

venn diagram on mitosis and meiosis

venn diagram on mitosis and meiosis serves as a powerful visual tool to compare and contrast two fundamental processes of cell division in biology. Both mitosis and meiosis play critical roles in the life cycle of cells, yet they differ significantly in their mechanisms, purposes, and outcomes. Understanding these distinctions and similarities is essential for students, educators, and researchers in the field of genetics, cellular biology, and developmental biology. This article delves into the detailed comparison of mitosis and meiosis through the lens of a venn diagram, highlighting their unique and shared features. It will explain the stages of each process, their biological significance, and the key cellular events that define them. By the end, readers will gain a comprehensive understanding of how these two types of cell division relate to each other and why they are crucial for growth, reproduction, and genetic diversity. The following sections outline the main areas of focus in this exploration.

- Overview of Mitosis
- Overview of Meiosis
- Similarities Between Mitosis and Meiosis
- Differences Between Mitosis and Meiosis
- Biological Significance of Mitosis and Meiosis

Overview of Mitosis

Mitosis is a type of cell division responsible for producing two genetically identical daughter cells from a single parent cell. It occurs in somatic cells and is essential for growth, tissue repair, and asexual reproduction in some organisms. The process of mitosis ensures that each daughter cell receives an exact copy of the parent cell's DNA, maintaining genetic continuity across cell generations.

Stages of Mitosis

Mitosis is divided into several distinct phases, each characterized by specific cellular events that prepare the cell for division and ensure accurate distribution of chromosomes:

- **Prophase:** Chromosomes condense, becoming visible under a microscope. The nuclear envelope breaks down, and spindle fibers begin to form.
- **Metaphase:** Chromosomes line up along the metaphase plate, an imaginary plane equidistant from the two spindle poles.
- **Anaphase:** Sister chromatids separate and are pulled toward opposite poles by the spindle fibers.

- **Telophase:** Chromatids reach the poles, nuclear envelopes re-form around each set of chromosomes, and the chromosomes begin to decondense.
- **Cytokinesis:** The cytoplasm divides, resulting in two identical daughter cells.

Function and Importance of Mitosis

Mitosis plays a vital role in the maintenance and development of multicellular organisms. It facilitates:

- Growth by increasing cell number
- Repair and replacement of damaged or dead cells
- Asexual reproduction in certain plants and unicellular organisms

Because mitosis produces genetically identical cells, it preserves the organism's genetic stability over time.

Overview of Meiosis

Meiosis is a specialized form of cell division that produces haploid gametes, such as sperm and eggs, from diploid germ cells. This process reduces the chromosome number by half, ensuring that when fertilization occurs, the resulting offspring have the correct diploid chromosome complement. Meiosis introduces genetic variation through recombination and independent assortment, which is critical for evolution and species diversity.

Stages of Meiosis

Meiosis consists of two consecutive divisions, meiosis I and meiosis II, each with its own phases:

- **Meiosis I:** Homologous chromosomes pair up and exchange genetic material during prophase I, then separate during anaphase I. This division reduces the chromosome number by half.
- **Meiosis II:** Similar to mitosis, sister chromatids separate during anaphase II, resulting in four haploid daughter cells.

The key phases include:

- **Prophase I:** Homologous chromosomes undergo synapsis and crossing over.
- **Metaphase I:** Paired homologous chromosomes align on the metaphase plate.
- **Anaphase I:** Homologous chromosomes separate to opposite poles.

- **Telophase I and Cytokinesis:** Two haploid cells form.
- **Prophase II, Metaphase II, Anaphase II, Telophase II:** Sister chromatids separate, producing four genetically distinct haploid cells.

Genetic Variation in Meiosis

Meiosis introduces genetic diversity through two primary mechanisms:

- **Crossing Over:** Exchange of genetic material between homologous chromosomes during prophase I.
- **Independent Assortment:** Random distribution of maternal and paternal chromosomes into gametes.

This genetic variation is fundamental for natural selection and adaptation in populations.

Similarities Between Mitosis and Meiosis

A venn diagram on mitosis and meiosis highlights several important similarities between these two processes despite their distinct functions. Both mitosis and meiosis are forms of nuclear division that involve DNA replication and chromosome segregation. They share common phases such as prophase, metaphase, anaphase, and telophase, and both rely on spindle fibers to separate chromosomes or chromatids. Additionally, both processes occur after the DNA in the parent cell has been replicated during the S phase of the cell cycle.

