplines as a support in their training and to reinforce their knowledge. The lecture of this book is enjoyed while reading and reinforces the basic knowledge that every biological sciences student should know, regardless of their specialization. The glossaries are very complete, the self-assessments reinforce what was learned in each lesson, and the reading comprehension is excellent. It is a very didactic book, an enormous effort to summarize the most important issues about molecules, cells, systems, organisms, and their habitat. My recognition to Professor Ommati for his contribution, not only to the field of reproductive toxicology but also as a generous and grateful teacher for the gifts he has received from God.

Socorro Retana-Márquez
Autonomous Metropolitan University
Mexico City, Mexico

PREFACE AND DEDICATION TO THE FIRST EDITION

The twenty-first century is an era of rapid advancements in biological sciences, marked by continuous breakthroughs in knowledge and innovative methodologies. To support the effective learning and application of this specialized knowledge, and in response to the increasing demand for creativity and innovation in higher education, I have designed this book. It is my hope that it will meet the needs of students and researchers around the world, fostering scientific exchange and collaboration across borders. Drawing inspiration from a range of international references, this book is presented to you, the global community of learners, educators, and researchers.

Though I am physically distant from my homeland, *Iran*, my thoughts and efforts remain firmly anchored in its academic community. Despite being far from home, I have always kept a close eye on the developments within my country, eager to support its students and educators. Even from this distance, I continue to dedicate myself to advancing knowledge through my publications—over 250 articles in prestigious global journals, several books, and chapters in international volumes. It is my sincere hope that these contributions, however modest they may seem, can support and inspire the next generation of scholars and students, both in Iran and beyond.

Exploring the Intricacies of Biology: From Cells to Systems and Beyond

In this book, efforts have been made to cover various topics such as modern biology, the use of new resources, and attention to new developments in the field of biology. As mentioned above, this book addresses aspects of writing research papers, submitting articles, searching for resources, and using scientific sources, somewhat tailored to the level of graduate students. This book can serve as a primary educational resource in universities for students in fields such as biology, animal sciences, veterinary medicine, and other related medical disciplines. It has also been designed to be a reference source for individuals working in fields like biology, agriculture, veterinary medicine, and other related areas.

This book is meticulously structured to appeal to students, educators, and biology enthusiasts. It provides a thorough exploration of fundamental and advanced concepts in four main sections. Each section includes several chapters, and each chapter comprises various chapters. At the end of the book, answers to exercises and a glossary are provided to support your learning further. This comprehensive text covers a variety of topics, including cell biology, genetics, animal biology, microbiology, biochemistry, biosystematics, principles and models of evolution, information science, and writing research papers.

Section One: Cell Biology - Structure, Function, and Division. In this section, I embark on a journey into the microscopic world of cells. **Chapter 1** provides an in-depth understanding of cellular components and their functions, while **Chapter Two** explores the complex processes of mitosis and meiosis, shedding light on cellular reproduction.

Section Two: Foundations of Genetics - History and Molecular Basis. This section traces the evolution of genetic science. **Chapter Three** takes you from ancient theories to modern genetic insights, and **Chapter Four** unravels the chemical and structural foundations of genes, offering a molecular perspective on genetic inheritance.

Section Three: The Diversity of Life - Development, Ecology, and Evolution. Here, I explore the vast diversity of life forms. **Chapter Five** narrates the story of life's evolution, **Chapter Six** examines the crucial role of fungi, and **Chapter Seven** guides you through animal development from gamete production to fertilization. **Chapter Eight** and **Chapter Nine** discuss the evolutionary forces and ecological dynamics shaping species diversity and population ecology.

Section Four: Advances in Biological Research and Information Systems. This section highlights modern advancements in biology. **Chapter Ten** focuses on cancer systems biology, providing insights into the complexities of cancer research, and **Chapter Eleven** explores the evolution and prospects of the ISI Web of Knowledge platform, a crucial tool for modern biological research.

Section Five: Navigating the Academic Manuscript Journey. This section is an invaluable resource for aspiring scholars. **Part A** offers a detailed guide to creating effective tables and figures, discusses the art of crafting a compelling discussion section, and provides tips for developing an effective manuscript draft and selecting the right journal. **Part B** outlines guidelines for manuscript submission, includes a submission checklist, and offers strategies for promoting your publication. **Parts C and D** delve into language editing services, while **Parts E to H** cover comprehensive referencing guides and provide additional information on major research databases like Elsevier ScienceDirect, ISI Web of Knowledge, and Springer Link.

Section Six: Answers. This section provides answers and explanations for all chapters from sections One to Eleven, serving as a crucial resource for self-assessment and deeper understanding.

Section Seven: Appendix. The appendix offers additional resources and references. It breaks down the fundamental components of medical English, focusing on roots, prefixes, and suffixes.

Main Features of this Book:

1. **Expanded Vocabulary and Specialized Terminology:** Critical biological terms and concepts are highlighted in **bold** throughout the chapters, providing immediate recognition for students. These terms are further clarified in the "*Vocabulary (Index of Terms)*" section, located just before the exercises and reading questions, ensuring that students can easily look up definitions while engaging with the content. This approach makes it easier for students to grasp new vocabulary in context.

2. **Development of Core Scientific Skills**: This book not only focuses on delivering biological content but also prioritizes the development of essential academic skills. Throughout the chapters, students are encouraged to read specialized articles, search for scientific information, and write scientific papers. These practices are integrated into the book to prepare students for advanced studies or professional endeavors in the biological sciences.

3. **Practical and Engaging Content**: The chapters cover a broad range of topics that are both practical and interesting, ensuring that the material is both informative and engaging. Students will encounter complex concepts presented in an accessible way, fostering a deeper understanding and sparking curiosity.

4. **Broad and Relevant Coverage**: The content spans diverse and contemporary areas of biology, from molecular biology to ecology, ensuring that students gain a holistic understanding of the discipline. Each chapter is designed to provide insights into the latest trends and advancements, empowering students to stay informed and adaptable in their future careers.

5. **The Brainstorm (Roadmap)**: The "Brainstorm" feature is a key component of each chapter, placed right after the keywords. It serves as a concise summary and guide to the core concepts, helping students gain a clearer understanding of the chapter’s objectives. By offering a structured outline of

the chapter's key points, this feature encourages active reading and enhances comprehension, allowing students to better focus on the most important aspects of the material. This roadmap is a unique feature that empowers students to approach complex topics with more confidence and clarity.

By integrating insights from the latest international textbooks, scientific journals, and online resources, this book ensures that students are exposed to the most current knowledge in the field. This educational approach broadens students' understanding of biology, while also fostering their self-learning capabilities, preparing them for success both in their studies and in their professional lives. I hope this book serves as an invaluable resource, helping students build a strong foundation in biology and equipping them for lifelong learning and scientific inquiry.

With deep respect and gratitude, I extend my appreciation to those who will enhance the value of this book with their feedback and suggestions. The sources used in this book are listed in the references (see the last pages: Sources and Additional Resources), and I am obliged to thank the authors of these works. Despite my utmost efforts to present a complete and accurate work, errors and omissions are inevitable. I kindly ask readers to share their opinions and criticisms with me *via* email (mehdi_ommati@outlook.com).

This book was finalized on May 2, 2024, coinciding with my 38^{th} birthday, in Luoyang, China. With the grace of the Almighty, this work has come to an end. I sincerely thank my wife, *Samira Sabouri*, who has always been a guide and a loyal friend with her wisdom and calm demeanor. I am deeply grateful to my son, *Adrian Ommati*, whose thirst for knowledge and big dreams have always been a source of inspiration for me, and to my newborn daughter, *Ariana Ommati*, whose pure and beautiful presence brings me peace and joy. May their presence always inspire me to create remarkable works. Finally, I dedicate this book to my dear parents, *Hossein Ommati* and *Akram Piroozfar*, and wish them health from afar.

The Path of Love and Sacrifice

As I the close this preface, I would like to share with you, dear readers, a couplet by the great Persian poet Hafez that beautifully captures the depth of love and sacrifice:

"The path of love is such that it has no borders, There is no solution but to give up one's life in it."

Hafez, a revered poet of Iran, speaks of the "path of love" in this couplet—a path without borders or an end, where the only way to reach the destination is through self-sacrifice and dedication. This concept holds true not only in literature but also in life and science. The love for knowledge and research is also an endless journey that requires relentless effort and sacrifice. This couplet, like a guiding light, reminds us that in the pursuit of knowledge and progress, we must never shy away from dedication and hard work. It is my hope that this book can serve as a companion on this path filled with love and sacrifice, aiding you every step of the way.

Mohammad Mehdi Ommati

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INTRODUCTION

Chapter Overview

Welcome to a comprehensive journey through the multifaceted world of biological sciences, where foundational principles meet cutting-edge research and technological advancements. This book is structured to guide readers through a broad spectrum of topics, from the molecular underpinnings of life to the intricate dynamics of ecosystems, and from evolutionary processes to the latest in cancer systems biology and bibliometrics. Each chapter stands as a testament to the complexity and beauty of life, offering insights that are both profound and practical.

In Chapter one, we delve into the core principles that form the bedrock of biological understanding. "Chapter One: Cell Biology - Structure, Function, and Division" begins with an exploration of the inner workings of cells. Here, we uncover the structure and function of cellular components, laying a foundation that is essential for understanding more complex biological processes. We then move on to the intricacies of cellular reproduction, examining the processes of mitosis and meiosis, which are fundamental to the continuity of life.

"*Chapter Two*: Foundations of Genetics - History and Molecular Basis" takes us through the historical evolution of genetic thought, from ancient notions to modern insights. We explore the chemical foundations and structural complexities of genes, providing a thorough understanding of how genetic information is encoded, transmitted, and expressed. This chapter sets the stage for comprehending the profound impact of genetics on all living organisms.

The third chapter, "The Diversity of Life - Development, Ecology, and Evolution," celebrates the vast array of life forms and their developmental processes. We trace life's story from its origins to the diverse forms we see today, including a detailed look at fungi, the mighty decomposers of the natural world. This chapter also covers the journey of animal development, from gamete production to fertilization, and the evolutionary forces that shape species diversity. Understanding population dynamics and ecology, we learn how species interact with their environments and each other, maintaining the delicate balance of ecosystems.

In "*Chapter Four*: Advances in Biological Research and Information Systems," we transition to the forefront of biological research. We explore the realm of cancer systems biology, where a systems-level approach is essential to understanding and treating this multifaceted disease. The evolution and future prospects of the ISI Web of Knowledge platform are discussed, highlighting its role in revolutionizing how we access and analyze scientific literature.

Section Five of the book, "Crafting the Scholar's Path - Navigating the Academic Manuscript Journey," serves as a practical guide for aspiring researchers. It offers step-by-step instructions for crafting effective Tables and Figures, developing a robust first draft of your manuscript, and selecting the appropriate journal for publication. Detailed guidelines for writing and submitting manuscripts, a journal submission checklist, and strategies for promoting your publication are also provided. Additionally, this section includes insights into language editing services and comprehensive guides on referencing, including the Harvard Referencing System and additional resources such as Elsevier ScienceDirect and Springer Link.

Section Seven, "*Answers*," provides comprehensive answers to the questions and tasks presented throughout the lessons, reinforcing key concepts and ensuring a deep understanding of the material.

Finally, *Section Eight*, *"Appendix*," includes valuable supplementary materials. The appendices feature a general vocabulary list and an exploration of the fundamental components of medical English vocabulary, including roots, prefixes, and suffixes. These resources are designed to support readers in mastering the specialized language of biology and medicine.

One core innovation of this book is the **Brainstorm (Roadmap)** feature, placed after each chapter’s keywords. This section offers a structured guide that highlights key ideas, connections to other topics, and the broader context, helping students navigate complex material and enhancing comprehension.

Book Objectives

This book aims to provide a thorough and accessible exploration of contemporary biological sciences. By bridging foundational knowledge with the latest research and technological developments, it offers readers a comprehensive understanding of the field. Whether you are a student, educator, researcher, or enthusiast, this book will serve as a valuable resource for deepening your knowledge and appreciation of the living world.

Conclusion

As we embark on this journey through the chapters, we invite you to delve into the intricacies of life, from the molecular to the ecological level. Each chapter not only imparts essential knowledge but also inspires curiosity and a deeper understanding of the natural world with vocabulary and reading sections that help the readers to extend their knowledge and skills. The interconnectedness of life is a central theme, highlighting the complexity and beauty of biological systems and the ever-evolving nature of scientific discovery.

