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RESOURCES FOR SCHOOL TEACHERS

GENETICS & EVOLUTION IN BIOLOGY

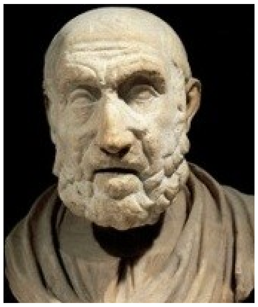
- THE BLUEPRINT OF LIFE -

The *Atlas of Human Imagination* and its many pioneers have played a major role in our understanding of modern biology. Within biology, the story of inheritance, heredity, genetics and evolution is one of humanity's longest-running intellectual adventures, spanning philosophy, mathematics, art and the life sciences.

From Hippocrates's first reflections on heredity to modern genome editing, understanding how traits pass from one generation to the next has demanded both careful scientific observation and creative imagination. Each breakthrough - whether conceptual, experimental or technological - represents a leap in our ability to understand the invisible patterns that govern life.

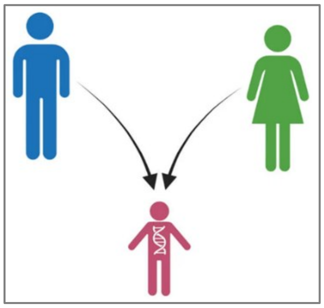
This document highlights 18 pioneering minds from the *Atlas* poster, outlining their bold discoveries and concepts, and how they link to our current biological understanding of inheritance, genetics and evolution. By placing philosophers, artists, mathematicians, technicians, and life scientists alongside each other, it demonstrates that true discovery is rarely confined to a single discipline – it is almost always a team effort.

1. Hippocrates (400 BCE)



Research Discovery

The concept that both parents influence offspring features – first ideas of heredity



Hippocrates was an Ancient Greek physician, traditionally regarded as the "father of medicine," who sought natural rather than supernatural explanations for disease and bodily function. He proposed one of the earliest naturalistic theories of inheritance, known as *pangenesis*, in which material from all parts of the body was thought to contribute to offspring (see image, right). Although incorrect, this idea framed *inheritance* as a physical, transmissible process, establishing heredity as a legitimate subject for biological explanation rather than myth or theology.

Key breakthroughs related to:

- Introduced the idea that both parents influence offspring characteristics
- Set the foundation for later mechanistic (rather than mystical) theories of inheritance

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2. Fibonacci (1202)

Research Discovery

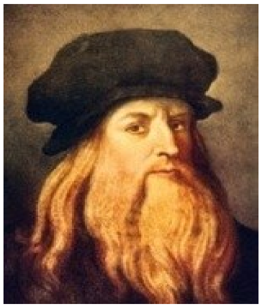
The Fibonacci sequence and its application to breeding and population growth in rabbits (see image right)

Fibonacci was an Italian mathematician who, in his book *Liber Abaci* (1202), described a numerical sequence that could be used to model idealised population growth, later known as the Fibonacci sequence. Although not a biological theory of inheritance, this formulation provided a mathematical framework for understanding how simple rules can produce growth across generations, a concept that later proved crucial in *population biology* and evolutionary modelling.

Key breakthroughs related to:

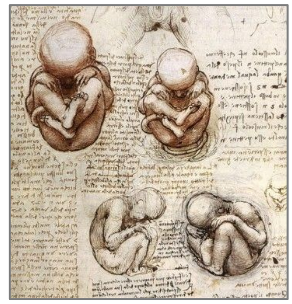
- Introduced mathematical laws describing growth across generations
- Provided an abstract framework applied to population dynamics and heredity patterns

3. Leonardo da Vinci (1510)



Research Discovery

Anatomy as a way of empirically observing inherited traits from both parents



Leonardo da Vinci was an Italian polymath of the Renaissance whose work spanned art, anatomy, engineering and natural philosophy. Through careful *anatomical study* and observation (see image, right), he recognised that inherited traits could be transmitted from both parents and rejected theories that assigned exclusive generative power to either sex. Although he did not formulate a formal theory of heredity, Leonardo's empirical approach helped shift thinking towards observation-based explanations of inheritance.

