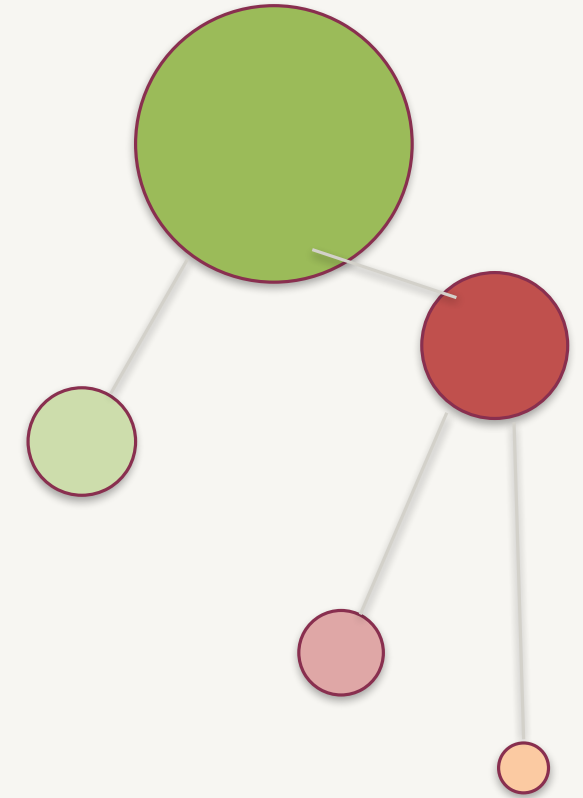


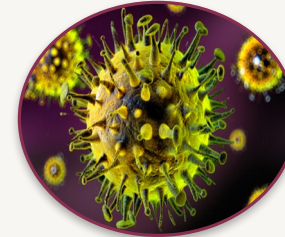
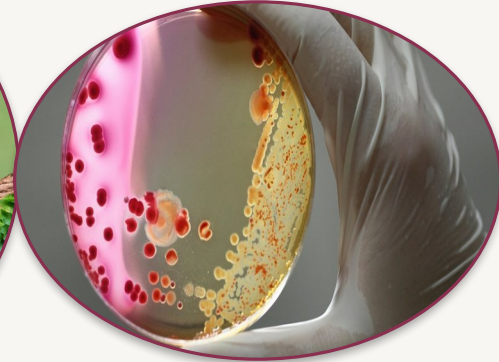
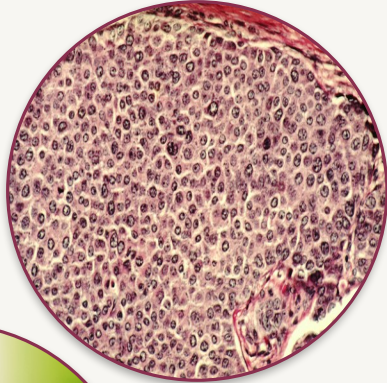
The Essence of Life (Biology 101)

A short subtitle or framing question



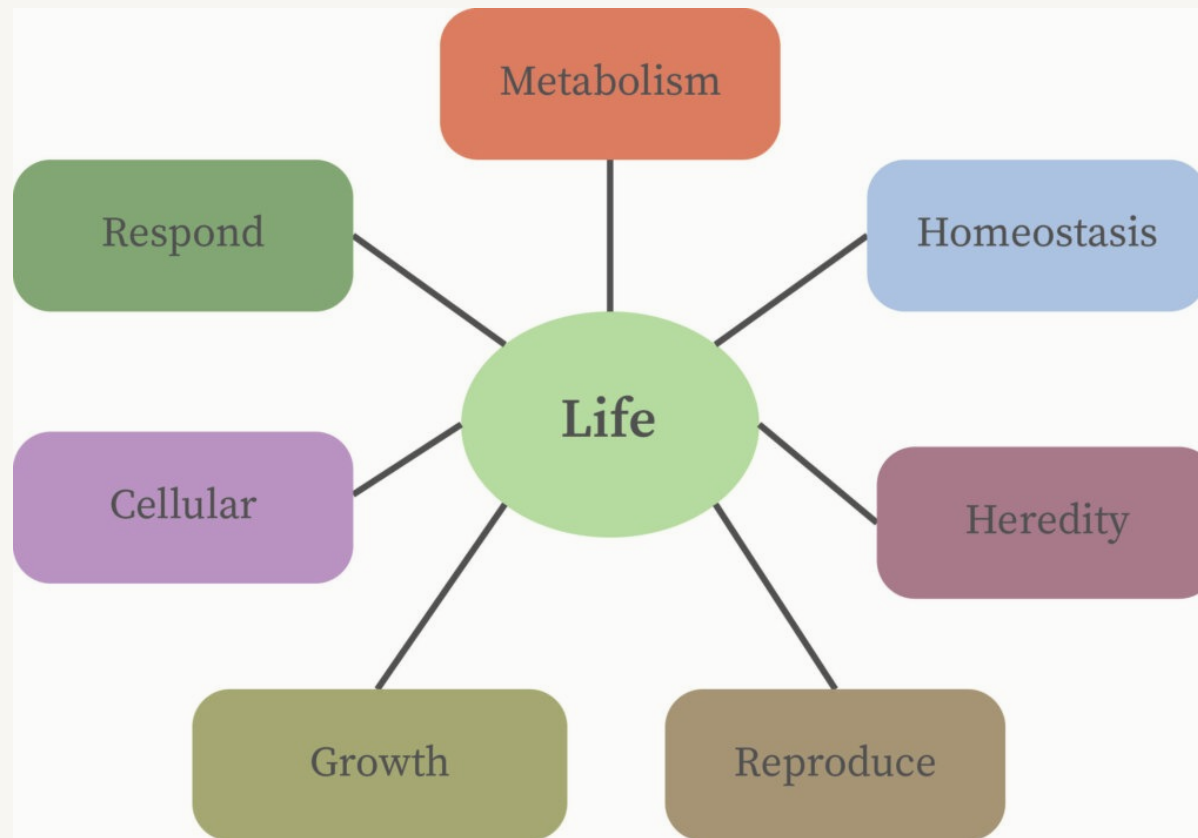
What is *life*? When is something *alive*?