Section 1

Cell Biology - Structure, Function, and Division

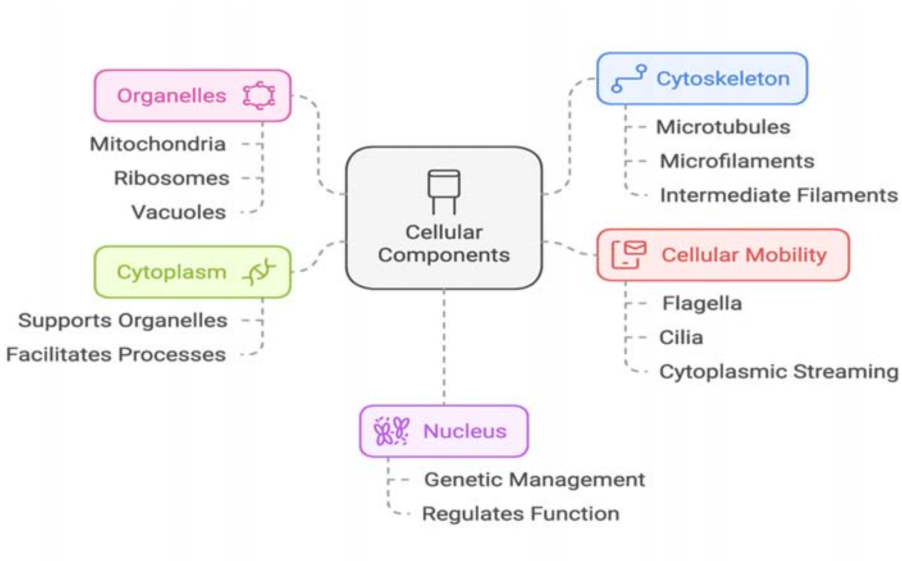
CHAPTER 1

Exploring the Inner Workings of Cells: Understanding the Structure and Function of Cellular Components

Abstract: This chapter delves into the complex and intricate structures within cells, focusing on the cytoplasm, nucleus, organelles, cytoskeleton, and cellular movements. It begins by examining the dynamic nature of the cytoplasm, highlighting its role as the mobile center of cellular activity. The nucleus is discussed as the central hub of genetic information, enclosed by the nuclear envelope. The chapter then explores various organelles, including plastids, ribosomes, lysosomes, vacuoles, mitochondria, the endoplasmic reticulum, and the Golgi complex, each contributing uniquely to cellular functions. The cytoskeleton's role in providing support and facilitating movement within the cell is analyzed, followed by an exploration of cellular mobility mechanisms, including chemotaxis, cilia, and flagella. Plant cell-specific processes like cytoplasmic streaming are also covered, providing a comprehensive overview of cellular components and their functions.

Keywords: Cytoplasm, Cytoskeleton, Nucleus, Organelles, Protein synthesis.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. CYTOPLASM: A DYNAMIC AND MOBILE CENTER

The cytoplasm exhibits numerous vital characteristics of life, functioning as a dynamic and mobile center within cells. This semifluid substance constitutes a significant proportion of cellular mass and is enclosed by the plasma membrane. Within the cytoplasm, organelles are suspended and supported structurally by the filamentous **cytoskeleton**. Additionally, the cytoplasmic fluid contains vital nutrients, soluble proteins, ions, and other key substances necessary for proper cellular function.

2. NUCLEUS: THE CELL'S CONTROL CENTER CONTAINING DNA

The **nucleus**, a prominent organelle in eukaryotic cells, serves as the central hub for genetic information. As the largest organelle, it stores the cell's genetic material, DNA, which is organized into chromosomes (in prokaryotic cells, genetic material is located in the nucleoid). The nucleus also contains one or more nucleoli, which play a critical role in ribosome biogenesis and are essential for cell division. The nucleus is enclosed by a porous double membrane called the **nuclear envelope**, which separates it from the cytoplasm. While small molecules can diffuse freely across this membrane, larger molecules like mRNA and ribosomal subunits require specialized nuclear pores for transport.

3. ORGANELLES: DEDICATED CELLULAR UNITS

Specialized units known as organelles are present in all eukaryotic cells, each performing specific roles essential for cellular activity. Organelles such as mitochondria, the Golgi apparatus, the endoplasmic reticulum, vacuoles, ribosomes, lysosomes, and plastids (in plant cells) are responsible for diverse functions (Fig. **1**).

3.1. Ribosomes and Protein Synthesis

Ribosomes, critical for protein production, can number from a few hundred to several thousand within a single cell. Composed of a large and a small subunit, ribosomes link amino acids to form proteins during translation, moving along mRNA strands. Groups of ribosomes can attach to a single mRNA strand, forming **polysomes**. Proteins synthesized in the cytoplasm are used within the cell, whereas those intended for export or membrane integration are produced in conjunction with the rough endoplasmic reticulum (RER).

3.2. Endoplasmic Reticulum: Protein and Lipid Synthesis

The **endoplasmic reticulum (ER)** is a complex system of interconnected sacs, tubules, and vesicles that occurs in two forms: rough (RER) and smooth (SER). The RER, studded with ribosomes, specializes in protein synthesis and transport, while the SER focuses on lipid synthesis and detoxification of harmful substances. Additionally, the RER is involved in the formation of the nuclear envelope following cell division.

Transport vesicles carry molecules from the ER to the **Golgi apparatus**, where they are further modified and packaged for export or intracellular distribution.

3.3.Vacuoles and Lysosomes: Cellular Storage and Recycling

Vacuoles, which appear as empty sacs under a microscope, are filled with fluid and dissolved substances. In plant cells, large central vacuoles store water, nutrients, and waste products, while in animal cells, vacuoles are involved in processes such as **phagocytosis** (engulfing particles) and **pinocytosis** (cellular intake of liquids).

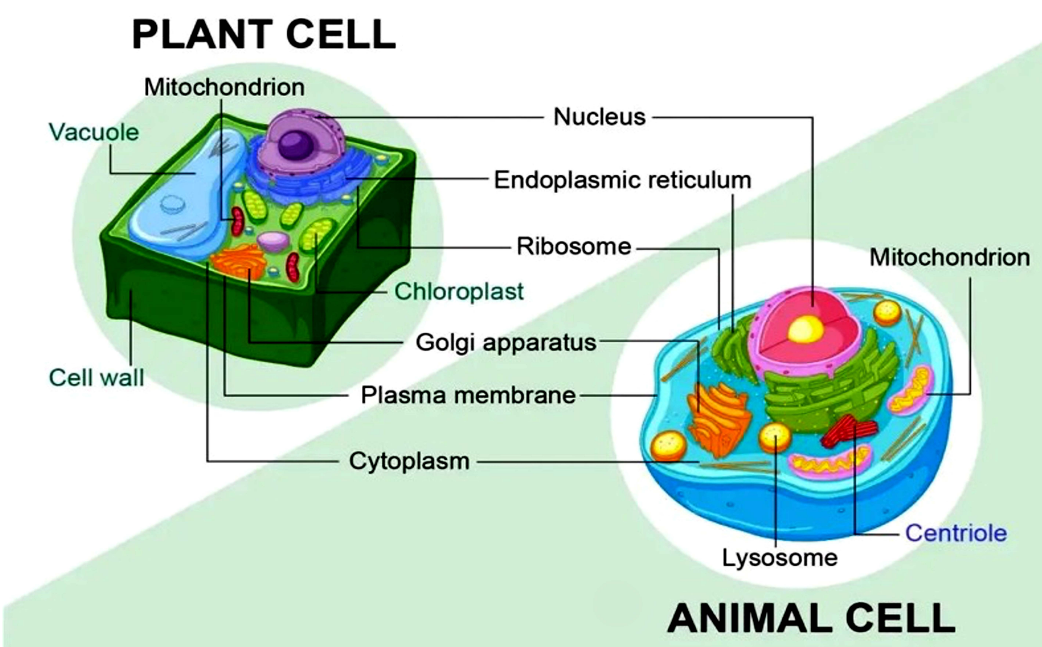


Fig. (1). Structural and functional differences between plant and animal cells.

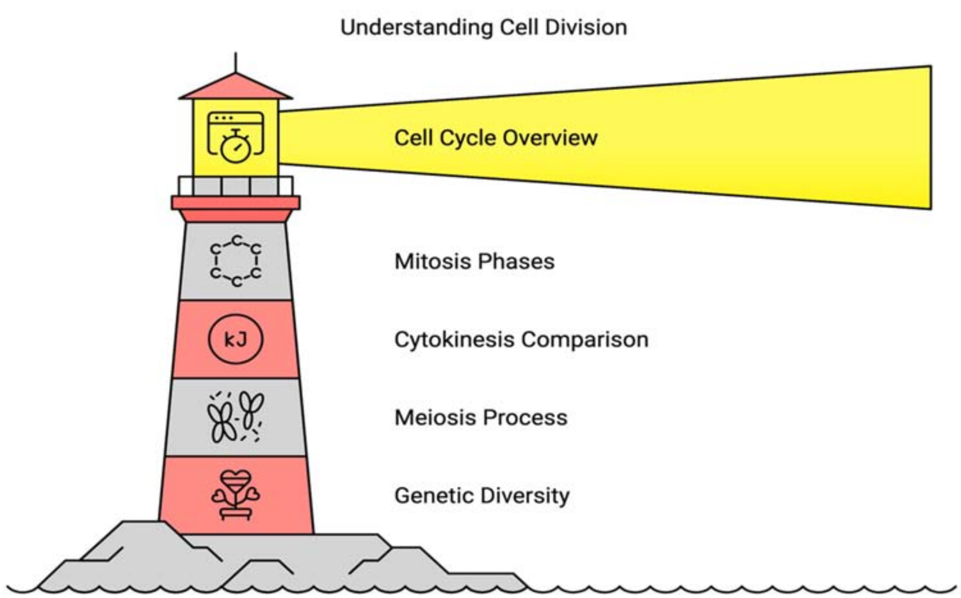
CHAPTER 2

Cell Division (Cellular Reproduction): Exploring the Intricacies of Mitosis and Meiosis

Abstract: This chapter provides a detailed examination of the processes of mitosis and meiosis, crucial mechanisms in cellular reproduction. It begins with an overview of the nucleus and chromosomes, emphasizing their structure and function within the cell. The cell cycle is then dissected, highlighting its phasses and their significance in preparing a cell for division. Mitosis is explored through its phases—prophase, metaphase, anaphase, and telophase—focusing on the segregation of genetic material and the role of spindle microtubules. The chapter proceeds to discuss cytokinesis, comparing its occurrence in animal and plant cells. Meiosis is analyzed next, elucidating its role in sexual reproduction and the genetic diversity it fosters through crossing over and the production of haploid cells. The final section contrasts asexual and sexual reproduction, underscoring their respective advantages and disadvantages in terms of genetic diversity and adaptability.

Keywords: Cell cycle, Chromosomes, Cytokinesis, Meiosis, Mitosis.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. THE NUCLEUS AND CHROMOSOMES

The nucleus functions as the central repository of genetic information in a cell. Within the nucleus are chromosomes, composed of tightly coiled DNA strands interwoven with associated proteins. These proteins, known as **histones**, enable the DNA molecule to form bead-like complexes called **nucleosomes**. Further coiling and supercoiling result in densely packed structures known as chromosomes. **Chromatin**, the substance that constitutes chromosomes, is made up of long DNA strands bound with histones and nonhistone proteins.

A **karyotype** is a visual representation of an organism's chromosomes in their condensed and coiled state. It reveals that, apart from the sex chromosomes, chromosomes are organized in **homologous pairs**. Chromosomes other than sex chromosomes are referred to as autosomes. Cells containing two complete sets of parental chromosomes are called **diploid**, whereas those with only one set are **haploid**.

2. THE CELL CYCLE

The cell cycle describes the sequential events of cellular growth, preparation for division, and, eventually, division to produce two daughter cells, perpetuating the cycle. This cycle confers a form of immortality on single-celled organisms. In multicellular organisms, however, certain cell types, such as those in animal muscle and nerve tissues, slow down or exit the cycle entirely.

The conventional cell cycle comprises four distinct phases (Fig. **1**). The first three phases, collectively known as **interphase**, include:

- **G_1 phase**, characterized by normal metabolic activities;
- **S phase**, during which DNA replication and the synthesis of essential biological molecules occur; and
- **G_2 phase**, a short period of further growth and preparation for division.

The fourth phase, the M phase, encompasses mitosis, where replicated chromosomes condense and segregate, leading to cell division. The regulation of the cell cycle depends on the properties of the cytoplasm and external factors, such as stimulatory or inhibitory agents like **chalones**.

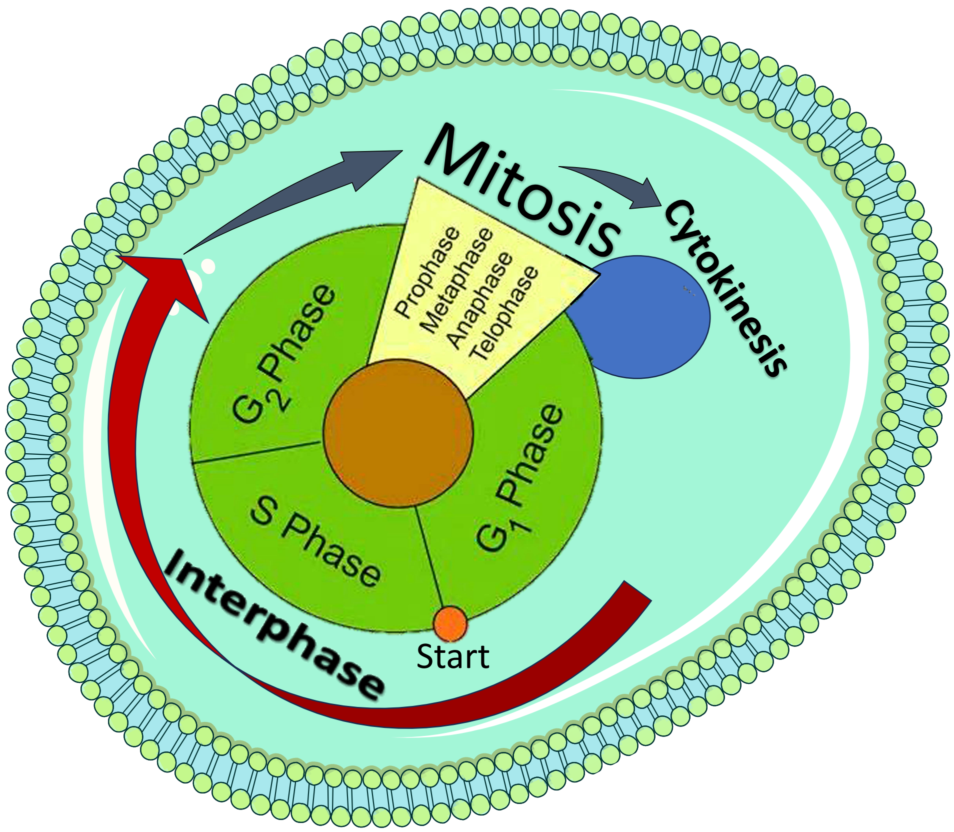


Fig. (1). Cell Cycle Stages: From Prophase to Cytokinesis.