Key breakthroughs related to:

- Recognised biparental contribution to inherited traits through empirical observation
- Advanced an evidence-based approach to heredity grounded in anatomy

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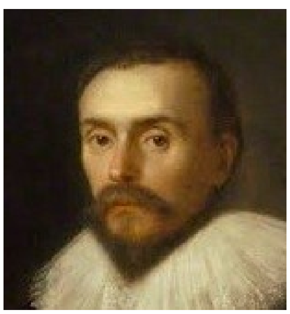
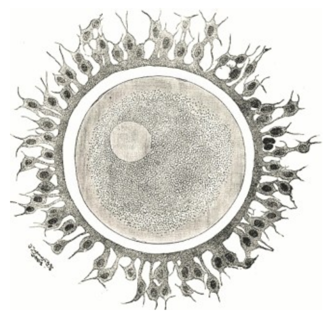
4. William Harvey (1651)



Research Discovery

The concept that "all life comes from the egg" (Latin: *omne vivum ex ovo*) – see image, right



William Harvey was an English physician and anatomist best known for discovering the circulation of blood in 1628 and later for his work on embryology. In *Exercitationes de Generatione Animalium* (1651), he argued for *epigenesis*, the idea that development unfolds progressively rather than arising from preformed miniature organisms. This perspective laid important groundwork for understanding heredity as a process integrated with development.

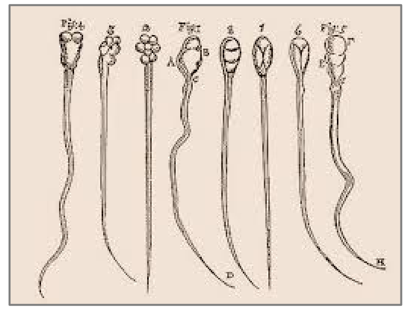
Key breakthroughs related to:

- Proposed that organisms develop progressively from undifferentiated material rather than preformed structures

5. Antonie van Leeuwenhoek (1674)

Research Discovery

High-resolution optical microscopy, making heredity visible to the human eye



The Dutchman Antonie van Leeuwenhoek invented the single-lens microscope capable of magnification up to x300. Through his microscopic observations in the late seventeenth century, he was the first to describe *sperm cells* (see image, right) and single-celled organisms, revealing previously invisible biological structures. Although he did not develop a theory of inheritance, Leeuwenhoek's work provided the visual and technical foundation necessary for later discoveries in cell biology, reproduction and ultimately genetics.

Key breakthroughs related to:

- Enabled the observation of cells, gametes and microorganisms through advanced microscopy, crucial to cell theory, reproductive biology and later genetic research

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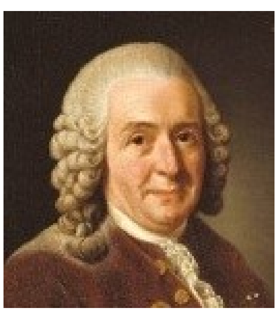
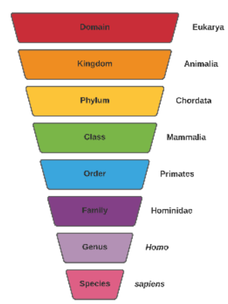
6. Carl Linnaeus (1735)



Research Discovery

Taxonomy of life – and the key concept that species traits are stable and heritable

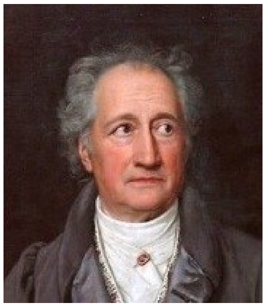


Carl Linnaeus was a Swedish botanist, physician and zoologist, often called the "father of modern taxonomy," who developed the binomial system for classifying organisms. By organising species into a systematic hierarchy (see image, right), Linnaeus implied that traits are stable and heritable across generations, providing a framework in which heredity could be studied comparatively.