Shared Cellular Mechanisms

Key cellular components and events are common to both mitosis and meiosis:

- DNA replication precedes both divisions
- Chromosomes condense and become visible
- Spindle apparatus formation guides chromosome movement
- Separation of chromatids or homologous chromosomes ensures correct genetic distribution
- Presence of cytokinesis to divide the cytoplasm

Role in Organismal Life Cycle

Both mitosis and meiosis are essential for the continuity of life. They contribute to the growth, development, and reproduction of organisms. While mitosis maintains genetic stability, meiosis promotes genetic diversity, balancing the needs of an organism's lifecycle.

Differences Between Mitosis and Meiosis

The venn diagram on mitosis and meiosis clearly illustrates the critical differences that define each process. These differences include the number of cell divisions, chromosome number changes, genetic outcomes, and biological roles.

Number of Divisions and Daughter Cells

Mitosis involves a single cell division resulting in two diploid daughter cells genetically identical to the parent. In contrast, meiosis includes two sequential divisions, meiosis I and II, producing four haploid daughter cells that are genetically unique.

Chromosome Number and Genetic Variation

One of the most significant differences is the chromosome number in the resulting cells. Mitosis preserves the diploid chromosome number, whereas meiosis reduces it by half. Meiosis also introduces genetic recombination and independent assortment, increasing genetic diversity among offspring. Mitosis does not cause genetic variation, maintaining genetic continuity.

Purpose and Biological Function

The primary purpose of mitosis is growth, repair, and asexual reproduction, ensuring that somatic cells maintain genetic stability. Meiosis, on the other hand, is essential for sexual reproduction, generating gametes with half the chromosome number and contributing to genetic diversity within a population.

Summary of Differences

- **Mitosis:** One division, two identical diploid cells, no genetic variation, functions in growth and repair.
- **Meiosis:** Two divisions, four genetically different haploid cells, promotes genetic diversity, functions in sexual reproduction.

Biological Significance of Mitosis and Meiosis

The distinct roles of mitosis and meiosis are crucial for the survival and evolution of living organisms. Both processes are indispensable for maintaining life's complexity and continuity.

Importance of Mitosis

Mitosis is fundamental for the development of multicellular organisms. It ensures that new cells contain the correct genetic information needed for proper function. Without mitosis, organisms would not be able to grow, heal wounds, or replace damaged cells, leading to impaired health and viability.

Importance of Meiosis

Meiosis plays a pivotal role in sexual reproduction by producing gametes with half the chromosome number, preventing chromosome doubling in offspring. Its contribution to genetic variation through recombination and independent assortment drives evolution and adaptation, allowing populations to respond to environmental changes.

Integration in Life Cycles

In many organisms, mitosis and meiosis are integrated into complex life cycles. Mitosis supports somatic growth and maintenance, while meiosis generates reproductive cells, together sustaining the organism's lifecycle and the species' genetic health.

Frequently Asked Questions

What is a Venn diagram and how is it used to compare mitosis and meiosis?

A Venn diagram is a visual tool that uses overlapping circles to show similarities and differences between two or more subjects. In comparing mitosis and meiosis, it helps illustrate which processes and features are unique to each and which are shared.

What are the key similarities between mitosis and meiosis shown in a Venn diagram?

Both mitosis and meiosis involve cell division, start with a single parent cell, go through phases like prophase, metaphase, anaphase, and telophase, and involve DNA replication prior to division.

What are the main differences between mitosis and meiosis

highlighted in a Venn diagram?

Mitosis results in two genetically identical diploid daughter cells, involves one cell division, and is used for growth and repair. Meiosis results in four genetically diverse haploid gametes, involves two cell divisions, and is involved in sexual reproduction.

How does a Venn diagram illustrate the number of divisions in mitosis and meiosis?

In a Venn diagram, the section unique to mitosis would note one division cycle, while the section unique to meiosis would note two division cycles. This visually emphasizes the fundamental difference in the number of divisions.

Can a Venn diagram show the genetic variation outcomes of mitosis and meiosis?

Yes, the Venn diagram would show that mitosis produces genetically identical cells, whereas meiosis produces genetically diverse cells due to crossing over and independent assortment.

Why is crossing over included in the meiosis section of a Venn diagram comparing mitosis and meiosis?