3. MITOSIS: SEGREGATING THE GENETIC MATERIAL

Mitosis is divided into four distinct phases (Fig. **2**):

- **Prophase:** Chromosomes condense, each consisting of two highly compacted **chromatids** connected at a **centromere**.
- **Metaphase:** Chromosomes align along the spindle apparatus on the **metaphase plate**, a plane perpendicular to the **spindle** fibers.
- **Anaphase:** Chromatids of each chromosome separate and migrate toward opposite poles of the cell.
- **Telophase:** Nuclear envelopes form around the segregated chromosomes, and the cytoplasm divides.

Section 2

Foundations of Genetics - History and Molecular Basis

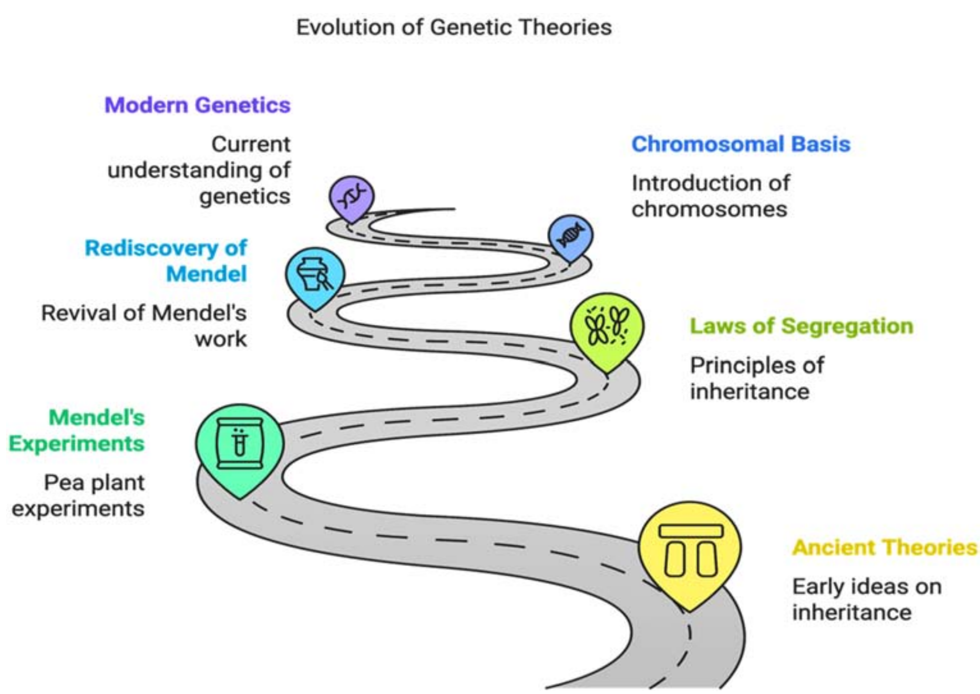
CHAPTER 3

From Ancient Notions to Modern Insights: Unraveling the Foundations of Genetics

Abstract: This chapter traces the historical evolution of genetic theories from ancient concepts to contemporary understanding. It begins with early theories of inheritance, including Hippocrates' pangenesis and Weismann's germ plasm theory. The focus then shifts to Gregor Mendel, whose experiments with pea plants laid the groundwork for modern genetics. Mendel's laws of segregation and independent assortment are detailed, along with his methods and findings. The chapter concludes by discussing the rediscovery of Mendel's work and the chromosomal basis of heredity, highlighting contributions from scientists such as Sutton, Boveri, and Morgan. This comprehensive overview elucidates the foundational principles of genetics and their historical development.

Keywords: Alleles, Chromosomes, Inheritance, Mendel, Segregation.

UNDERSTANDING THE CHAPTER’S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. EARLY THEORIES OF INHERITANCE

Early theories of inheritance, such as Hippocrates' **Pangenesis** and August Weismann's **Germ Plasm Theory**, laid crucial groundwork for understanding heredity. August Weismann (1834 – 1914), a German biologist, conducted experiments with mice and proposed that hereditary information is transmitted exclusively through gametes. His Germ Plasm Theory suggested that "germ cells" (sperm and egg cells) carry hereditary material, while somatic cells do not. This was a significant departure from earlier notions, like the blending hypothesis, which posited that traits from both parents combine in offspring, resulting in a loss of distinct characteristics. Weismann demonstrated that acquired traits, such as the removal of a mouse's tail, do not influence hereditary traits passed to offspring. His findings refuted the concept of inheritance of acquired traits, strengthening the idea that germ cells are the sole carriers of genetic information.

Pangenesis, attributed to ancient Greek philosopher Democritus (c. 460[1] – c. 370[2] BCE), proposed that particles from different parts of the body (pangenes) contribute to the formation of offspring. While Hippocrates (c. 460 – c. 375 BCE), often referred to as the "Father of Medicine," made notable contributions to medical science, there is no direct evidence to suggest he explicitly rejected pangenesis. It is important to note that pangenesis was later disproven by scientific discoveries, such as Gregor Mendel's (1822 – 1884) groundbreaking work in genetics, which provided a more accurate understanding of heredity.

On the other hand, Hippocrates, often referred to as the "Father of Medicine," lived in ancient Greece and made significant contributions to medical science. While Hippocrates made many observations about health and disease, there is no direct evidence to suggest that he specifically rejected the idea of pangenesis. Pangenesis was a theory proposed by the ancient Greek philosopher Democritus, who lived before Hippocrates. According to pangenesis, particles called pangenes from different parts of the body contribute to the formation of offspring. However, this theory was later refuted by later scientific discoveries, such as Mendel's work on genetics in the 19th century, which provided a more accurate understanding of heredity. Therefore, it is unlikely that Hippocrates explicitly rejected pangenesis since it was not a widely held or established concept during his time.

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[1] c. 460 BCE means approximately 460 years before the Common Era (or before the traditional birth of Christ).

[2] c. 370 BCE means approximately 370 years before the Common Era.

2. GREGOR MENDEL: PIONEER OF GENETIC INQUIRY

Gregor Mendel, often regarded as the "Father of Genetics," revolutionized our understanding of inheritance. As an Augustinian monk in Brünn, Austria, Mendel combined his mathematical training with a keen interest in natural science. His experiments, designed to investigate the particulate nature of heredity, challenged the prevailing blending hypothesis. Despite the groundbreaking nature of his findings, Mendel's work was not fully appreciated until decades after his death.

3. MENDEL'S SEMINAL INVESTIGATIONS

Mendel's pioneering investigations focused on plant breeding experiments with the garden pea, a species characterized by self-fertilization and true breeding. Selecting seven distinct traits, such as seed color and plant height, each with clear binary outcomes, Mendel meticulously recorded progeny characteristics across two generations to challenge the prevailing blending theory (Fig. **1**).

In his experiments, Mendel consistently observed **dominant** and recessive traits, with a 3:1 ratio of dominant to **recessive** traits in the second filial (F2) generation. Mendel proposed that organisms inherit two hereditary units for each trait, one from each parent. These units, now known as **alleles**, are alternative forms of genes—the basic units of heredity. He clarified that organisms with identical alleles (*e.g.*, TT or tt) are **homozygous**, while those with differing alleles (*e.g.*, Tt) are **heterozygous**. Importantly, dominant alleles express their traits in the phenotype, while recessive alleles do not manifest unless paired together.

In heterozygous organisms, the dominant allele typically manifests in the **phenotype**, representing its physical appearance, while the **genotype** encompasses both the dominant and recessive alleles, reflecting the genetic composition. To visualize the possible allele pairings from a genetic cross, Mendel employed the **Punnett square**, which illustrates the potential genotypes and phenotypes of the offspring. Mendel's experiments on dominant and recessive inheritance led to his first law, the **law of segregation**. This principle states that each organism inherits one allele from each parent, forming an allele pair, and during meiosis, these alleles separate into different gametes. Mendel performed **test crosses** to confirm his theory, mating organisms of unknown genotype with those homozygous recessives for the trait in question, observing the ratio of dominant phenotypes in the offspring to determine the genotype of the unknown parent.

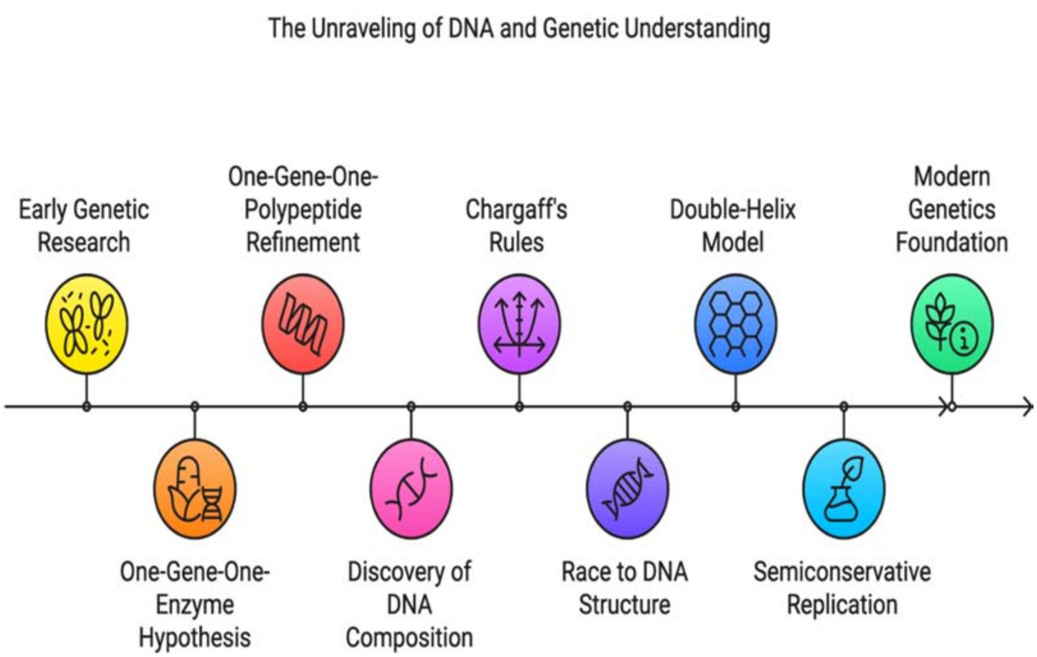
CHAPTER 4

The Chemical Foundations and Structural Unveiling of the Gene

Abstract: This chapter delves into the chemical and structural basis of genes, starting with early investigations that linked genes to enzyme activity. It highlights significant milestones, such as Beadle and Tatum's one-gene-one-enzyme hypothesis and Linus Pauling's refinement to one-gene-one-polypeptide. The chapter also explores the discovery of DNA's chemical composition, emphasizing contributions from scientists like Miescher, Avery, and Levene. Chargaff's rules and the race to unveil DNA's double-helix structure by Watson and Crick are discussed. Finally, it explains the mechanisms of DNA replication, emphasizing the semiconservative model and the roles of leading and lagging strands.

Keywords: Base pairing, DNA replication, DNA structure, Gene expression, Nucleic acids.

UNDERSTANDING THE CHAPTER’S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. EXPLORING THE CHEMICAL BASIS OF GENETIC EXPRESSION

Sir Archibald Garrod emerged as a pioneering figure in linking genes to phenotypic traits, particularly through his early work on alkaptonuria, which suggested a correlation between genes and enzyme activity. Building on Garrod's insights, Beadle and Ephrussi conducted seminal studies demonstrating the association between specific genes and biosynthetic processes governing eye pigmentation in *Drosophila melanogaster*. Subsequently, Beadle and Tatum's landmark investigations into mutation effects in *Neurospora crassa* led to the formulation and exploration of the **one-gene-one-enzyme hypothesis**, positing a direct correspondence between individual genes and specific enzymatic functions. Their groundbreaking research laid the groundwork for subsequent inquiries into the intricate mechanisms through which enzymes regulate complex metabolic pathways. Furthermore, Linus Pauling's investigations into the role of hemoglobin in sickle cell anemia contributed to refining the initial hypothesis, culminating in the proposition of the **one-gene-one-polypeptide paradigm (hypothesis)**.

Neurospora crassa, a model organism widely employed in genetic research, particularly in the study of mutants exhibiting auxotrophic traits, has played a pivotal role in elucidating genetic pathways and metabolic processes.