Key breakthroughs related to:

- Established species continuity, implying that inherited traits persist reliably across generations, and allowing patterns of heredity to be systematically studied

7. Johann Wolfgang von Goethe (1790)



Research Discovery

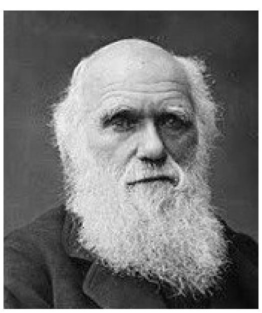
The concept of *Urpflanze* – an inherited biological form that influences plant morphology

Johann Wolfgang von Goethe was a German writer, naturalist and philosopher whose studies extended beyond literature to botany and morphology. In his work *Metamorphosis of Plants* (1790), he proposed that all plant forms derive from a fundamental archetype (*Urpflanze* in German). While not a geneticist, Goethe's ideas introduced the concept that development and inherited form are constrained by underlying patterns (see image, right).

Key breakthroughs related to:

- Introduced the concept of morphological archetypes, showing continuity and transformability in inherited forms

8. Charles Darwin (1859)



Research Discovery

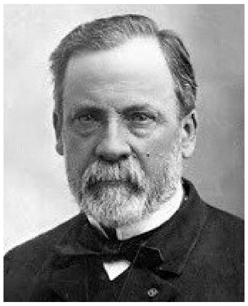
The concept and evidence for evolution, based on natural selection of organisms

Charles Darwin was an English naturalist and geologist, best known for developing the *theory of evolution by natural selection*. In *On the Origin of Species* (1859), he argued that heritable variation within populations drives evolutionary change (see image, right). While he did not know the mechanisms of inheritance, Darwin clearly established that traits must be transmissible across generations for natural selection to operate. This theory of evolution was also independently proposed by Alfred Russel Wallace, at a similar time to Darwin.

Key breakthroughs related to:

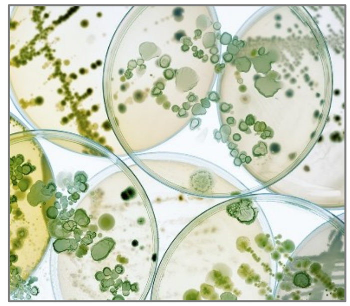
- Formulated natural selection, showing that heritable traits influence survival
- Emphasised the importance of heritable variation as the engine of evolutionary change

9. Louis Pasteur (1862)



Research Discovery

The concept of biogenesis: that *"life only comes from life"*



Louis Pasteur was a French chemist and microbiologist renowned for his work on fermentation, vaccination and the germ theory of disease. Through experiments with microbes in the early 1860s (see image, right), he demonstrated the principle of *biogenesis* - that life only arises from pre-existing life - showing that living organisms maintain stable biological properties across generations.

Key breakthroughs related to:

- Proved that living organisms maintain stable properties across generations, and that life can only come from pre-existing life

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10. Gregor Mendel (1866)

Research Discovery

The key concept of inheritance and the laws of segregation

Gregor Mendel was an Austrian monk and scientist, often called the "father of modern genetics," who conducted systematic experiments on pea plants (see image, right). Through his work published in 1866, he demonstrated that traits are inherited as discrete units, now called *genes*, which segregate and assort independently during reproduction. Mendel's discoveries provided the first mathematical framework for inheritance, explaining why traits do not simply blend between parents. This seminal work later inspired countless scientists, like Wilhelm Johannsen who then coined the terms *gene*, *genotype* and *phenotype* in 1909, as well as Thomas Hunt Morgan who discovered the important link between *genes and chromosomes* in 1910.

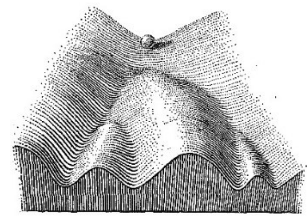
Key breakthroughs related to:

- Formulated the laws of segregation and independent assortment, describing predictable patterns of inheritance
- Introduced the concept of discrete heritable units (*genes*) underlying observable traits

11. Conrad Waddington (1942)

Research Discovery

Epigenetics – the landscape in which gene expression is influenced by environment



Conrad Waddington was a British developmental biologist and geneticist known for integrating genetics with embryology. He introduced the concept of the *epigenetic landscape* (see image, right) illustrating how genes interact with developmental processes to shape outcomes. Waddington's work later highlighted that inheritance is not just about DNA sequences but also about gene-environment interactions that influence how traits are expressed across generations. This was at a time when Oswald Avery would soon demonstrate in 1944 that DNA, not protein, is the substance responsible for heredity.