01 What is life? When is something alive?



QUESTION

What is **life**? When is something **alive**?



QUESTION

What is **life**? When is something **alive**?

Response: Ability to detect and react to changes in the internal or external environment.

Metabolism: The set of chemical reactions that transform matter and energy to maintain life.

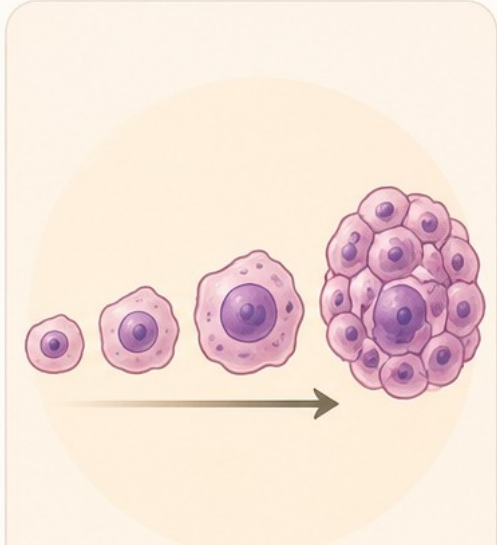
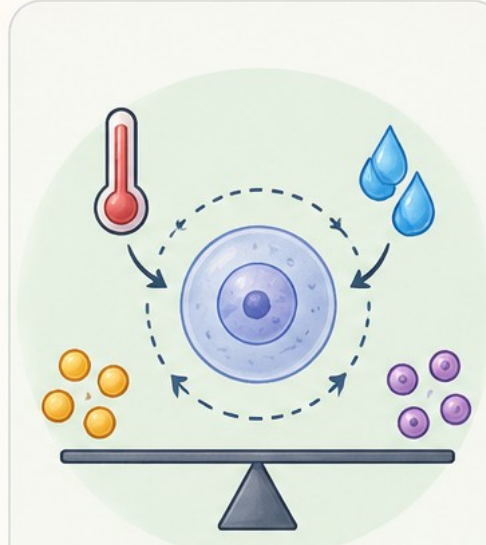
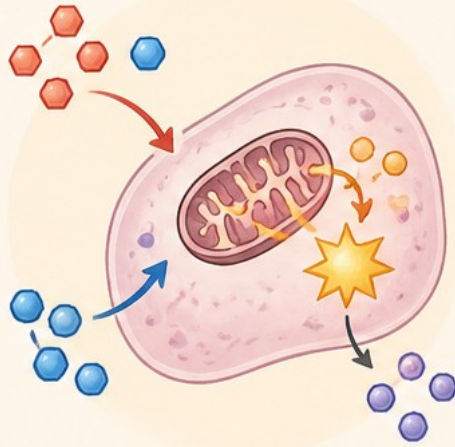
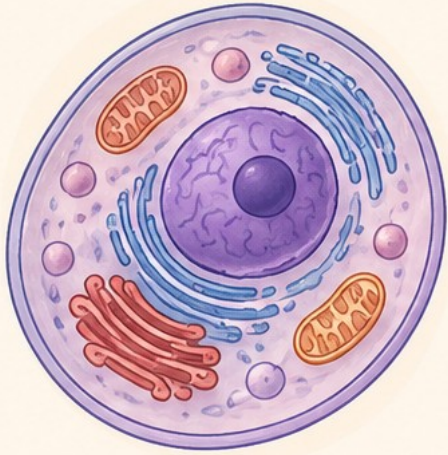
Homeostasis: Regulation of internal conditions within ranges compatible with life despite disturbances.

Cellularity: Being composed of one or more cells, the fundamental units of living systems.