2. PURSUING THE CHEMICAL COMPOSITION AND STRUCTURAL CHARACTERISTICS OF NUCLEIC ACIDS

Johann Miescher’s isolation of nucleic acids in 1871 was a pivotal step in unraveling the molecular constituents of chromosomes, further advanced by Feulgen’s red-staining technique for chromosomal visualization. Frederick Griffith's seminal experiments with pneumococcal strains underscored the transformative potential of unidentified bacterial material in phenotypic alteration, laying the groundwork for subsequent revelations regarding the nature of this transformative substance. Building upon Griffith's findings, Avery, MacLeod, and McCarty definitively identified this elusive material as deoxyribonucleic acid (DNA) in the 1940s. Concurrently, P.A. Levene's elucidation of DNA's structural components, comprising four nitrogenous bases—adenine, guanine, cytosine, and thymine—each bound to a sugar-phosphate backbone termed nucleotides, provided critical insights into DNA's molecular architecture. Martha Chase and Alfred Hershey's pivotal experiments (in the early 1950s) with Escherichia coli decisively resolved the debate regarding the carrier of genetic information, affirming DNA's central role in heredity. The structural elucidation of DNA revealed a double-helix configuration, wherein nucleotide base pairs—adenine-thymine and cytosine-guanine—are interconnected by hydrogen bonds, thereby establishing the foundation for genetic encoding within the DNA molecule. Within the structure of each DNA nucleotide lies a fundamental composition consisting of a pentose sugar (a five-carbon sugar), specifically deoxyribose, which is covalently linked to one of four nitrogenous bases: **adenine**, **guanine**, **cytosine**, or **thymine**. Notably, adenine and guanine have a distinctive molecular structure with double-ring structures, classifying them as **purines**, while cytosine and thymine have single-ring structures, categorizing them as **pyrimidines**. The amalgamation of a nitrogenous base with the deoxyribose sugar forms a foundational unit termed a **nucleoside**, representing the fundamental building block of DNA's intricate molecular framework. Chargaff's rules delineate two fundamental observations regarding the composition of DNA. Firstly, they stipulate a consistent parity between the quantities of adenine and thymine bases, as well as between cytosine and guanine bases, within the DNA molecule. Specifically, the principle asserts that the abundance of adenine is equivalent to that of thymine, while the quantity of cytosine matches that of guanine, thereby maintaining a balanced nucleotide composition critical for DNA stability and function.

Secondly, Chargaff's rules highlight interspecies variations in the ratios of adenine-thymine (A-T) and cytosine-guanine (C-G) base pairs. These relative proportions can differ across diverse organisms, reflecting the species-specific genomic signatures encoded within the DNA sequences. Thus, while the underlying principles of base pairing remain consistent, the precise ratios of complementary base pairs may exhibit variability, underscoring the adaptability and evolutionary divergence inherent in DNA structures among different biological taxa.

3. THE RACE FOR UNRAVELING THE MOLECULAR STRUCTURE OF DNA

In the quest to elucidate DNA's structure, researchers in the late 1940s and early 1950s drew on a confluence of scientific insights, including Chargaff's observations, Levene's biochemical analyses, and the pivotal **X-ray diffraction** images captured by Rosalind Franklin and Maurice Wilkins. These images provided crucial evidence for DNA’s helical structure, informing Watson and Crick’s double-helix model. Drawing on these multidisciplinary inputs, Watson and Crick proposed the iconic **double-helix model** of DNA, which described a helical framework consisting of intertwined sugar-phosphate backbones and nucleotide base pairs. Central to their model was the concept of complementary base pairing—adenine with thymine (A-T), and cytosine with guanine (C-G)—mediated by hydrogen bonds. Moreover, Watson and Crick postulated the sequence-specific

Section 3

The Diversity of Life - Development, Ecology, and Evolution

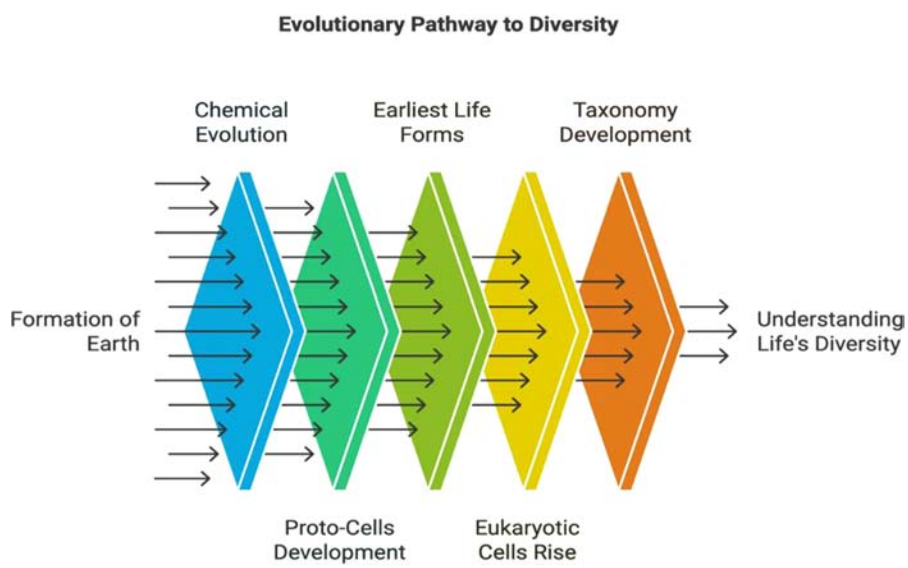
CHAPTER 5

Life's Story: From Start to Diversity

Abstract: The origins of life on Earth are believed to have occurred after the planet's formation, around 4.6 billion years ago. Life itself is thought to have emerged approximately 3.8 to 4 billion years ago, following a period of chemical evolution that led to the formation of organic molecules and proto-cells. This transition to life is marked by the development of complex molecular structures, including the role of RNA as a likely precursor to DNA in early life forms. As Earth's conditions became more conducive to life, cellular organisms evolved, starting with prokaryotic life and later giving rise to eukaryotes. Over time, life diversified into distinct domains, with advances in molecular biology leading to the adoption of the three-domain system—Bacteria, Archaea, and Eukarya—replacing the older five-kingdom classification system. This modern framework reflects our current understanding of the evolutionary relationships among life forms. The development of taxonomy, with its hierarchical structure, continues to evolve as we refine our understanding of the interconnectedness and evolutionary history of all living organisms.

Keywords: Chemical evolution, Eukaryotic cells, Phylogenetic trees, Proto-cells, Taxonomy.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. HOME FOR LIFE: THE BIRTH OF OUR SOLAR SYSTEM AND PLANET EARTH

The story of life's origins begins after the formation of Earth, approximately 4.6 billion years ago, when conditions became suitable for life to emerge. This narrative starts with a colossal event known as the **Big Bang**, marking the inception of our universe around 13.8 billion years ago. About 5 billion years ago, the sun, the centerpiece of our solar system, began to form from a vast cloud of primordial matter. Following this, planets like Earth began to emerge through a process known as accretion, around 4.6 billion years ago. Earth itself is characterized by distinct layers, comprising a solid **crust**, a semi-solid **mantle**, and a predominantly molten **core** with a solid inner region. Crucial aspects such as Earth's size, temperature, composition, and orbital distance from the sun played pivotal roles in shaping its suitability for life.

Scientists propose that life originated on early Earth through a process known as chemical evolution, where simple non-living molecules gradually became more complex, eventually giving rise to the first forms of life. This likely occurred around 3.8 to 4 billion years ago, after billions of years of chemical processes, thus ushering in the dawn of biological complexity.

2. THE RISE OF LIFE: FROM CHEMICAL BUILDING BLOCKS TO PROTO-CELLS

The journey towards life's emergence is marked by the intricate dance of organic and biological molecules on the primordial stage of our planet. Laboratory experiments, inspired by the conditions of early Earth, have yielded valuable insights into the pre-life stages of chemical organization. Pioneering endeavors, notably the experiments of Miller and Urey, have demonstrated the formation of organic monomers like amino acids, simple sugars, and nucleic acid bases under simulated early Earth conditions. These fundamental building blocks set the stage for the subsequent assembly of larger polymers such as **proteinoids** and nucleic acids, potentially on clay or rock surfaces.

Studies have unveiled three primary types of organic molecular aggregates that could have played pivotal roles in the transition from non-life to life. Aleksandr Oparin's research yielded polymer-rich droplets known as **coacervates**, and Sidney Fox's experiments produced proteinoid microspheres from amino acids and water mixtures, and **liposomes**, spherical lipid bilayers, formed from phospholipids. It is hypothesized that one or more of these aggregates may have served as precursors to the earliest cellular structures.

As the narrative of life's emergence unfolds, attention turns to the development of RNA and DNA as indispensable informational molecules. RNA, with its ability to spontaneously form under conditions akin to those of early Earth, is postulated to have been the initial bearer of biological information. The discovery of RNA ribozymes, molecules capable of catalytic activity akin to enzymes, suggests a potential mechanism for assembling new RNAs from early nucleotides. These catalytic RNAs might have also facilitated crucial processes like RNA-mediated exchanges, akin to primitive forms of genetic recombination.

Beyond the realm of informational molecules, the journey towards cellular life involves the formation of lipid-protein surface layers, the establishment of the genetic code, the sequestering of RNA or DNA within cell-like structures, and the development of metabolic pathways. Each of these milestones represents a crucial step in the complex tapestry of life's evolution from simple molecular aggregates to the dawn of cellular complexity.

3. EARLY LIFE FORMS: TRACING THE ORIGIN OF CELLS

The quest to uncover the earliest traces of cellular life leads us to rocks dating back approximately 3.5 billion years, where we find fossils that may hold the secrets of life's humble beginnings. These ancient relics suggest that anaerobic heterotrophs were the first cells to populate our planet, with autotrophs emerging later and playing a critical role in shaping Earth's atmosphere. These pioneering autotrophs, capable of self-nourishment, played a pivotal role in shaping Earth's atmosphere by releasing oxygen as a metabolic by-product. This oxygenation led to the formation of the **ozone layer**, a protective shield against harmful ultraviolet radiation, allowing life to flourish in shallow waters and on land surfaces.

The rise in atmospheric oxygen levels also catalyzed the evolution of aerobic cells and ushered in the era of cellular respiration, marking the onset of the global carbon cycle. As oxygen levels increased, aerobic cells thrived, paving the way for diverse metabolic pathways and ecological niches to emerge. This transformative phase in Earth's history laid the groundwork for the intricate web of life that we observe today.

While the earliest cells were exclusively prokaryotic in nature, approximately 1.5 billion years ago, a significant evolutionary leap occurred with the appearance of

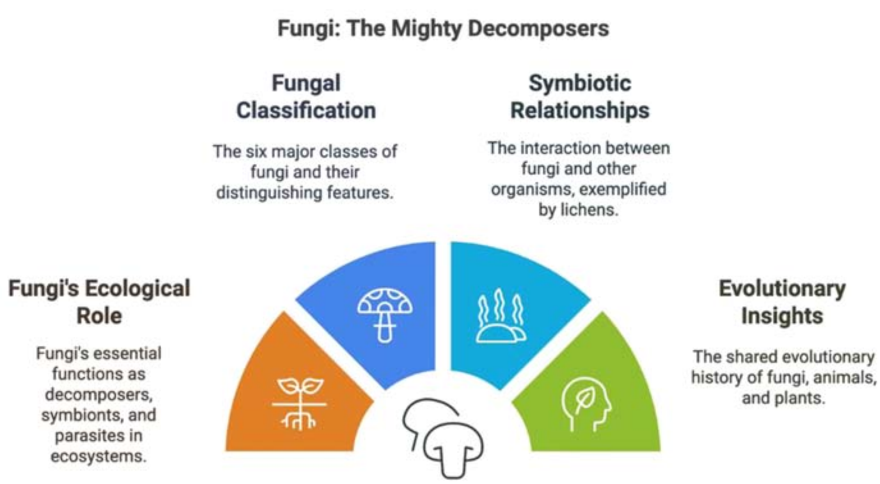
CHAPTER 6

Fungi: The Mighty Decomposers

Abstract: Fungi, a diverse group of approximately 175,000 species, play critical roles in ecosystems as decomposers, parasites, and symbiotic partners. They exhibit a fundamental body structure composed of hyphae, which form a mycelium network facilitating nutrient absorption and growth. Hyphae may be septate or coenocytic, and fungi reproduce *via* spores, categorized as dispersal or survival spores. Fungi classification involves distinguishing between lower fungi (Chytridiomycetes, Oomycetes, Zygomycetes) and higher fungi (Ascomycetes, Basidiomycetes, Deuteromycetes), with each class exhibiting unique reproductive and morphological traits. Lichens represent a notable symbiotic relationship between fungi and algae, demonstrating resilience and nutrient acquisition abilities. Evolutionary insights suggest that fungi, as eukaryotes, share a common ancestor with animals and plants, highlighting their shared evolutionary history. While fungi and prokaryotes share some basic cellular features, fungi evolved within the eukaryotic lineage, making them more closely related to animals and plants than to prokaryotes.

Keywords: Fungal classification, Hyphae, Lichens, Mycelium, Spore reproduction.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. FUNGI'S ATTRIBUTES

The vast array of fungi, comprising around 175,000 species, includes some of nature's simplest multicellular organisms. Exhibiting diverse lifestyles, fungi can function as **saprobes**, breaking down dead organic matter; they can adopt parasitic tendencies, drawing nutrients from living hosts; or they may form symbiotic relationships with algae or higher plant roots. Despite these varied roles, all fungi share a common trait: extracellular digestion. They secrete enzymes to break down organic material and then absorb the resulting nutrients.

Most fungi have a fundamental body structure consisting of a primary thallus made up of threadlike filaments called **hyphae** (Fig. **1**). The cell walls of hyphae typically contain chitin. In some species, hyphae specialize in forming rhizoids, which serve as root-like anchors, or transform into feeding structures known as **haustoria**. Additionally, hyphae can be either **septate** or non-septate, with septate hyphae having cross walls that divide individual cells, each containing at least one nucleus. Lower fungi exhibit a coenocytic structure, where the hyphae are a continuous mass of cytoplasm containing multiple nuclei.

Hyphae proliferate and branch out, forming a filamentous network called a **mycelium** (Fig. **1**). Digestion and nutrient absorption occur at the tips of each hypha, while new hyphae continue to form, enabling rapid fungal growth. This growth relies on mitosis and the rapid production of cytoplasm, with fungal mitosis occurring exclusively within the nucleus. Hyphae from genetically distinct organisms may fuse, resulting in a **heterokaryon**—one cytoplasm housing different nuclei.