Key breakthroughs related to:

- Developed the epigenetic landscape concept, linking genes, development, environment and even behaviour

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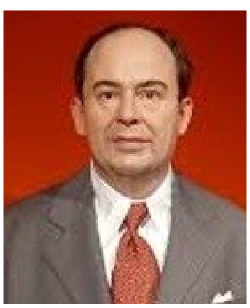
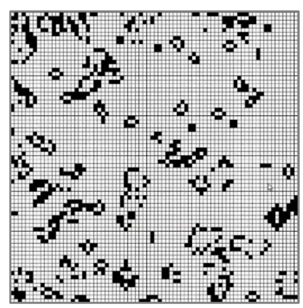
12. John von Neumann (1945)



Research Discovery

The key concept of self-replicating systems – before DNA's structure was even discovered



John von Neumann was an exceptionally talented physicist and mathematician with great breadth. He developed the concept of *self-replicating automata* (see image, right), formalising inheritance as the transmission of information through a system that can copy itself while preserving the original structure. Von Neumann's ideas provided a theoretical framework for understanding heredity as an information-based process, influencing both molecular biology and later computational models of evolution.

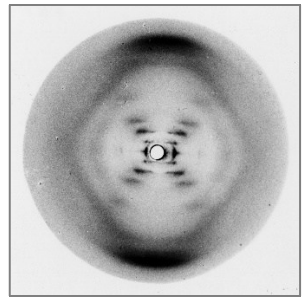
Key breakthroughs related to:

- Conceptualised inheritance as information replication within a self-reproducing system
- Provided an abstract model linking genes, replication and system-level continuity

13. Rosalind Franklin (1952)

Research Discovery

The X-ray diffraction patterns of DNA molecules, unlocking the structure of life's code



Rosalind Franklin was a British chemist and X-ray crystallographer whose work was crucial to understanding the structure of DNA. Her X-ray diffraction images (see image, right) provided clear evidence that DNA has a helical structure, enabling Watson and Crick to model its double helix. Franklin's contributions demonstrated how molecular structure underpins heredity, linking the chemical composition of DNA to its ability to store and transmit genetic information.

Key breakthroughs related to:

- Produced X-ray diffraction images revealing the helical structure of DNA
- Provided the empirical foundation for understanding how DNA carries and transmits hereditary information

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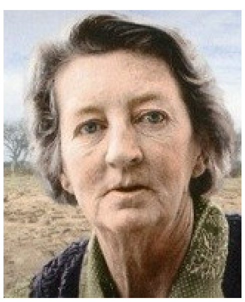
14. Mary Leakey (1962)



Research Discovery

Inheritance of the human species, spanning more than 3 million years

Mary Leakey was a British palaeoanthropologist whose discoveries transformed understanding of human evolution. Through fossil finds at Olduvai Gorge, Tanzania (see image, right) and later footprint evidence at sites such as Laetoli, she provided direct evidence of human ancestry, continuity and divergence over deep evolutionary time. While not a geneticist, Leakey's work grounded inheritance and evolution in the physical record of descent, demonstrating that heritable human traits persist and transform across millions of years.

Key breakthroughs related to:

- Provided fossil evidence demonstrating evolutionary continuity and divergence in human lineage spanning many millions of years

15. Dame Jane Goodall (1966)

Research Discovery

Inheritance of traits through social learning, rather than genetics alone

Jane Goodall was a British primatologist and anthropologist renowned for her long-term studies of wild chimpanzees in Gombe Stream National Park, Tanzania (see image, right). Beginning in the 1960s, she observed that chimpanzees transmit learned behaviours and tool-use practices across generations, demonstrating a form of inheritance independent of DNA. Goodall's work expanded the concept of heredity to include cultural and social transmission, showing that some traits can persist through learning rather than genetics alone.