Crossing over is a process unique to meiosis where homologous chromosomes exchange genetic material, increasing genetic variation. It does not occur in mitosis, so it is shown only in the meiosis part of the Venn diagram.

How are the functions of mitosis and meiosis represented in a Venn diagram?

The Venn diagram shows mitosis as responsible for growth, repair, and asexual reproduction, while meiosis is linked to the production of gametes for sexual reproduction. The shared section might include general cell division roles.

What role does chromosome number play in the Venn diagram comparison of mitosis and meiosis?

The Venn diagram highlights that mitosis maintains the diploid chromosome number in daughter cells, while meiosis reduces the chromosome number by half, producing haploid cells.

How can a Venn diagram help students understand the stages common to both mitosis and meiosis?

By placing the common stages such as prophase, metaphase, anaphase, and telophase in the overlapping section, the Venn diagram visually reinforces that both processes share similar phases despite their different outcomes.

Additional Resources

1. *Intersecting Life Cycles: A Venn Diagram Approach to Mitosis and Meiosis*

This book uses Venn diagrams to clearly illustrate the similarities and differences between mitosis and meiosis. It breaks down complex cellular processes into visual segments, making it easier for students and educators to understand. Each chapter includes detailed diagrams, step-by-step explanations, and comparison charts.

2. *Cell Division Simplified: Exploring Mitosis and Meiosis through Venn Diagrams*

Designed for high school and undergraduate students, this book employs Venn diagrams to simplify the concepts of mitosis and meiosis. It highlights key features, phases, and outcomes of each process, helping readers visualize how these mechanisms overlap and diverge. The book also features practice questions and summary tables.

3. *Visualizing Cell Division: Venn Diagrams for Mitosis and Meiosis*

This educational resource focuses on the power of visual learning, using Venn diagrams as the primary tool to compare mitosis and meiosis. It offers clear, colorful illustrations alongside concise explanations, making complex biology accessible. Additional sections cover genetic implications and cell cycle regulation.

4. *Mitosis and Meiosis: A Comparative Study with Venn Diagrams*

In this comparative guide, Venn diagrams serve as the foundation for exploring the distinct and shared characteristics of mitosis and meiosis. The book is ideal for biology students seeking a structured approach to mastering cell division. It includes real-world examples, experimental data, and review exercises.

5. *The Art of Cell Division: Using Venn Diagrams to Understand Mitosis and Meiosis*

Combining art and science, this book creatively employs Venn diagrams to dissect the processes of mitosis and meiosis. It emphasizes visual storytelling to engage readers and deepen comprehension. Readers will find annotated diagrams, mnemonic devices, and interactive activities.

6. *Biology Made Clear: Venn Diagram Comparisons of Mitosis and Meiosis*

This book provides a straightforward approach to learning about cell division by leveraging Venn diagrams for comparison. It breaks down each phase's functions and outcomes, clarifying common misconceptions. Useful for both self-study and classroom use, it includes quizzes and summary notes.

7. *Understanding Cell Division: Mitosis vs. Meiosis through Venn Diagrams*

Focused on enhancing conceptual clarity, this book uses Venn diagrams to highlight the critical differences and overlaps between mitosis and meiosis. It includes detailed explanations of chromosomal behavior, genetic variation, and cell cycle checkpoints. Supplementary materials provide practice scenarios and answers.

8. *Comparative Cytology: Venn Diagram Insights into Mitosis and Meiosis*

This text offers an in-depth analysis of mitosis and meiosis using Venn diagrams to visually organize information. It covers molecular mechanisms, regulatory pathways, and biological significance. The book is suitable for advanced high school students and early college learners.

9. *Cell Division Dynamics: A Venn Diagram Guide to Mitosis and Meiosis*

This concise guide employs Venn diagrams to map out the dynamic processes of mitosis and meiosis, emphasizing their roles in growth and reproduction. It features clear visuals, summary tables, and comparative discussions to support learning. The book is practical for quick review and exam

preparation.

Venn Diagram On Mitosis And Meiosis

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Unveiling the Secrets of Cell Division: A Venn Diagram Comparison of Mitosis and Meiosis

This ebook provides a comprehensive exploration of mitosis and meiosis, two fundamental processes of cell division, using a Venn diagram to highlight their similarities and differences. Understanding these processes is crucial for comprehending genetics, evolution, and various biological phenomena, including growth, repair, and reproduction. We'll delve into the intricacies of each process, comparing and contrasting their mechanisms, outcomes, and significance in living organisms.