As immobile heterotrophs, fungi must locate new nutrient sources over time. This critical function is carried out by spores, the reproductive entities of fungi. Spores are often borne on aerial hyphae and dispersed into the air. They can be either haploid or diploid, depending on the species. Spores fall into two primary categories: dispersal spores, which are short-lived and produced abundantly during active fungal growth, and survival spores, produced in smaller quantities during periods of environmental stress in the fungus's life cycle.

2. FUNGI CLASSIFICATION

Classifying fungi based on their evolutionary relationships can be challenging, as it requires an understanding of both molecular and morphological traits. Traditionally, fungi have been categorized by their morphology, reproductive methods, and spore production modes. Within the kingdom of *Fungi* (or *Mycota*), six primary classes are recognized.

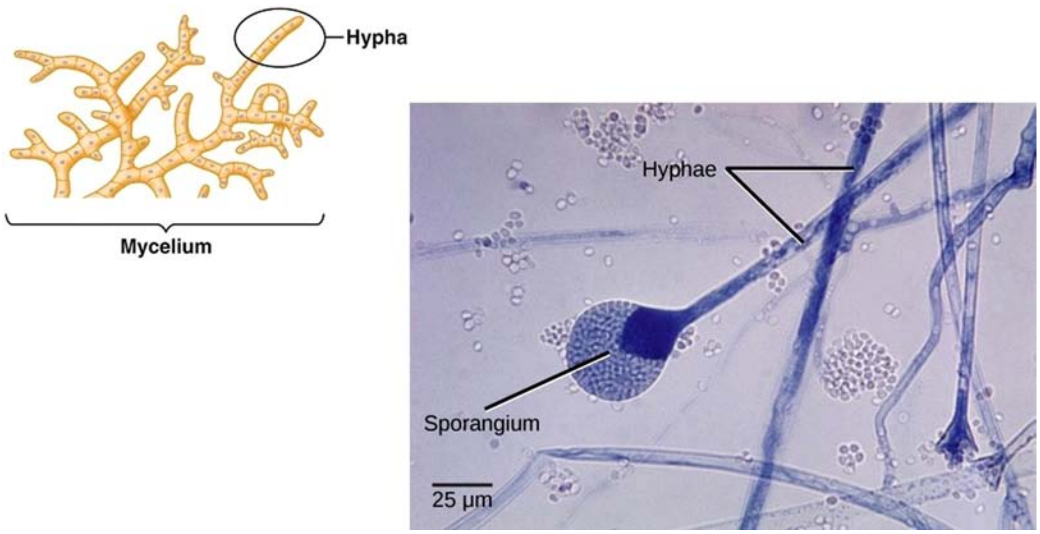


Fig. (1). Fungal Mycelia, Hyphae, and Sporangiospores. The right panel (the bright light micrograph) illustrates the release of spores from sporangium at the ends of hyphae called sporangiophores.

Lower fungi include *Chytridiomycetes*, *Oomycetes*, and *Zygomycetes*. These groups lack septate hyphae and are often coenocytic, relying primarily on asexual spore formation. Among these, only *Oomycetes* typically exhibit a diploid vegetative state. Both *Oomycetes* and *Chytridiomycetes* (commonly referred to as water molds) produce motile, flagellated spores in sporangia and gametes in **gametangia**. *Oomycetes* are distinctive for their large, immobile egg cells. Due to their unique characteristics, some biologists consider classifying these groups as protists rather than fungi. *Zygomycetes* resemble the previous two but produce nonmotile spores. Many *Zygomycetes* are terrestrial and some establish mycorrhizal relationships with plant roots.

Higher fungi include ***Ascomycetes***, the largest class, where most members function as saprobes or parasites. Asexual reproduction produces **conidia**, which form at the tips of specialized aerial hyphae. During the sexual cycle, hyphae from different mating strains fuse, resulting in ascospores that are formed inside small, sac-like structures called asci. Fruiting bodies emerge from clusters of asci. Well-known ascomycetes include truffles, yeasts, and species of *Penicillium*.

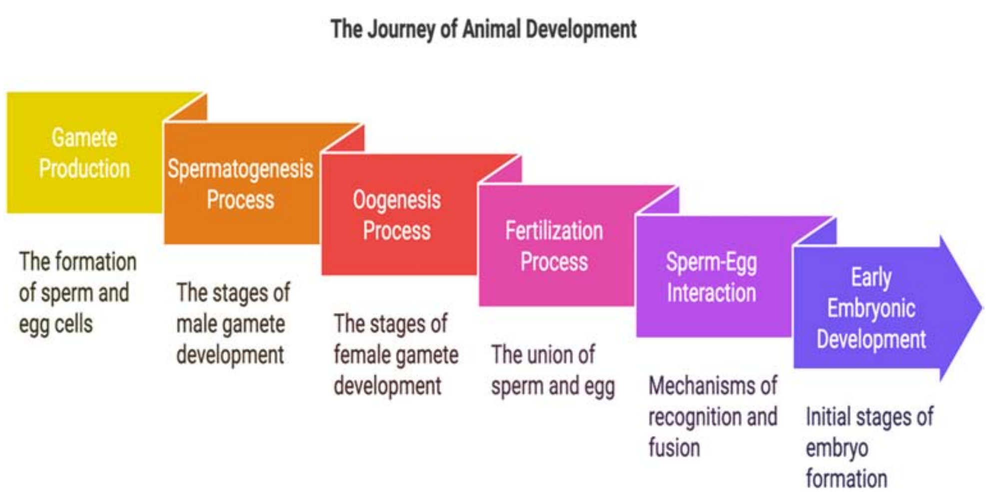
CHAPTER 7

The Journey of Animal Development: From Gamete Production to Fertilization

Abstract: Animal development begins with the production of gametes through spermatogenesis and oogenesis, processes crucial for sexual reproduction. Spermatogenesis produces sperm in the testes, characterized by its tail and acrosome, while oogenesis forms eggs in the ovaries, which vary in size and complexity. Fertilization, whether internal or external, initiates development by merging male and female gametes to form a diploid zygote. The subsequent cleavage stage involves rapid cell division, forming a blastula, and setting the stage for gastrulation, where the embryo develops distinct germ layers. Organogenesis follows, leading to the specialization of cells into functional tissues and organs. In land vertebrates, extraembryonic membranes protect and nourish the embryo, while growth dynamics are driven by cellular proliferation rather than individual cell enlargement. Aging concludes the developmental journey, characterized by a structural and functional decline over time.

Keywords: Cleavage, Fertilization, Gametogenesis, Gastrulation, Organogenesis.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. GENERATING SPERM AND EGGS

In organisms that reproduce sexually, males and females produce specialized sex cells called gametes, which are **sperms** in males and eggs (**ova**) in females. These processes in males and females are called gametogenesis, including spermatogenesis in males and oogenesis in females (Fig. **1**). **Spermatogenesis**, the process of sperm production, occurs in the testes, originating from gonial cells within seminiferous tubules. Through mitosis and meiosis, spermatocytes develop into haploid spermatids, each equipped with a nucleus containing chromosomes, a tail, and an acrosome housing enzymes crucial for fertilization. Conversely, **oogenesis**, the formation of eggs, begins with oogonia in the **ovaries**, undergoing a series of meiotic divisions after maturation and ovulation, resulting in the development of a fertilizable egg.

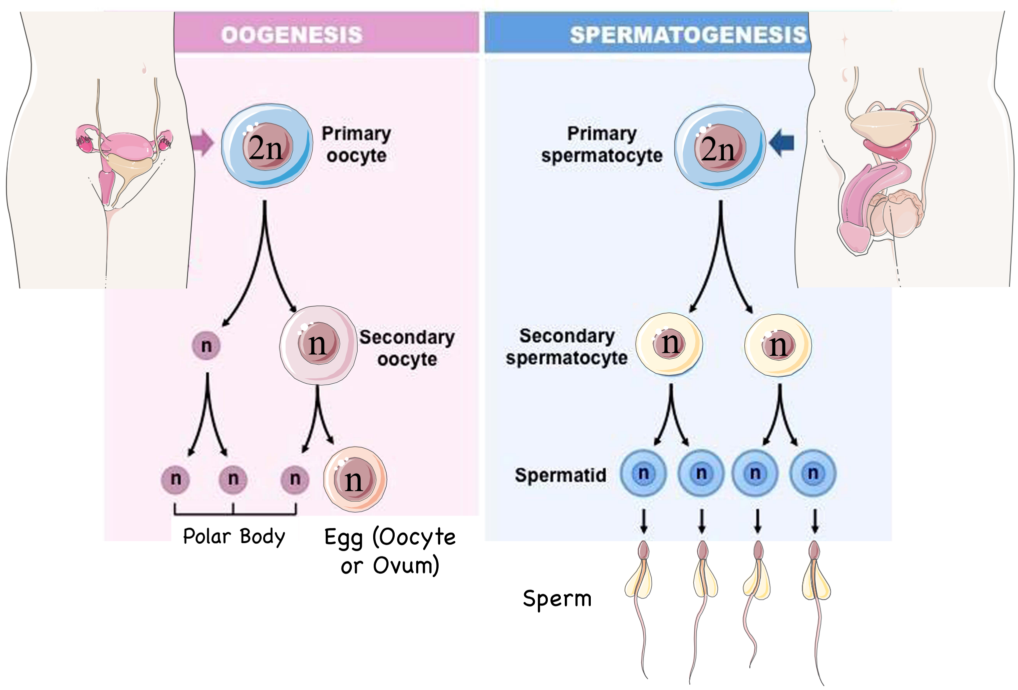


Fig. (1). Gametogenesis (Spermatogenesis and Oogenesis).

Eggs exhibit considerable variation in size and complexity across species and are typically enveloped by supporting cells such as follicle cells or nurse cells. They also store varying amounts of **yolk**, sourced from the mother's digestive glands, serving as a nutrient reservoir for the developing embryo. Additionally, eggs are shielded by protective coatings, including albumen and outer membranes, provided by follicle cells or maternal **oviduct** cells.

Frog oocytes have emerged as invaluable model systems for investigating oocyte development. Throughout maturation, these oocytes undergo a remarkable process of ribosome production facilitated by **gene amplification**, leading to the generation of vast quantities of ribosomes. Additionally, substantial amounts of mRNA are synthesized and stored during this period, further contributing to the intricate regulatory mechanisms governing oogenesis in frogs.

2. FERTILIZATION: THE GENESIS OF DEVELOPMENT

Fertilization, the union of male and female gametes, marks the inception of development. This process can occur either externally or internally, with the initial sperm-egg interaction triggering the **acrosome reaction**. This reaction involves the release of enzymes to facilitate sperm penetration through the egg's protective layers. Upon fusion of the sperm and egg plasma membranes, the male nucleus enters the egg cytoplasm, merging with the egg nucleus to form a diploid **zygote** (Fig. **2**). The egg's cortical reaction prevents polyspermy by ensuring that only one sperm fertilizes the egg, with the elevation of the fertilization membrane further impeding additional sperm entry.

In some species, such as reptiles, insects, and some invertebrates, fertilization can be bypassed through a process known as **parthenogenesis**. In this process, the egg activates and embarks on embryonic development without external fertilization, leading to offspring development. Parthenogenesis can produce both male and female offspring, depending on the species and the type of parthenogenesis exhibited. This reproductive strategy highlights the diversity and adaptability of reproduction across the animal kingdom.

Fertilization occurs on Day 0 when the sperm and egg unite to form a zygote. Following fertilization, the egg completes its second meiotic division, producing a polar body, and the zygote undergoes its first mitotic division, known as cleavage. These early divisions are rapid and lead to the formation of smaller cells, marking the initial stages of development (Fig. **2**).

3. CLEAVAGE: THE FOUNDATION OF CELL PROLIFERATION

Cleavage, the pivotal stage following fertilization, represents a specialized form of cell division (mitosis). It results in the formation of a **blastula**, characterized by a spherical arrangement of cells surrounding a central cavity, which is a hallmark of

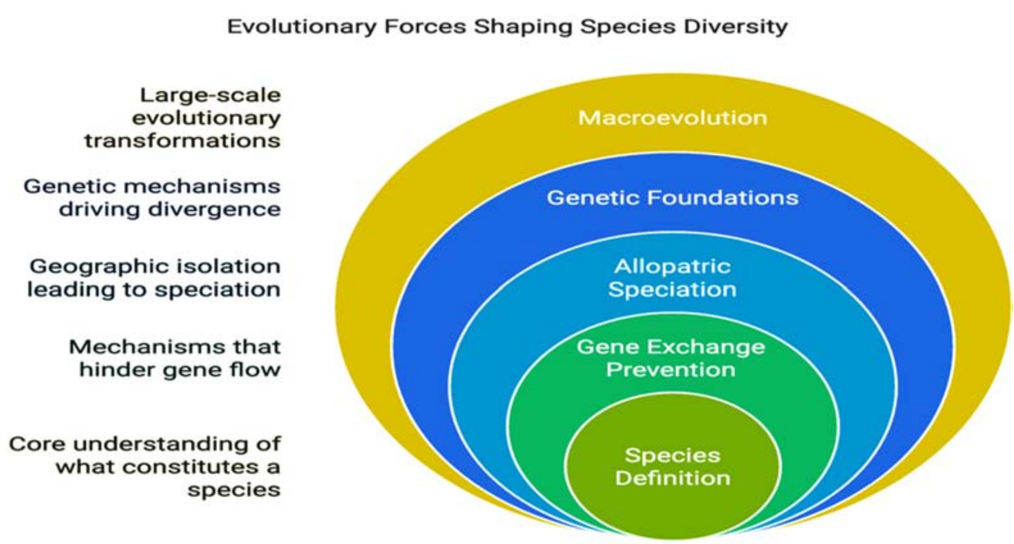
CHAPTER 8

Evolutionary Forces Shaping Species Diversity

Abstract: Understanding species diversity requires an exploration of various evolutionary forces and mechanisms. Modern biologists define a species as a group capable of interbreeding to produce viable offspring, though this concept primarily applies to sexually reproducing organisms. Asexual organisms are classified based on physical traits. Mechanisms such as prezygotic and postzygotic isolation prevent gene exchange between closely related groups. Prezygotic mechanisms include ecological, behavioral, mechanical, and temporal isolations, while postzygotic mechanisms result in hybrid sterility or breakdown. Ernst Mayr's allopatric speciation model outlines how geographic barriers and subsequent genetic divergence lead to speciation. Genetic identity measures the proportion of shared structural genes, and processes like polyploidization can drive rapid divergence. Macroevolution encompasses large-scale transformations, such as divergent and convergent evolution, and is often inferred through phylogenetic analysis and the fossil record. Microevolutionary processes contribute to macroevolutionary patterns, with ongoing research investigating the mechanisms underlying significant evolutionary changes.