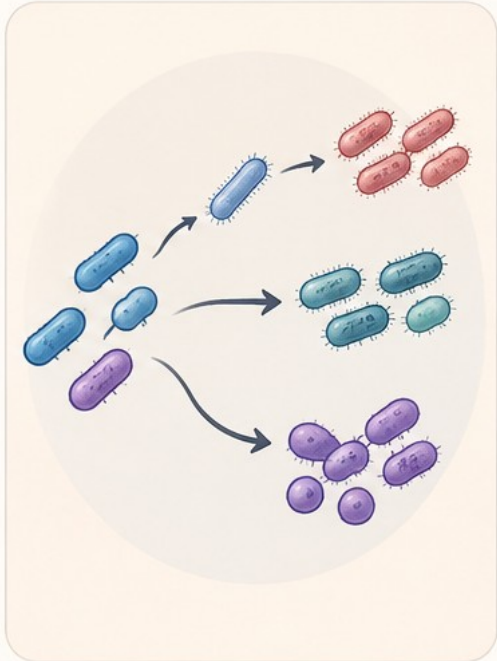
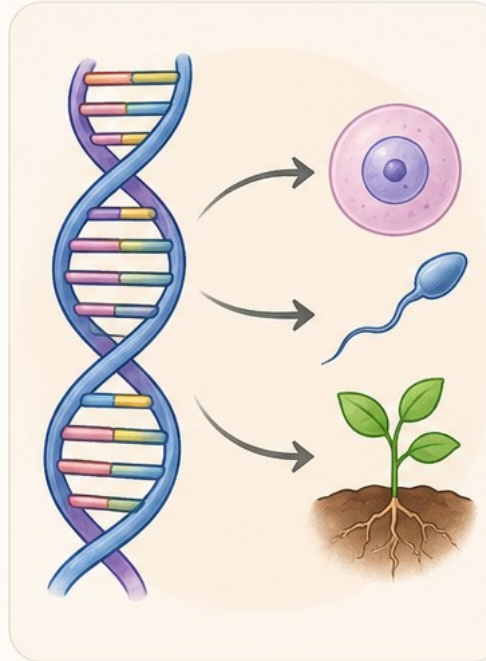
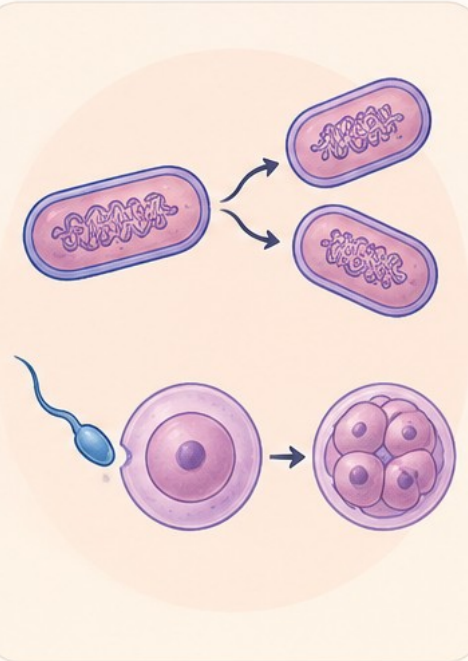
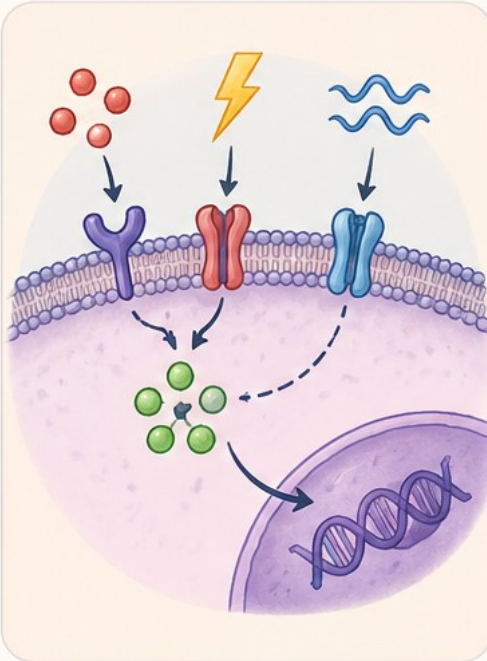
Heredity: Storage and transmission of biological information, primarily through DNA, from cells or organisms to their descendants.

Growth: Increase in cell size, cell number, or organized biological structure.

Reproduction: Production of new cells or organisms, sexually or asexually.



Cellularity: Being composed of one or more cells, the fundamental units of living systems.