Ebook Title: Mitosis vs. Meiosis: A Comparative Analysis with Venn Diagram

Contents:

Introduction: Defining mitosis and meiosis, their roles in the cell cycle, and the importance of understanding their distinctions.

Chapter 1: Mitosis - The Process of Cell Replication: Detailed explanation of the phases of mitosis (prophase, metaphase, anaphase, telophase), including chromosomal behavior and the resulting daughter cells. We'll also explore recent research on the regulation of mitosis and its implications in cancer development.

Chapter 2: Meiosis - The Foundation of Sexual Reproduction: A thorough examination of the two meiotic divisions (meiosis I and meiosis II), focusing on key events like crossing over, homologous chromosome pairing, and the reduction of chromosome number. We will incorporate recent findings on meiotic recombination and its role in genetic diversity.

Chapter 3: The Venn Diagram Comparison: A visual representation comparing and contrasting mitosis and meiosis using a Venn diagram, emphasizing similarities (e.g., phases of cell division) and differences (e.g., chromosome number, genetic variation). We will analyze the significance of these similarities and differences.

Chapter 4: Practical Applications and Implications: Discussion of the practical applications of understanding mitosis and meiosis in fields like medicine (cancer treatment, genetic counseling), agriculture (selective breeding), and biotechnology (genetic engineering). We'll explore how this knowledge benefits various sectors.

Conclusion: Summarizing the key differences and similarities between mitosis and meiosis, reiterating their biological importance, and highlighting avenues for future research. We'll underscore the importance of continued research in this area.

Introduction: Understanding the Fundamentals of Cell Division

Mitosis and meiosis are two essential processes of cell division, but they serve distinct purposes and employ different mechanisms. Mitosis, the process of asexual cell reproduction, results in two genetically identical daughter cells from a single parent cell. Meiosis, on the other hand, is a type of reductional cell division that produces four genetically unique haploid daughter cells from a single diploid parent cell, forming the basis of sexual reproduction. This foundational difference significantly impacts their roles in growth, development, and genetic diversity. Understanding these differences is crucial for comprehending various biological processes and has significant implications in fields ranging from medicine to agriculture. This ebook uses a Venn diagram as a powerful tool to visually represent and analyze these critical distinctions.

Chapter 1: Mitosis - The Engine of Growth and Repair

Mitosis is a fundamental process ensuring the growth and repair of somatic cells (all cells except reproductive cells). It's a continuous process divided into distinct phases: prophase, metaphase, anaphase, and telophase. During prophase, chromosomes condense and become visible, the nuclear envelope breaks down, and the mitotic spindle forms. In metaphase, chromosomes align at the metaphase plate, guided by the spindle fibers. Anaphase involves the separation of sister chromatids, pulled towards opposite poles of the cell. Finally, telophase sees the reformation of the nuclear envelope around the separated chromosomes, followed by cytokinesis—the division of the cytoplasm, resulting in two identical daughter cells, each with a complete set of chromosomes.

Recent research using advanced imaging techniques and molecular biology tools has significantly enhanced our understanding of mitotic regulation. For example, studies have identified specific checkpoint mechanisms that ensure accurate chromosome segregation, preventing errors that could lead to aneuploidy (abnormal chromosome number) and cancer. Understanding these checkpoints has implications for developing novel cancer therapies targeting mitotic processes.

Chapter 2: Meiosis - The Architect of Genetic Diversity

Meiosis is a specialized type of cell division responsible for generating gametes (sperm and egg cells) in sexually reproducing organisms. Unlike mitosis, meiosis involves two successive divisions, meiosis I and meiosis II, resulting in four haploid daughter cells, each containing half the number of chromosomes as the parent cell. Meiosis I is unique due to the pairing of homologous chromosomes (one from each parent) during prophase I, a process called synapsis. This pairing allows for crossing over, a crucial event where homologous chromosomes exchange genetic material, leading to genetic recombination and diversity among offspring. The separation of homologous chromosomes occurs during anaphase I, and the resulting daughter cells are haploid. Meiosis II is similar to mitosis, separating sister chromatids and producing four haploid daughter cells.