Keywords: Allopatric speciation, Gene exchange, Macroevolution, Speciation.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. HOW BIOLOGISTS DEFINE A SPECIES

Modern biologists typically define a species as a group of populations that can interbreed or have the potential to do so, maintaining reproductive isolation from other such groups. This means that individuals within a species can mate and produce viable offspring with one another, but cannot successfully reproduce with members of different species. This reproductive isolation concept is particularly precise, though it only applies to sexually reproducing organisms. For asexual reproducers, such as many prokaryotes, various plants, and certain animals, species classification relies on observable physical traits, including biochemical and morphological characteristics.

2. MECHANISMS OF GENE EXCHANGE PREVENTION

Two primary mechanisms function to impede gene exchange among closely related groups. The first mechanism comprises prezygotic isolating mechanisms, which hinder zygote formation. Prezygotic isolation encompasses ecological and behavioral categories. Ecological isolation arises when related groups adapt to slightly different environments over time, leading to genetic distinctions that hinder successful cross-fertilization. In behavioral isolation, distinct behaviors evolve among related groups, such as unique mating rituals, limiting gene exchange within each group. Occasionally, prezygotic isolation stems from mechanical barriers, rendering mating physically impossible due to structural genital incompatibility or failure of sperm and egg surface molecules to bind. Temporal isolation represents another prezygotic mechanism, where time-related environmental cues triggering reproductive processes differ among related species.

Postzygotic isolating mechanisms permit mating but yield inviable or sterile hybrid offspring. A specific instance, **hybrid sterility**, includes hybrid breakdown, wherein successive generations following a cross display reduced reproductive success. This contrasts sharply with the outcome of crossbreeding between genetically distant members of the same species, often resulting in heterozygote advantage, known as hybrid vigor.

Populations of a species distributed across a wide geographical range often exhibit a **cline**—a gradual variation in one or more characteristics as each population adapts to its local environment. Along a cline, distinct subspecies may emerge, with individuals at either end often experiencing reproductive isolation.

3. EVOLUTION INTO SPECIES: ESTABLISHING GENETIC ISOLATION

Ernst Mayr's **allopatric speciation** model posits a two-stage process for species formation. Initially, populations of a common species become divided by a physical or geographical barrier. Consequently, genetic disparities emerge over time, leading to either pre- or postzygotic isolation between the separated groups. Subsequently, in the second stage, these divergent populations may reestablish contact. Should this occur, speciation reaches completion through the influence of natural selection.

4. GENETIC FOUNDATIONS OF SPECIATION

The degree of variation between populations undergoing divergence into distinct species, or among species that have already diverged, is quantified by a measure known as genetic identity. This metric reflects the relative proportion of shared structural genes among individuals within the compared groups. Generally, biologists posit that the genetic transitions leading to speciation occur gradually. Once a new species emerges, it typically exhibits a faster rate of genetic divergence from related species. In certain cases, such as within the primate order, significant differences in physical characteristics do not align with corresponding variations in structural genes. Consequently, scientists propose that minor alterations in regulatory genes may underlie many of the substantial changes driving speciation and the emergence of higher taxonomic groups.

One mechanism capable of rapidly driving genetic divergence among populations is polyploidization—a sudden increase in the entire set of chromosomes. This phenomenon can lead to **sympatric speciation**, where new species arise without geographical isolation. A process akin to polyploidization, involving chromosome rearrangements, has been suggested to elucidate the evolutionary origins of giant pandas. Evidently, species can originate through diverse mechanisms.

5. UNDERSTANDING MACROEVOLUTION: MAJOR TRANSFORMATIONS

The transformations responsible for species divergence are often termed **microevolution**, while those leading to significant phenotypic distinctions separating genera, classes, orders, and beyond are termed **macroevolution**. Some lineages can be traced through the fossil record, while others necessitate inference through comparisons among related extant organisms. Constructing lineages of descent over evolutionary time yields a **phylogeny**.

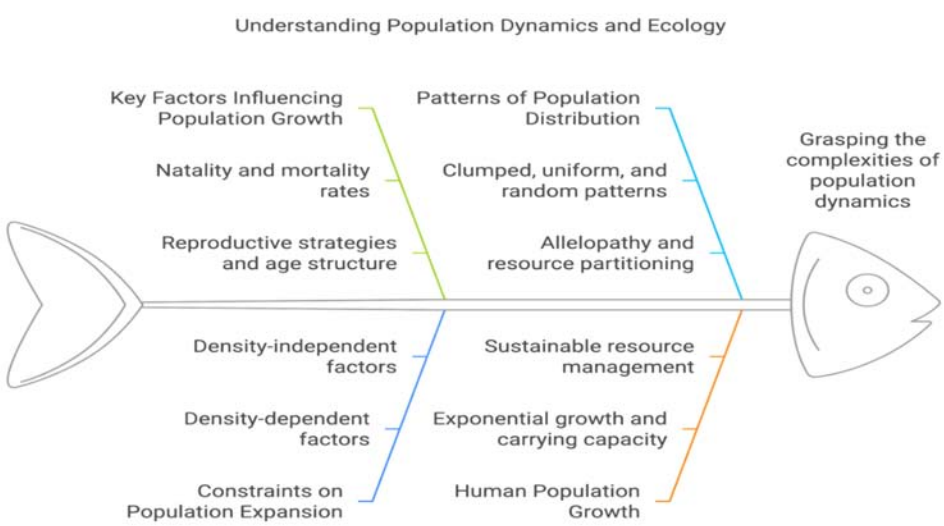
CHAPTER 9

Population Dynamics and Ecology

Abstract: Population dynamics is shaped by multiple factors influencing growth, distribution, and constraints. Key characteristics of populations include natality, mortality, and density. Exponential growth occurs under ideal conditions but is typically limited by carrying capacity, resulting in a logistic growth curve. Reproductive time lag affects population fluctuations, and age structure and reproductive strategies further influence growth rates. Populations are constrained by density-dependent factors such as predation and disease, and density-independent factors like natural disasters. Distribution patterns, including clumped, uniform, and random, are affected by interspecific interactions and competition. Allelopathy, resource partitioning, and character displacement illustrate competition in both terrestrial and aquatic environments. The exponential rise in human population highlights the urgency of sustainable resource management, with current growth rates potentially surpassing Earth's estimated carrying capacity.

Keywords: Allelopathy, Carrying capacity, Population dynamics, Reproductive strategies, Sustainable resource management.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. FACTORS INFLUENCING POPULATION GROWTH

Populations, defined as groups of individuals belonging to the same species, exhibit three key statistical characteristics: per capita birth rate (**natality**), per capita death rate (**mortality**), and population density (number of individuals per unit area).

As first described by Malthus, populations have the potential to grow exponentially if resources such as food and shelter are unlimited and if there are no threats from predation or competition. This type of growth is represented by an **exponential growth curve**. However, such ideal conditions rarely occur in nature. The finite availability of resources sets an upper limit to population size, known as the **carrying capacity** (K), which can be approached but not sustainably exceeded. **A logistic growth curve** depicts how population growth levels off as it reaches equilibrium with available resources.

When a population approaches or exceeds resource limits, there is a lag time before birth rates decrease and death rates increase. This response time is known as reproductive time lag, which contributes to the fluctuations in population numbers observed in natural populations. Seasonal changes often cause the carrying capacity and, consequently, population size to fluctuate. If a population significantly exceeds its environment's carrying capacity, it may cause lasting damage that permanently reduces the carrying capacity.

In addition to environmental carrying capacity, a population's growth rate is influenced by its age structure and reproductive strategy. **Age structure** reflects the proportion of young, middle-aged, and older individuals within a population. Populations with many individuals at or near reproductive age are likely to grow significantly. The age structure can also be depicted by a **survivorship curve**.

Reproductive strategies of populations are complex and have evolved over millennia. Generally, these strategies fall into two categories: R-selected and K-selected species. R-selected species mature quickly and produce many offspring, each small and equipped with few resources. Only a few offspring survive to reproductive age. K-selected species mature slowly and produce few offspring, but parents invest significant resources in each one, enhancing their survival chances until reproductive age.

2. CONSTRAINTS ON POPULATION EXPANSION

Population size is typically measured by its density. Regardless of whether **population density** is high or low, individuals within the population are usually unevenly distributed. Common distribution patterns include clumped, uniform, and random. High population density often leads to negative consequences and **density-dependent factors**, such as increased predation, parasitism, disease, and competition (both **intraspecific** and **interspecific**). Population size can also be affected by **density-independent factors**, such as natural disasters.

Predator-prey interactions affect population size in complex ways. These populations may cycle regularly between growth and decline, partly due to reproductive time lags. Predation can slow or halt prey population growth only when many reproductive individuals are removed. If predators mainly target the weak, sick, or young, the overall effect on population density may be minimal.

Ecologists debate whether species diversity in a community promotes stability or if stability fosters species diversity. One aspect of this debate is the hypothesis that complex food webs are more stable than simple ones. However, many stable, diverse communities in nature feature numerous simple food webs. It might be that stable environments foster diversity by allowing rare species to persist.

3. PATTERNS OF POPULATION DISTRIBUTION

Competition, predation, and other factors interact to determine a population's size within a community and its distribution. The distribution of a population within its potential range depends on the availability of food, suitable habitat, interspecific competition for resources, and other variables. In plants, one effective form of interspecific competition is **allelopathy**, where chemicals are released to inhibit competitors (Fig. **1**). Resource partitioning is common among species sharing similar habitats. In **character displacement**, closely related species evolve physical differences to exploit limited resources differently. Over time, these adaptations may lead to speciation. Similar to terrestrial plants, many aquatic plants, and algae release substances into the water that can affect other aquatic organisms. These chemicals can suppress the growth of competing plants or algae and sometimes affect other aquatic animals. However, it is not exclusive to plants, aquatic plants, or algae. Allelopathy can also occur in some animals, although it is less common and often referred to by different terms such as chemical defense or chemical communication.

Section 4
Advances in Biological Research and Information Systems

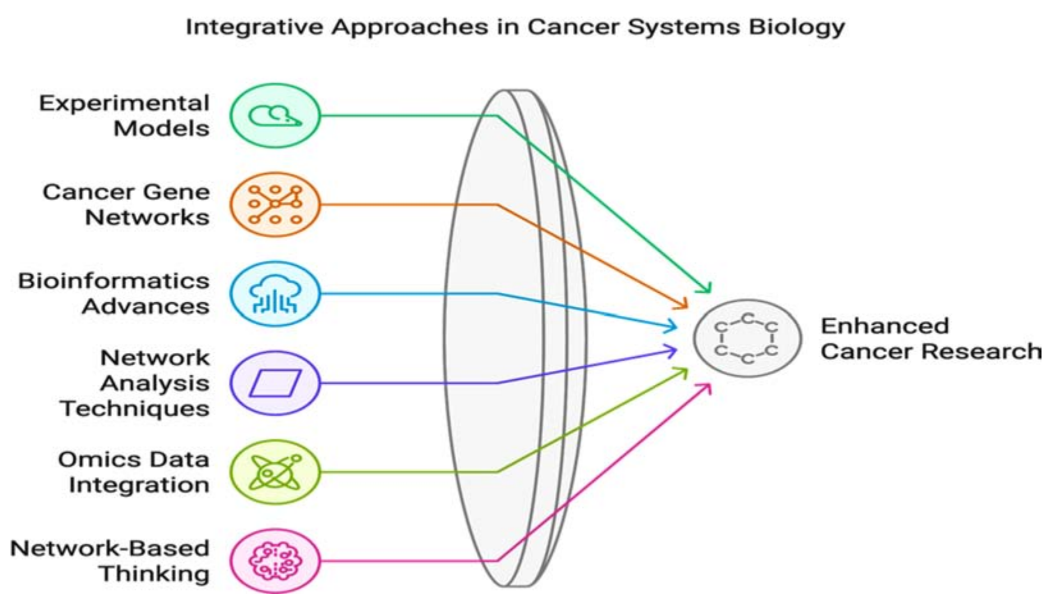
CHAPTER 10

Navigating Cancer Systems Biology

Abstract: Cancer systems biology integrates experimental models, data analysis, and dynamic network modeling to elucidate the complex mechanisms underlying cancer progression. This chapter outlines the essential requirements for experimental models, emphasizing the need for well-characterized cancer subtypes and high-quality mouse models that mimic clinical outcomes. It discusses various approaches to constructing cancer gene networks, including inference from genome-wide datasets, extension of protein interaction networks, and integration of high-throughput data with literature. The chapter also highlights advancements in bioinformatics, such as pattern recognition and machine learning, and the evolution of network visualization from static to dynamic models. Finally, it examines network analysis techniques for understanding biological systems and applying dynamic network modeling to decipher information processing in cancer cells. Data quality and model development challenges are noted, with a call for enhanced training in network-based thinking to further cancer research.