CONCEPT **Cell: The Smallest Unit of life**

Water / Lipid membrane

DNA, RNA

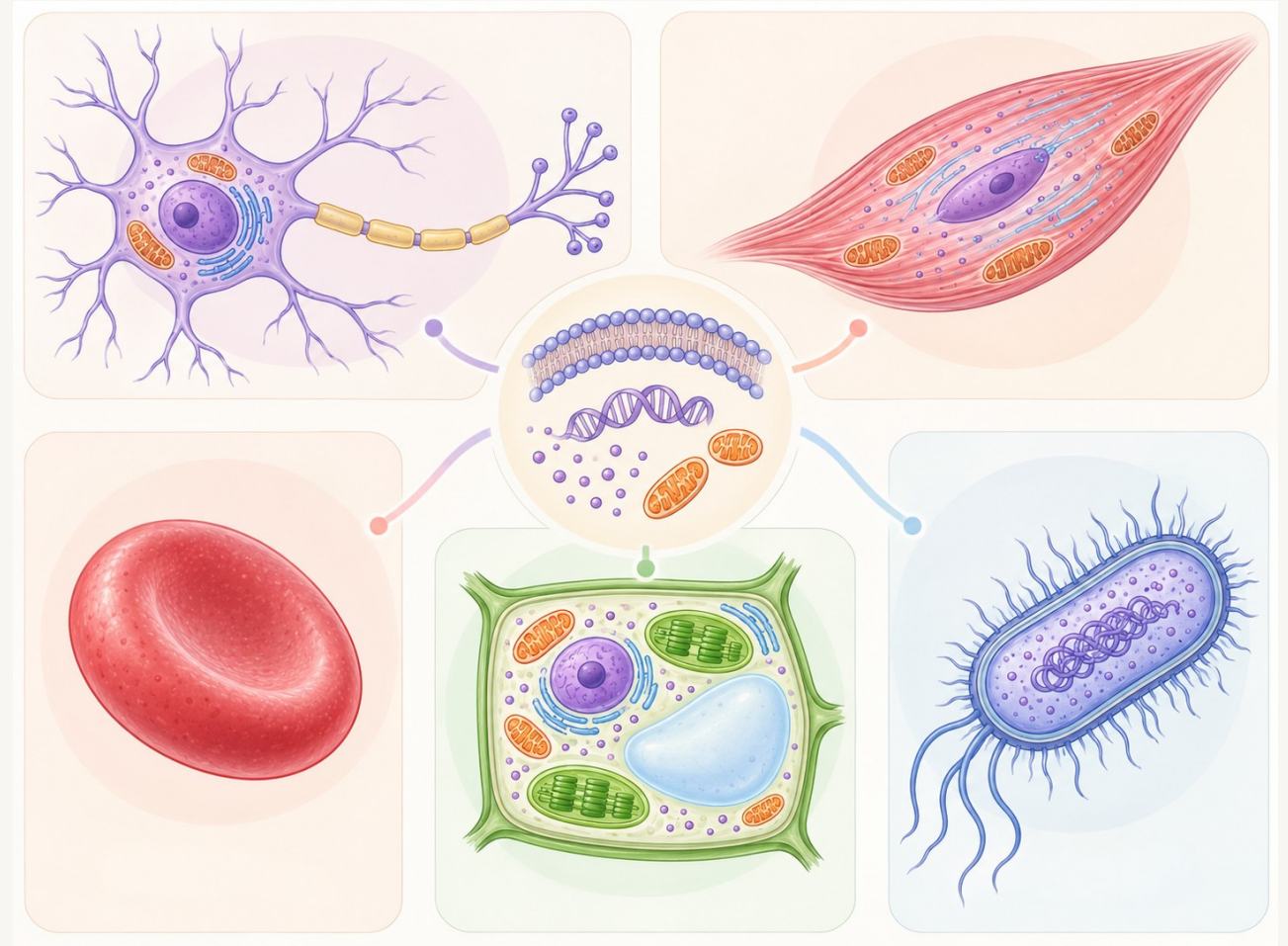
Ribosome, Proteins

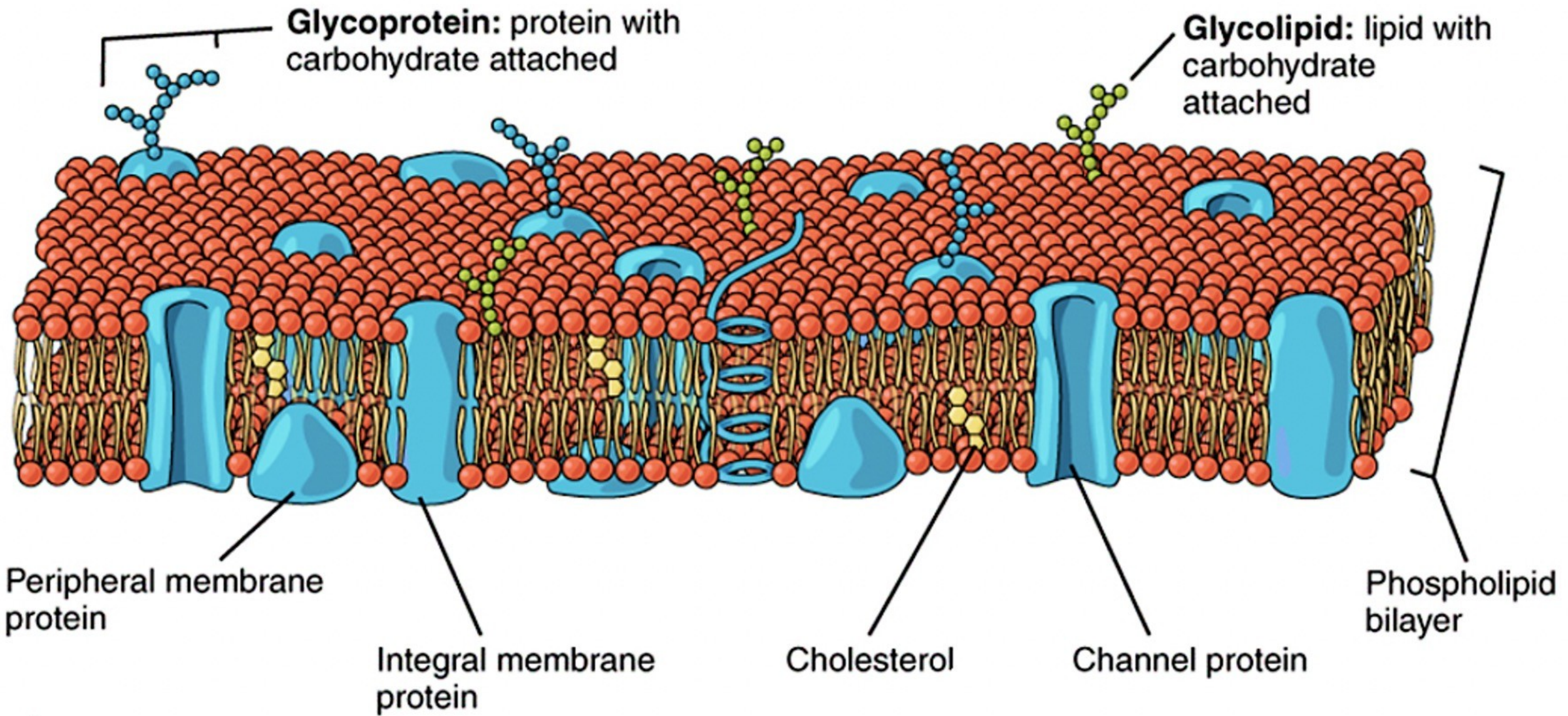
Using ATP to store energy

Duplication

Gene expression

Translation

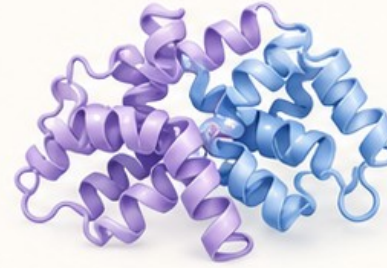
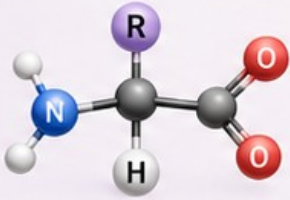




Biochemistry

small molecules → macromolecules

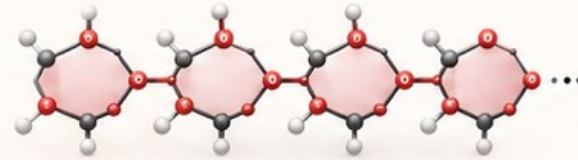
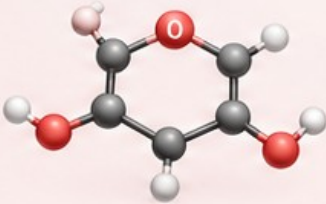
Amino acids



Proteins



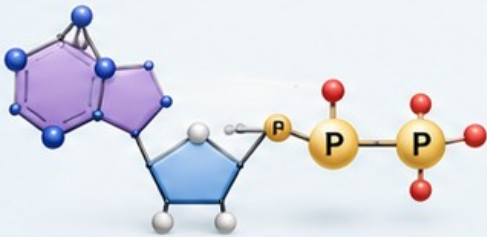
Sugars



Carbohydrates



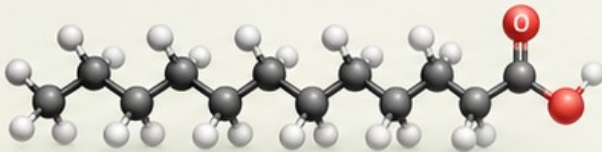
Nucleotides



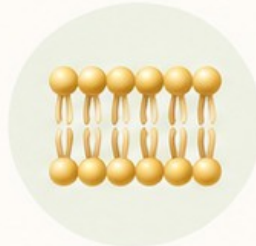
DNA / RNA



Fatty acids



Lipids



Cells are chemistry.

Gene Expression in a Eukaryotic Cell

From DNA to a functional protein

Nucleus

(DNA is inside the nucleus)

Gene

DNA

1

Transcription

RNA polymerase copies the gene's DNA sequence into pre-mRNA.

pre-mRNA

2

mRNA processing

- Add 5' cap
- Add poly(A) tail
- Remove introns (splicing)

mature mRNA

5' cap

poly(A) tail

3'

Nuclear pore

(exports mRNA to cytoplasm)

Cytoplasm

(site of protein synthesis)

3

Translation

The ribosome reads the mRNA sequence and links amino acids together.

polypeptide

4

Protein formation and folding

The polypeptide folds into a functional protein (with the help of chaperone proteins).