Key breakthroughs related to:

- Demonstrated cultural inheritance in non-human primates, showing traits can be passed via social learning

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16. Richard Dawkins (1976)

Research Discovery

Gene-centred view of evolution, with genes as the primary units of selection

Richard Dawkins is a British evolutionary biologist and author, known for his work in promoting the gene-centred view of evolution. In *The Selfish Gene* (1976), he proposed that genes are the primary units of selection (see image, right), framing evolution in terms of replicators and their survival rather than individual organisms. Dawkins introduced memorable concepts and terms, such as *replicators* and *memes* - extending evolutionary thinking to culture more generally.

Key breakthroughs related to:

- Developed the gene-centred view of evolution, emphasising replicators as the units of selection; as well as cultural replicators like *memes*

17. Sir Ian Wilmut (1996)

Research Discovery

Cloned *Dolly* the sheep – demonstrating that adult cells can be re-programmed

Sir Ian Wilmut is a British embryologist and geneticist best known for leading the team that cloned the sheep *Dolly* in 1996 (see image, right). This work demonstrated that differentiated adult cells retain the complete nuclear genome, showing that full hereditary information can be preserved and reprogrammed. Wilmut's experiments provided a powerful proof that genetic continuity is maintained across cell types and can be manipulated experimentally.

Key breakthroughs related to:

- Showed that differentiated cells retain the full nuclear genome, confirming genomic continuity, and that hereditary information can be reprogrammed for cloning

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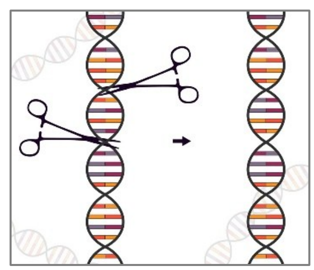
18. Jennifer Doudna & Emmanuelle Charpentier (2012)

Research Discovery

Precise gene-editing of DNA via *CRISPR-Cas9* technology



Jennifer Doudna is an American biochemist who, together with her French collaborator Emmanuelle Charpentier, jointly developed the *CRISPR–Cas9* gene-editing technology. In 2012, they demonstrated that DNA can be precisely and programmably modified, allowing targeted changes to hereditary material. This work, enabled by advances in genomics following the Human Genome Project *(*HGP), transformed heredity from a naturally transmitted process into one that can be directly edited. CRISPR technology, with its scissor-like precision (see image, right), is now opening the door to revolutionary applications in genetics, medicine and biotechnology.

Key breakthroughs related to:

- Developed CRISPR–Cas9 technology, enabling precise, programmable editing of DNA
- Transformed inheritance from a fixed process into an experimentally controllable system

Conclusion:

Together, these 18 pioneers from the *Atlas of Human Imagination* show that our understanding of inheritance, genetics and evolution did not emerge from biology alone, but from the convergence of many diverse forms of imagination. Physicians, naturalists, mathematicians, artists, technicians and theorists each contributed essential pieces: observation and anatomy from figures such as Leonardo da Vinci, mathematical structure from Fibonacci and von Neumann, technical vision from Leeuwenhoek's microscopy, and biological insight from Darwin through to Doudna.

This **cross-disciplinary interplay** reveals how major breakthroughs arise when ideas, tools and perspectives from different domains intersect. In this way, the history of heredity reflects the broader story captured in the *Atlas of Human Imagination*: *progress is not solely driven by isolated genius, but by creative connections across fields, cultures, generations and different ways of thinking.*

David Jarvis

Some Honourable Mentions in the World of Genetics and Evolution:

These additional 24 figures further highlight how biology has been shaped by contributions from philosophy, botany, computing and biotechnology:

- Aristotle (c. 350 BCE) – argued that inheritance involves the transmission of organising form rather than material substance
- Galen (c. 180 CE) – argued that both parents contribute material to offspring, reinforcing the concept of biparental inheritance
- Thomas Malthus (1798) – argued that population growth outpaces resources, creating competition that drives natural selection
- Jean-Baptiste Lamarck (1809) – proposed that acquired characteristics could be inherited as a mechanism for evolution
- Alfred Russel Wallace (1858) – independently formulated the theory of evolution by natural selection
- Ernst Haeckel (1866) – illustrated embryonic development, linking form, evolution and inheritance through artful scientific visualisation
- August Weismann (1892) – distinguished between germ cells and somatic cells, rejecting inheritance of acquired traits
- William Bateson (1900) – popularised Mendel's work and coined the term *genetics*
- Wilhelm Johannsen (1909) – defined the concepts of gene, genotype, and phenotype
- Thomas Hunt Morgan (1910) – demonstrated that genes are carried on chromosomes
- Hermann Muller (1927) – demonstrated that mutations can be induced by X-rays, linking genetics to environmental change
- Oswald Avery (1944) – showed that DNA is the molecule responsible for heredity
- Colin MacLeod (1944) – co-authored the experiments identifying DNA as the hereditary material
- Maclyn McCarty (1944) – helped establish DNA as the chemical basis of inheritance
- Barbara McClintock (1950) – discovered transposable elements, showing genomes are dynamic rather than fixed
- Erwin Chargaff (1950) – discovered base-pairing rules (A=T and G=C), critical for understanding faithful DNA replication
- Maurice Wilkins (1952) – collaborated on X-ray diffraction data that revealed DNA's helical structure, complementing Franklin's work
- Francis Crick & James Watson (1953) – published DNA's double helix structure, based on Franklin's work
- Matthew Meselson & Franklin Stahl (1958) – experimentally demonstrated semi-conservative DNA replication, showing that DNA is copied without destroying the original template
- Sydney Brenner (1961) – worked on the genetic code and RNA, linking heredity to protein synthesis
- Craig Venter (2000) – advanced genomics by leading rapid sequencing of the human genome
- Shinya Yamanaka (2006) – induced pluripotent stem cells (iPSCs), showing adult cells can be reprogrammed, complementing Wilmut's work

FOR TEACHERS

Using the *Atlas of Human Imagination* in Lessons

Some Classroom Ideas about Heredity, Genetics and Evolution (14-18 Yrs):

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1. From bodies to inheritance

Pioneers: *Hippocrates → Harvey*
Idea: Students compare Hippocrates' *pangenesis* with Harvey's *epigenesis* to discuss how ideas of inheritance moved from whole-body contribution to developmental processes.
Concepts: Early inheritance models, development vs transmission.

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2. Fibonacci and runaway populations

Pioneers: *Fibonacci → Darwin*
Idea: Use the Fibonacci sequence to model ideal population growth, then introduce environmental limits to show why natural selection becomes inevitable.
Concepts: Population growth, competition, evolution.

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3. Seeing the invisible

Pioneers: *Leonardo da Vinci → Leeuwenhoek*
Idea: Students examine drawings of anatomy alongside microscope images to explore how observation and technology changed our understanding of reproduction and life.
Concepts: Observation, anatomy, microscopy.

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4. Classifying life

Pioneers: *Linnaeus*
Idea: Students classify everyday animals, plants or organisms using *Linnaean* principles, then discuss why stable inheritance is required for classification to work.
Concepts: Species, taxonomy, heredity.

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5. Form and transformation

Pioneers: *Goethe → Waddington*
Idea: Students analyse and draw developmental pathways or "*epigenetic landscapes*" to show how form changes within inherited constraints.

Concepts: Development, morphology, gene–environment interaction.

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6. Natural selection in action

Pioneers: *Darwin → Pasteur*
Idea: Model selection using microbial survival or resistance scenarios, linking variation, selection, and biological continuity.
Concepts: Variation, selection, survival.

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7. Cracking inheritance with peas

Pioneers: *Mendel*
Idea: Use coins or cards to simulate *Mendelian* crosses and explore probability in inheritance.
Concepts: Genes, segregation, non-blending inheritance.

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8. DNA as information

Pioneers: *Franklin → Crick & Watson → von Neumann*
Idea: Compare DNA replication with copying information (recipes, code), showing how structure enables faithful information transfer.
Concepts: DNA structure, information, replication.

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9. Inheritance beyond genes

Pioneers: *Mary Leakey → Jane Goodall*
Idea: Compare fossil inheritance over deep time with cultural inheritance in chimpanzees.
Concepts: Evolutionary inheritance, culture, behaviour.

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10. From understanding to intervention

Pioneers: *Wilmut → Doudna & Charpentier*
Idea: Debate how cloning and CRISPR gene-editing change the meaning of inheritance.
Concepts: Reprogramming, gene editing, ethics.