Recent research focuses on the intricate mechanisms governing meiotic recombination. Studies have identified specific proteins involved in homologous chromosome pairing and crossing over, providing valuable insights into the control of genetic variation. These findings have important implications for understanding the evolution of sexual reproduction and the generation of genetic diversity within populations. Furthermore, research is exploring the impact of meiotic errors on human health, as these errors can lead to chromosomal abnormalities such as Down syndrome and other genetic disorders.

Chapter 3: A Venn Diagram of Mitosis and Meiosis: Visualizing the Differences and Similarities

(Insert Venn Diagram Here - A visually appealing Venn diagram is crucial. The diagram should clearly illustrate the overlapping and distinct features of mitosis and meiosis, including aspects like chromosome number, cell type, number of daughter cells, and genetic variation.)

The Venn diagram above provides a clear visual comparison of mitosis and meiosis. The overlapping section represents shared features, such as the presence of phases like prophase, metaphase, anaphase, and telophase, and the involvement of spindle fibers. However, the distinct sections highlight the crucial differences: mitosis produces two diploid, genetically identical daughter cells, whereas meiosis results in four haploid, genetically unique daughter cells. The process of crossing over, exclusive to meiosis, is a major contributor to genetic diversity, and the reduction in chromosome number is fundamental to sexual reproduction. This visual representation reinforces the key concepts and aids in understanding the fundamental differences and similarities between these two crucial cellular processes.

Chapter 4: Practical Applications and Future Directions

Understanding mitosis and meiosis has far-reaching implications across various fields. In medicine, knowledge of these processes is fundamental to understanding cancer development. Uncontrolled mitosis is a hallmark of cancer, and targeting mitotic checkpoints is a promising strategy for developing new cancer therapies. Genetic counseling utilizes an understanding of meiosis to assess the risk of inherited genetic disorders. In agriculture, understanding meiosis is critical for selective breeding programs aimed at improving crop yields and disease resistance. Furthermore, advancements in biotechnology, particularly in genetic engineering, heavily rely on manipulating these cellular processes to achieve desired outcomes. This extends to applications like gene therapy and the creation of genetically modified organisms.

Future research will undoubtedly continue to explore the intricate molecular mechanisms that govern mitosis and meiosis. Advanced technologies like CRISPR-Cas9 gene editing offer exciting possibilities for investigating gene function and manipulating these cellular processes. Further research into meiotic recombination will enhance our understanding of genetic diversity and evolution. Similarly, deeper understanding of the regulation of mitosis is crucial for developing more effective cancer treatments.

Conclusion: A Foundation for Biological Understanding

Mitosis and meiosis are fundamental processes that underpin many aspects of biology. Their distinctions, highlighted through the comparative analysis and Venn diagram in this ebook, are pivotal to comprehending growth, development, reproduction, and the maintenance of genetic diversity within populations. The ongoing research into these processes continues to refine our understanding and opens avenues for numerous applications across diverse fields, further emphasizing their significance in biological sciences and beyond.

FAQs

1. What is the main difference between mitosis and meiosis? Mitosis produces two identical diploid cells, while meiosis produces four genetically unique haploid cells.
2. What is the role of crossing over in meiosis? Crossing over shuffles genetic material between homologous chromosomes, increasing genetic diversity.
3. How does mitosis contribute to growth? Mitosis increases the number of cells, leading to the growth and development of multicellular organisms.
4. What are the consequences of errors during meiosis? Errors during meiosis can lead to chromosomal abnormalities and genetic disorders.
5. How is mitosis involved in cancer development? Uncontrolled mitosis is a characteristic of cancer cells, leading to uncontrolled cell growth.
6. What are some practical applications of understanding mitosis and meiosis? Applications include cancer treatment, genetic counseling, and selective breeding in agriculture.
7. What is the significance of haploid cells produced during meiosis? Haploid cells are essential for sexual reproduction, allowing the fusion of gametes to form a diploid zygote.
8. How does the spindle apparatus function in both mitosis and meiosis? The spindle apparatus separates chromosomes and chromatids during both processes.
9. What are some future research directions in the field of mitosis and meiosis? Future research includes exploring the molecular mechanisms of these processes and developing new therapies targeting mitotic and meiotic errors.

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9. Advanced Microscopic Techniques for Studying Cell Division: A review of advanced imaging technologies used to visualize and analyze cell division processes.