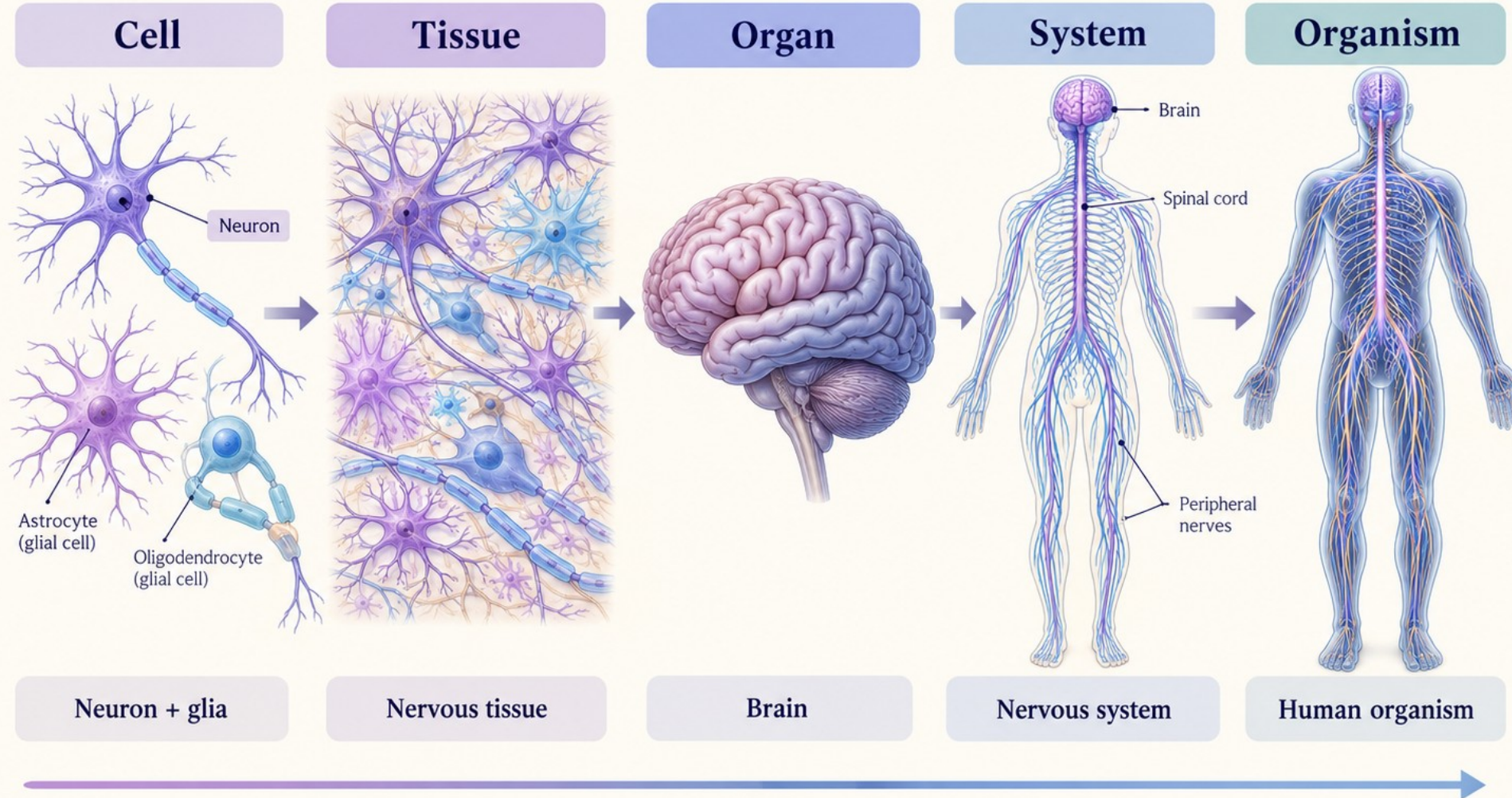
protein

(functional, folded)