Keywords: Bioinformatics, Cancer networks, Data integration, Dynamic modeling, Network visualization.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



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1. CANCER SYSTEMS BIOLOGY AND ITS IMPACT ON PRECISION MEDICINE

1.1. The Transformative Impact of Systems Biology on Cancer Research

When a collision disrupts a congested road during rush hour in a bustling city like Tehran, Beijing, Toronto, or New York, traffic comes to a temporary standstill. Soon, however, drivers find alternative routes to reach their destinations. Similarly, the city's road map—a web of interconnected routes—allows for alternative paths. Increasing evidence indicates that cellular molecules are networked in a similar manner. This interconnected structure enables cancer cells to evade the effects of drugs.

Traditional biological investigations usually use straightforward reasoning and descriptions without any math. These methods work well only for simple processes that involve just a few parts or short cause-and-effect links. As a result, traditional biology finds it challenging to understand the complicated interactions between different molecules that are typical of many diseases, such as cancer. Cancer involves numerous interacting elements forming complex networks with highly nonlinear dynamics. Thus, focusing on just one molecule in a biochemical pathway often doesn't work well for treating cancer, since cells can discover other ways to work around the blockage. This challenge emphasizes why numerous existing drug designs do not achieve success and underscores the importance of adopting a systems perspective rather than a gene-centric approach in developing new cancer treatments.

Systems biology integrates empirical data with mathematical and computational techniques to understand complex biological occurrences. For instance, a multitude of proteins can play a role in signaling processes that are crucial for cell function. Disruptions in these networks can lead to cancer. Systems biology provides detailed maps of these cellular networks and utilizes sophisticated quantitative, statistical, and computational techniques to examine them. By understanding these complex systems, more effective therapeutic strategies can be developed, such as targeting multiple key points in a biochemical network simultaneously. This approach promises significant advancements in cancer treatment, transforming traditional reductionist methods into comprehensive systems-level strategies for drug discovery.

The emergence of systems biology is fueled by advancements in large-scale techniques designed for life science applications. Innovative techniques like next-generation genome sequencing, RNA-seq, ChIP-seq, and microarrays enable researchers to assess gene expression and regulatory elements across the entire genome. These advancements have transformed biological research from a "single gene model," which emphasizes individual genes and proteins, to a "multiple gene model," acknowledging that biological entities function as systems composed of interconnected components. With the decreasing cost and greater accessibility of these technologies, large-scale biological research projects are becoming more prevalent.

The rise of systems biology has significantly increased the amount of biological data, and this growth is expected to persist in the future. Large-scale data generated through advanced techniques is both extensive and impartial, greatly transforming cancer research. Scientists now face the challenge of managing, interpreting, and extracting insights from vast datasets. In this huge amount of data, important signals and biological patterns can be hidden, so using math and computers is key to finding them.

Systems biology tackles these problems by combining different types of omics data and creating computer tools to understand complex systems. It uses network and graph theory to mathematically explain, study, and model these biological systems. By applying network theory, biological language is transformed into a computable mathematical language, capable of handling the vast number of relationships in biological data. The foundation of systems biology is network biology, which uses networks to represent, analyze, and model biological complexity, aiming to reveal key biological principles.

This chapter presents various strategies, methodologies, and computational approaches used to study cancer systems biology, with an emphasis on network reconstruction, analysis, and modeling of biological networks. Relevant chapters of this book will guide readers through these strategies and procedures. Additionally, the chapter discusses the obstacles and difficulties faced in cancer systems biology.

1.2. Systems Biology as a Tool for Customized Medicine

New investigations reported that many medications work for less than half of the prescribed patients. In addition, around 3 million prescriptions are either incorrect or ineffective each year, leading to over 100,000 deaths in the U.S. from drug-related complications. These numbers highlight the shortcomings of a one-size-fits-all approach to medicine and preventive care. It is essential to consider the individual's unique genetic background to treat diseases effectively. Precision

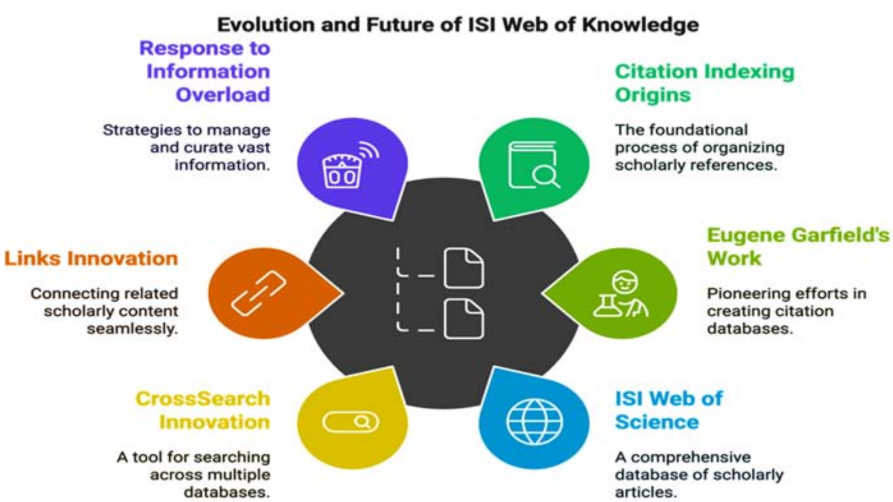
CHAPTER 11

The Evolution and Future Prospects of the ISI Web of Knowledge Platform

Abstract: The ISI Web of Knowledge, evolving from Eugene Garfield's pioneering citation indexes, represents a sophisticated web-based platform central to modern scholarly research. This paper explores its transformative journey from print citation indexes to a dynamic, integrated digital environment. Initially, citation indexes such as the Science Citation Index® facilitated scholarly communication by linking references and tracking research impact. The transition to the ISI Web of Knowledge marked a significant advancement, incorporating advanced technologies for seamless access to multidisciplinary content. This platform features enhanced search capabilities, including ISI CrossSearch and ISI eSearch, and robust linking systems like ISI Links and RoboLinks. By integrating context-sensitive linking *via* SFX, the ISI Web of Knowledge supports comprehensive access to diverse information sources, thus addressing challenges of information overload and accessibility. Future developments promise further expansion of content and capabilities, solidifying the platform's role as a pivotal resource in the landscape of academic research and bibliometrics.

Keywords: Bibliometrics, Citation indexes, Information access, Scholarly communication, Web-based research platforms.

UNDERSTANDING THE CHAPTER'S FOCUS: A ROADMAP



Mohammad Mehdi Ommati

1. OVERVIEW

In 1955, Eugene Garfield reported a groundbreaking article in Science called "Citation Indexes for Science: A New Dimension in Documentation through Association of Ideas." At present, Dr. Garfield is recognized as a pioneer in the field of bibliometrics, which is the study of how information is cited and used in research. His original idea of building a citation database that covers multiple disciplines has greatly changed over the years, now using advanced technologies that were not even possible 45 years ago. This evolution has transitioned citation data from print to electronic formats, eventually creating a web-based environment characterized by hypernavigation, intuitive linking, and sophisticated contextual interactions.

This paper will explore how citation indexes evolved into the ISI Web of Knowledge, an integrated resource platform widely used by research libraries around the world. It will start by discussing Dr. Garfield's important contributions to bibliometrics, which formed the foundation for the ISI® platform. The paper will then focus on three key aspects: first, the platform's ability to offer access to a diverse range of multidisciplinary content, which is vital for modern research; second, the innovative query engine for knowledge management that allows users to search across different types of content; and third, ISI Links, the main system that provides confirmation, access, and routing, which supports the platform's extensive linking features.

2. THE ROLE OF CITED REFERENCES IN SHAPING SCIENTOMETRICS

A cited reference is a way for an author to acknowledge the influence of other scholars in their work. Citation indexes take this concept further by showcasing a wide range of influences from different authors and works. One major benefit of citation indexing is that it helps researchers find relevant articles across various fields without needing to know specific jargon—the citation itself can serve as a useful search term.

Citation indexes allow users to discover related papers, see how their research is being used by others, and find connections between different research topics that may seem unrelated at first. This makes citation indexes an essential tool for both researchers and those studying the history of science, as they help track the development of scientific knowledge and reveal links between different areas of study.

Dr. Garfield understood these relationships well. In 1961, ISI received funding from the NIH to create the "Genetics Citation Index," which was a forerunner to the Science Citation Index®. Garfield pointed out that the citations found at the end of a scientific paper do more than just give credit to other researchers; when these citations are indexed and included in a database, they can help track and link important research developments over time.

The Science Citation Index was first released in 1964 as a five-volume set that included 613 journals and 1.4 million citations. While this was an exciting new resource for accessing scientific research, finding information was often slow and cumbersome because it was in print format. Two years later, the citation data became available on magnetic tapes, enabling institutions with the right technical skills to automate the handling of citation data.

As technology improved, so did ISI's offerings. The Science Citation Index was expanded in 1972 with the introduction of the Social Sciences Citation Index® and in 1978 with the Arts & Humanities Citation Index®, which eventually moved to online platforms and later to CD-ROMs. In recent years, the time it takes for new information to become part of the global knowledge base has greatly decreased. The expansion of electronic access to scholarly literature has played a crucial role in this acceleration. While the publication and distribution of printed journals and indexes once meant that communication among researchers could take months or even years, current technology has reduced this cycle to mere days. The widespread availability of personal computers, the Internet, and electronic journals has dramatically enhanced global access to scientific information.

For many years, researchers in bibliometrics and scientometrics have depended on citations, utilizing ISI citation indexes as their main source of data for analysis. However, it was not until 1997, when these citation indexes were transitioned to a web-based platform known as the ISI Web of Science®, that researchers began to actively participate in searching for cited references.

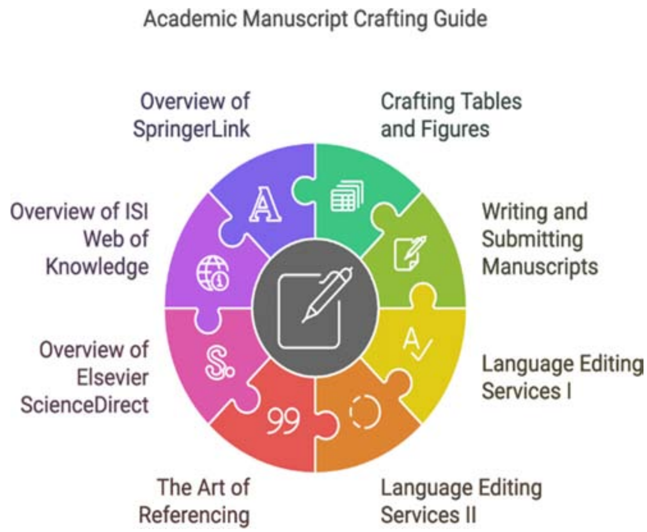
2.1. How 'Citation Indexes' Transformed into the 'ISI Web of Science'

The development of hypertext links and web browsers made it possible to create the Web of Science, a user-friendly and easy-to-understand tool for tracking citations. Dr. Garfield's innovative idea of organizing scientific literature was far ahead of its time, and he had to wait over 40 years for technology to catch up. Standardizing how references were recorded was a crucial first step, but the ISI

Section 5
Crafting the Scholar's Path - Navigating the Academic Manuscript Journey

Crafting the Scholar's Path: Navigating the Academic Manuscript Journey

Understanding the Chapter's Focus: A Roadmap



I. SECTION A

1.1. Crafting Effective Tables and Figures: A Twelve-Step Guide

Tables and figures serve a crucial purpose in scientific communication, providing a means to present complex or voluminous data efficiently and to illustrate trends or patterns inherent in the data. They are pivotal components of scholarly manuscripts, often serving as the focal point for readers who delve beyond the abstract.

Prior to commencing the initial draft of your manuscript, it is paramount to meticulously organize the data intended for presentation. This entails not only preparing the tables and figures themselves but also drafting their accompanying titles, and legends, and performing requisite statistical analyses. This preparatory phase ensures that your results are firmly established before proceeding to their interpretation, fostering confidence in the accuracy and integrity of your findings.

Mohammad Mehdi Ommati

Additionally, this stage offers an opportune moment to assess the completeness of your dataset, identifying any gaps or deficiencies that may need addressing.

Furthermore, before embarking on the drafting process, careful consideration should be given to which results directly address the research questions posed and which data may be omitted without compromising the coherence or comprehensiveness of the manuscript. This strategic planning ensures that the manuscript remains focused and aligned with the overarching objectives of the research endeavor.

(1) Determine the appropriate presentation format for your results, considering whether they are best suited for inclusion within the text, or if they would be more effectively communicated through tables or figures.

(2) Exercise discretion in the inclusion of tables and figures, prioritizing only those that convey essential information that cannot be adequately conveyed through textual description alone.

(3) Ensure that the results presented are directly relevant to the research questions posed in the introduction, regardless of whether they align with or contradict the initial hypotheses.

(4) Design each table and figure to be self-explanatory, capable of conveying meaningful information independently of accompanying text.

(5) Sequentially number each figure and table in correspondence with their order of reference in the text, with separate numbering systems for figures and tables.