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provides necessary background, it has chapters on the evidence for evolution that cover the fossil
record, DNA-sequence homologies, and protein homologies (evo-devo). It also includes a full history
of life from the first universal common ancestor, through the rise of the eukaryote and on to the
major groups of phyla. This section is followed by one on the mechanism of evolution with chapters
on variation, selection and speciation. The main part of the book ends with a chapter on human
evolution and this is followed by appendices that expand on the making of fossils, the history of the
subject and creationism. What marks this book as different from others on evolution is its
systems-biology perspective. This new area focuses on the role of protein networks and on
multi-level complexity, and is used in three contexts. First, most biological activity is driven by such
networks and this has direct implications for understanding evo-devo and for seeing how variation is
initiated, mainly during embryogenesis. Second, it provides the natural language for discussing
phylogenetics. Third, evolutionary change involves events at levels ranging from the genome to the
ecosystem and systems biology provides a context for integrating material of this complexity. The
book assumes a basic grounding in biology but little mathematics as the difficult subject of
evolutionary population genetics is mainly covered qualitatively, with major results being discussed
and used rather than derived. Principles of Evolution will be an interesting and thought-provoking
text for undergraduates and graduates across the biological sciences.

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Thomson, 2009-07-09 Keena Ford is so excited to go on a field trip to the United States Capitol with
her second-grade class! At school, she is running for a spot on the student council, and on the field
trip she's going to meet a real live U.S. representative. The only trouble is, mean Tiffany Harris

keeps teasing Keena and taking the best place in line. Keena doesn't mean to get into trouble, but trouble seems to find her anyway!

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Informatics Arvind Kumar Bansal, Javed Iqbal Khan, S. Kaisar Alam, 2019-12-23 This class-tested textbook is designed for a semester-long graduate or senior undergraduate course on Computational Health Informatics. The focus of the book is on computational techniques that are widely used in health data analysis and health informatics and it integrates computer science and clinical perspectives. This book prepares computer science students for careers in computational health informatics and medical data analysis. Features Integrates computer science and clinical perspectives Describes various statistical and artificial intelligence techniques, including machine learning techniques such as clustering of temporal data, regression analysis, neural networks, HMM, decision trees, SVM, and data mining, all of which are techniques used widely used in health-data analysis Describes computational techniques such as multidimensional and multimedia data representation and retrieval, ontology, patient-data deidentification, temporal data analysis, heterogeneous databases, medical image analysis and transmission, biosignal analysis, pervasive healthcare, automated text-analysis, health-vocabulary knowledgebases and medical information-exchange Includes bioinformatics and pharmacokinetics techniques and their applications to vaccine and drug development

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across the phyla and explained the mechanisms by which new species form. This textbook covers both this history and the mechanisms of speciation; it also aims to provide students with the background needed to read the research literature on evolution. Students will therefore learn about cladistics, molecular phylogenies, the molecular-genetical basis of evolutionary change including the important role of protein networks, symbionts and holobionts, together with the core principles of developmental biology. The book also includes introductory appendices that provide background knowledge on, for example, the diversity of life today, fossils, the geology of Earth and the history of evolutionary thought. Key Features Summarizes the origins of life and the evolution of the eukaryotic cell and of Urbilateria, the last common ancestor of invertebrates and vertebrates. Reviews the history of life across the phyla based on the fossil record and computational phylogenetics. Explains evo-devo and the generation of anatomical novelties. Illustrates the roles of small populations, genetic drift, mutation and selection in speciation. Documents human evolution using the fossil record and evidence of dispersal across the world leading to the emergence of modern humans.

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significance of this genetic design has been vividly evident since the discovery of non-Mendelian inheritance by Baur and Correns at the beginning of this century, and became indisputable in principle after Renner's work on interspecific nuclear/plastid hybrids (summarized in his classical article in 1934), studies on the genetics of organelles have long suffered from the lack of respectability. Non-Mendelian inheritance was considered a research sideline~ifnot a freak~by most geneticists, which becomes evident when one consults common textbooks. For instance, these have usually impeccable accounts of photosynthetic and respiratory energy conversion in chloroplasts and mitochondria, of metabolism and global circulation of the biological key elements C, N, and S, as well as of the organization, maintenance, and function of nuclear genetic information. In contrast, the heredity and molecular biology of organelles are generally treated as an adjunct, and neither goes as far as to describe the impact of the integrated genetic system.

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