The Biological Hierarchy

FROM CELLS TO A HUMAN ORGANISM

A continuous organization from specialized cells to complex function



CONTINUITY OF STRUCTURE AND FUNCTION

The same nervous system, organized across levels of biological complexity

EMBRYO DEVELOPMENT



Fertilized
egg



2-cell
stage



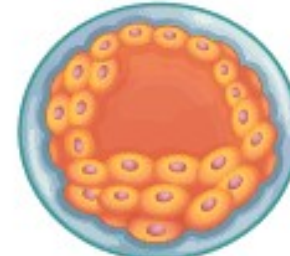
4-cell
stage



8-cell
stage



16-cell
stage



Blastocyst



Foetus
4-weeks



Foetus
10-weeks



Foetus
16-weeks

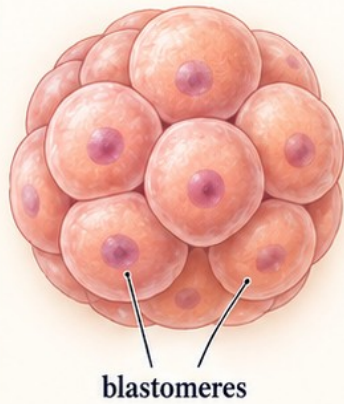


Foetus
20-weeks

From Early Embryo to Germ Layers and Neurulation

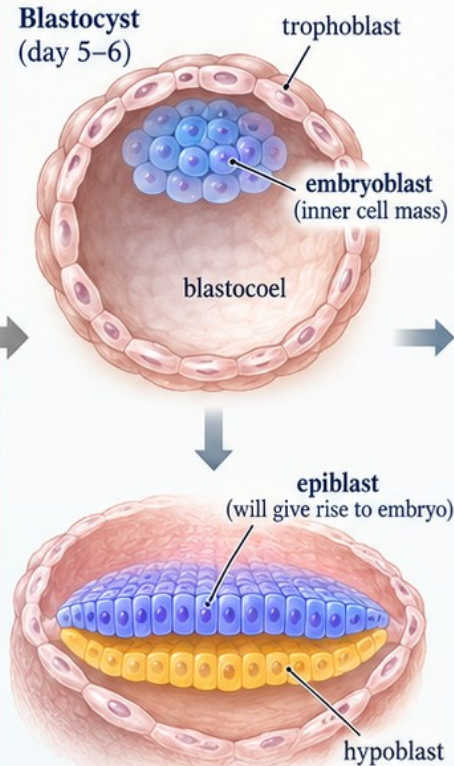
Four stages of early human development

1 Stage 1: Morula (16–20 cells)



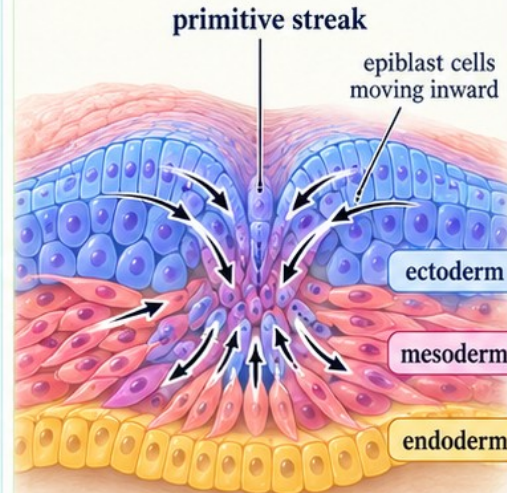
A compact ball of 16–20 blastomeres resulting from cleavage divisions.

2 Stage 2: Blastocyst / early embryonic disc



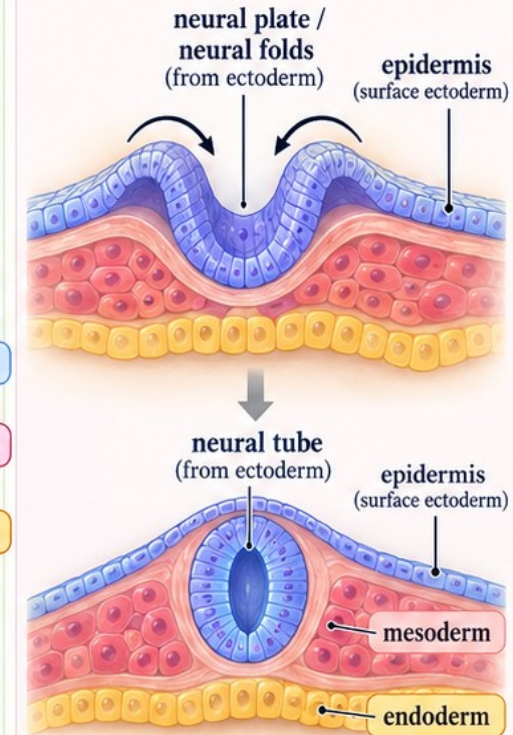
Early embryonic disc (day 6–7)

3 Stage 3: Gastrulation – three germ layers form



Epiblast cells move through the primitive streak, giving rise to the three germ layers: ectoderm, mesoderm, and endoderm.

4 Stage 4: Neurulation and surface ectoderm



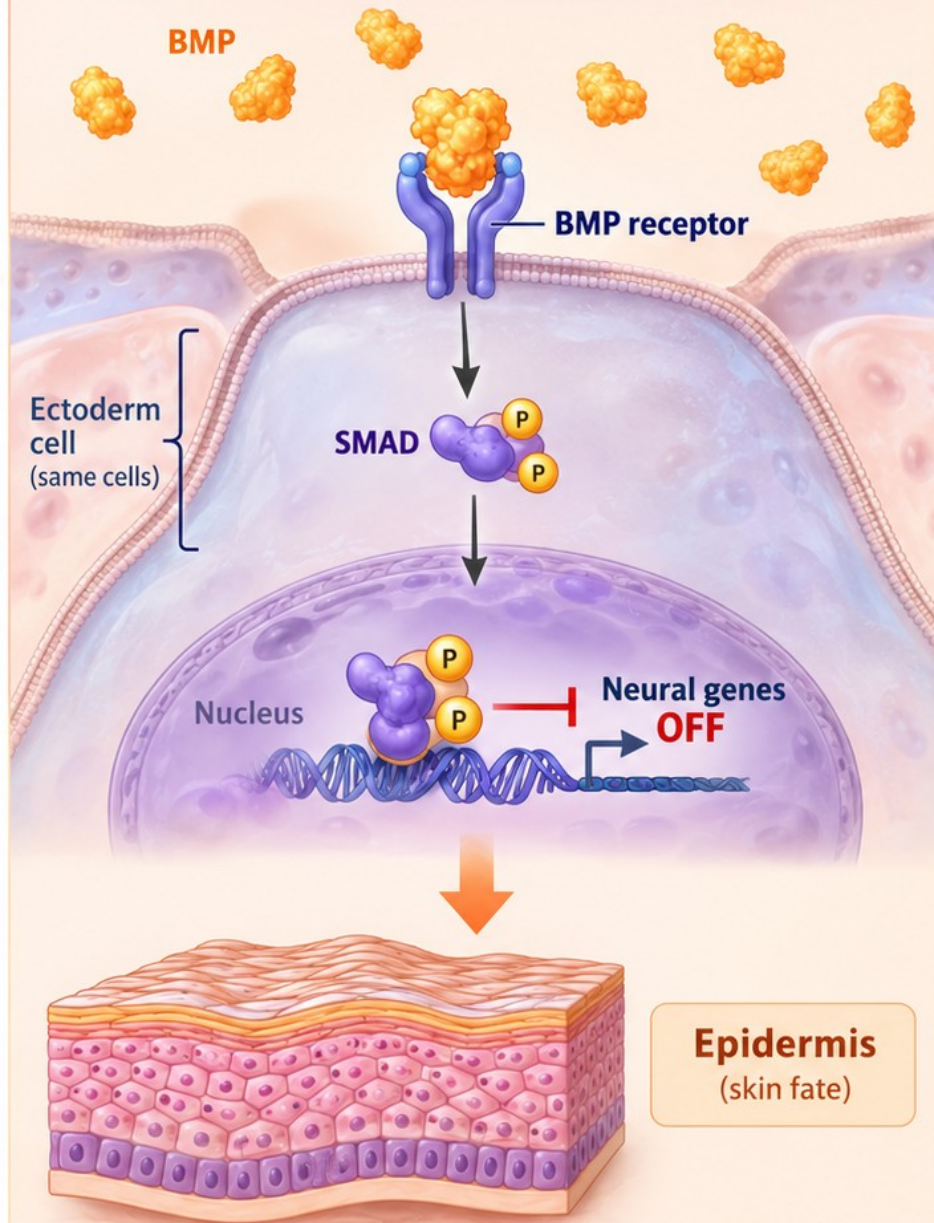
The neural plate (ectoderm) folds to form the neural tube, while the outer ectoderm becomes the epidermis. Mesoderm lies beneath and around the neural tube, and endoderm remains below.