(6) Arrange tables and figures in a logical sequence that narrates a cohesive storyline, facilitating comprehension and flow for the reader.

(7) Adhere to the formatting guidelines of the target journal, typically placing tables and figures on separate pages following the reference section.

(8) Avoid page breaks within tables or figures, particularly if the journal requires their integration into the main text. Additionally, refrain from wrapping text around tables or figures.

(9) Ensure that all tables and figures referenced in the article text are appropriately cited and discussed within the manuscript.

(10) Obtain necessary permissions from copyright holders, typically publishers, when including previously published tables or figures, and provide appropriate acknowledgment of the source.

(11) Draft table titles and figure legends in the past tense to maintain consistency with the reporting style of scientific manuscripts.

(12) Provide concise descriptions of the content presented in tables and figures within their titles and legends, refraining from offering interpretations or summaries of the results.

1.1.1. Tables

Tables serve as a means to enhance the readability of an article by presenting numeric data in a structured format. They can also synthesize literature, elucidate variables, or convey survey question wordings.

(1) Utilize the table function within Microsoft Word to create tables, avoiding the use of tabs for formatting.

(2) Employ clear column headings and precise table notes to simplify and elucidate the content of the table. The information presented within each column should be comprehensible without reference to the accompanying text.

(3) Consult the journal's guidelines; typically, they require the table title and table to be situated on the same page, with each table presented on a separate page in numerical order.

1.1.2. Figures

Figures are instrumental in conveying primary findings visually, providing impactful representations of data trends or group results. They can effectively communicate processes or simplify the presentation of detailed data.

(1) Ensure each axis of the figure is labeled with units of measurement, clearly identifying the displayed data (*e.g.*, label each line in a graph).

(2) Refer to the journal's specifications; typically, they require figure legends to be listed in numerical order on a separate page, with each figure presented on a separate page in numerical order.

Section 6
Conclusion

CHAPTER 12

Conclusion: The Symphony of Life - Integrating Knowledge and Advancing Frontiers

As we reach the culmination of this comprehensive exploration into the biological sciences, it is essential to reflect on the interconnected themes and lessons presented throughout this book. The journey we embarked upon has traversed the fundamental principles of life, the complexities of ecosystems, the mechanisms driving evolution, and the frontiers of modern biological research and information systems. Each chapter has contributed to a holistic understanding of biology, painting a detailed portrait of the natural world and our place within it.

In the initial chapters, we laid the groundwork by delving into the structure and function of cells, the basic units of life. Understanding cellular components and their roles provided a foundation upon which more complex biological processes are built. The detailed examination of cellular reproduction, through mitosis and meiosis, highlighted the continuity of life and the intricate mechanisms that ensure genetic information is accurately passed on to the next generation.

Transitioning to genetics, we traced the historical evolution of genetic thought, from early hypotheses to the sophisticated molecular understanding we have today. By exploring the chemical foundations and structural intricacies of genes, we gained insight into how genetic information is encoded, transmitted, and expressed. This understanding is crucial for appreciating the profound impact genetics has on all living organisms, influencing traits, behaviors, and evolutionary trajectories.

The chapters on the diversity of life celebrated the vast array of organisms and their developmental processes. We journeyed through the origins of life, the ecological roles of fungi, and the detailed processes of animal development. The exploration of evolutionary forces underscored the dynamic nature of life, driven by natural selection, genetic drift, and gene flow. Understanding population dynamics and ecological interactions revealed the delicate balance that sustains ecosystems and the impact of human activities on this balance.

In the realm of advanced biological research, we explored the cutting-edge field of cancer systems biology, emphasizing the importance of a systems-level approach

Mohammad Mehdi Ommati

to understanding and treating this multifaceted disease. The evolution and future prospects of the ISI Web of Knowledge platform highlighted the revolution in accessing and analyzing scientific literature, enabling researchers to discover new connections and drive scientific progress.

The practical guide in Section V, "Crafting the Scholar's Path," equipped aspiring researchers with essential skills for navigating the academic manuscript journey. From crafting effective tables and figures to developing a robust first draft and selecting appropriate journals, this section provided invaluable guidance. Detailed guidelines for writing and submitting manuscripts, promoting publications, and utilizing language editing services were designed to support researchers in disseminating their findings effectively.

In Section VII, the comprehensive answers to questions and tasks reinforced key concepts and ensured a deep understanding of the material. This section served as a vital resource for self-assessment and further learning.

The appendices in Section VIII offered valuable supplementary materials, including general vocabulary lists and the fundamental components of medical English vocabulary. These resources aimed to support readers in mastering the specialized language of biology and medicine, enhancing their ability to engage with scientific literature and communicate their findings effectively.

The Road Ahead: Emerging Fields and Ethical Considerations

As we look to the future, the field of biological sciences continues to evolve, driven by advancements in technology and interdisciplinary approaches. Emerging fields such as synthetic biology, systems ecology, and bioinformatics promise to transform our understanding of life and address complex biological challenges. However, with these advancements come ethical and societal considerations. It is imperative to approach scientific progress with a sense of responsibility, ensuring that innovations benefit society and preserve the integrity of natural ecosystems.

The interconnectedness of life remains a central theme, highlighting the complexity and beauty of biological systems. By appreciating the intricate web of relationships that sustain life, we gain a deeper understanding of our role within this symphony of existence. As researchers, educators, students, and enthusiasts, we are called to contribute to the collective knowledge and stewardship of the living world.

Final Thoughts

This book aims to provide a thorough and accessible exploration of contemporary biological sciences. By bridging foundational knowledge with the latest research and technological developments, it offers readers a comprehensive understanding of the field. Whether you are a student beginning your journey, an educator seeking to inspire, a researcher pushing the boundaries of knowledge, or an enthusiast captivated by the wonders of life, this book serves as a valuable resource.

As we conclude this journey, we invite you to continue exploring, questioning, and discovering. The field of biology is ever-evolving, and the pursuit of knowledge is a lifelong endeavor. Embrace the curiosity that drives scientific inquiry, and let the beauty of the natural world inspire you to contribute to the advancement of biological sciences.

Thank you for embarking on this journey with me. May this book ignite your passion for biology and deepen your appreciation for the intricate and awe-inspiring tapestry of life.

Section 7
Answers

Answers

Answers (Lesson 1):

Exploring the Inner Workings of Cells: Understanding the Structure and Function of Cellular Components

<u>Exc. 1:</u>

1. Polysome - **G.** RNA and ribosomes

2. Pinocytosis - **N.** cell drinking

3. Exocytosis - **k.** expel

4. Plastid - **I.** in plants only

5. Golgi complex - **O.** packaging

6. Flagella - **M.** whiplike

7. Phagocytosis - **F.** engulfment

8. Lysosome - **B.** baglike structure

9. Basal body - **D.** where flagella grow

10. Chemotactic - **E.** toward or away from a chemical stimulus

11. Nucleus - **H**. weblike

12. Vacuole - **L.** packaging

13. Ribosome - **A.** protein synthesis

14. Cytoskeleton - **H.** weblike

15. Mitochondrion - **C.** power generator

Mohammad Mehdi Ommati

Exc. 2:

1. False
2. False: Ribosomes are synthesized in the nucleolus, a structure within the nucleus of eukaryotic cells. They are formed from ribosomal RNA (rRNA) and proteins. Once assembled, ribosomes can be found in the cytoplasm or attached to the endoplasmic reticulum. So, they are not derived from the nucleoli but are produced there.
3. False
4. True
5. True
6. True
7. True
8. True
9. False
10. True
11. True
12. True
13. False
14. False

Exc. 3:

1. Engulfed
2. Golgi complex, Lysosomes
3. Lipofuscin granules, lipofuscin granules, aging
4. Mitochondria - chloroplasts

5. Microfilaments - intermediate filaments -microtubules

6. Actin

7. Chemotactic

8. Basal body

Exc. 4:

1. **E.** None of the above. Properties associated with processes of life are not solely attributed to any single component listed.

2. **A.** Serve as organelles involved in protein synthesis

3. **D.** All of the above

4. **B.** Nucleoli

5. **A.** Hydrolytic enzymes

6. **A.** Engulfing solid particles within vacuoles

7. **D.** Mitochondria: powerhouse organelles

8. **A.** Inside the mitochondrial matrix

9. **D.** Plastid

10. **B.** A polysome: a ribonucleoprotein complex

11. **C.** Serve as reservoirs for proteins, fats, and starch

12. **D.** A cytoskeleton structure

13. **C.** Compacted into a region known as the nucleoid

14. **B.** At the sites of ribosomes

15. **C.** A polysome

16. **B.** An amino acid sequence referred to as a signal peptide

Section 8
Appendix

Biology for Students, 2025, 382-418

Appendix: Vocabulary Prefixes and Suffixes Roots

Appendix- The fundamental components of medical English vocabulary: roots, prefixes, and suffixes commonly used.

1. Position-related roots		
Caud- (related to the Tail, in anatomy towards the lower part of the body)		**Later**- (related to Lateral, pertaining to the side)
Cephal- (related to Head)		**Medi-** (related to Medial, pertaining to the middle)
Coron- (related to Crown, top of the head)		**Mes-** (related to Mesial, middle)
Crani- (related to Skull)		**Pariet-** (related to Parietal, pertaining to the walls of the body)
Dextr- (related to Right side)		**Proxim**- (related to Proximal, near, closer to the point of reference)
Dist- (related to Far, farthest point from the center)		**Sinistr**- (related to Sinister, pertaining to the left side)
Extern- (related to External, outside)		**Transvers**- (related to Transverse, horizontal)
Front- (related to Front, forehead)		**Ventr-** (related to Ventral, pertaining to the abdomen or belly side)
Intern- (related to Internal, inside)		**Viscer**- (related to Visceral, pertaining to internal organs)

Mohammad Mehdi Ommati

(Table) cont.....

2. Skeletal system-related roots		
Arthr- (related to Joint)		**Patell**- (related to Patella: kneecap)
Articul- (related to Joint)		**Pector**- (related to Pectoral: chest)
Astragal- (related to Astragalus, bone in the ankle)		**Pelv**- (related to Pelvis: hip bone)
Burs- (related to Bursa, fluid-filled sac in joints)		**Phalang**- (related to Phalanx: finger or toe bone)
Calcane- (related to Calcaneus, heel bone)		**Por**- (related to Pore or Passage)
Carp- (related to Wrist)		**Pub**- (related to Pubic: pubic bone)
Cervic- (related to Neck)		**Rachi**- (related to Rachi: spine)
Chondr- (related to Cartilage)		**Ment**- (related to Mental: chin)
Clavic- (related to Clavicle)		**Myel**- (related to Myel: marrow or spinal cord)
Cox- (related to Hip)		**Nas**- (related to Nasal: nose)
Dactyl- (related to Finger or Toe)		**Radi**- (related to Radius: forearm bone)
Desm- (related to Ligament)		**Scapul**- (related to Scapula: shoulder blade)
Femor- (related to Femur, thigh bone)		**Scler**- (related to Scler: hardness or sclera)
Fibul- (related to Fibula, bone in the lower leg)		**Scoli**- (related to Scoliosis: lateral curvature of the spine)
Fleet/flex- (related to Flexibility)		**Spin**- (related to Spine)

(Table) cont.....

Gnath- (related to Jaw)		**Spondyl**- (related to Spondyl: vertebra)
Gon(at)/gony- (related to Generation, Birth)		**Stern**- (related to Sternum: breastbone)
Humer- (related to Humerus, bone in the upper arm)		**Tal**- (related to Talus: ankle bone)
Ischi- (related to Ischium, bone in the pelvis)		**Tars**- (related to Tarsus: ankle bones)
Lumb- (related to Lumbar, lower back)		**Tempor**- (related to Temporal: temple)
Mandibul- (related to Mandible, jawbone)		**Thorac**- (related to Thoracic: chest)
Maxill- (related to Maxilla, upper jawbone)		**Tibi**- (related to Tibia: shinbone)
Oss(e)- (related to Bone)		**Uln**- (related to Ulna: forearm bone)
Ost(e)- (related to Bone)		**Vertebr**- (related to Vertebra: backbone)

3. Roots related to the muscular and connective tissue		
Adip- (related to Fat, Adipose tissue)		**K/cin**- (related to Movement)
Coll(a)- (related to Collagen)		**K/cine(s)**- (related to Movement)
Cut- (related to Skin)		**Muc**- (related to Mucus)
Cyt- (related to Cell)		**Muscul**- (related to Muscle)
Derm(at)- (related to Skin)		**My**- (related to Muscle)

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SUBJECT INDEX

A

B

C

D

E

T

V

W

X

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Prof. Mohammad Mehdi Ommati is an associate professor in the College of Animal Science and Technology, Henan University of Science and Technology. He is an internationally recognized expert in animal sciences and reproductive physiology, with over 250 peer-reviewed articles, 25 book chapters, and four authored books. He has made significant contributions to academic collaboration, notably receiving a diploma from Universidad Autónoma Metropolitana in Mexico for his work in their master's program in animal reproductive biology. Ranked among the most-cited researchers by Elsevier in 2024, he received the Outstanding Scientist Award in 2020 and the Outstanding Teacher Award for 2023-2024. He is serving on a number of editorial boards, enhancing research in reproductive health and toxicology, and is a visiting professor at Shiraz University of Medicine. He has supervised over 50 undergraduate and postgraduate students, including Ph.D. candidates. His groundbreaking contributions to reproductive physiology and toxicology, combined with his commitment to mentorship and international collaboration, have solidified his reputation as a trailblazer in his field. His research continues to drive innovation and provide actionable insights to improve reproductive health worldwide.