Ectoderm
(nervous system, epidermis)

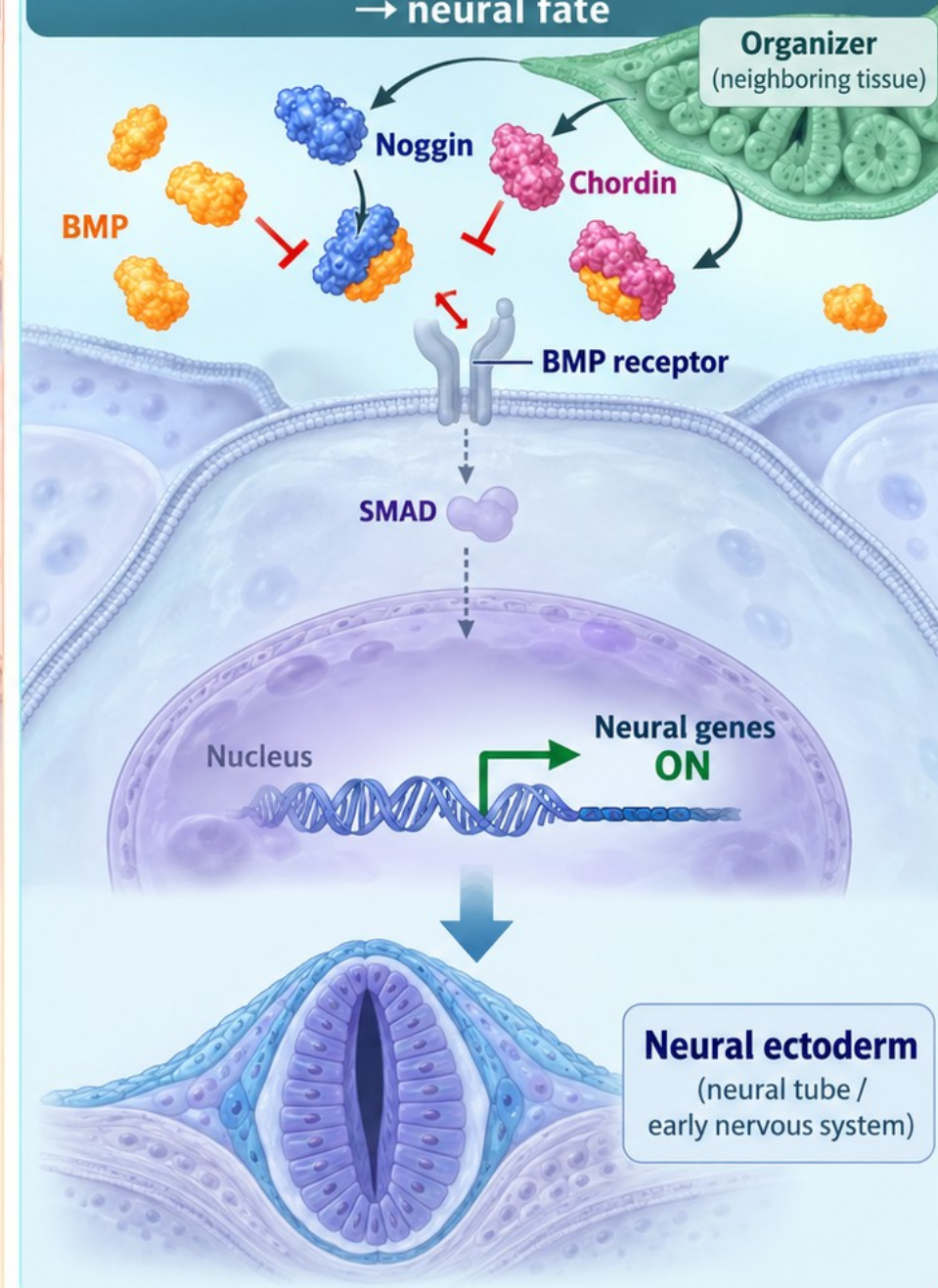
Mesoderm
(muscle, bone, heart, kidneys, connective tissues)

Endoderm
(epithelial lining of gut, lungs, liver, pancreas)

BMP present → epidermal fate

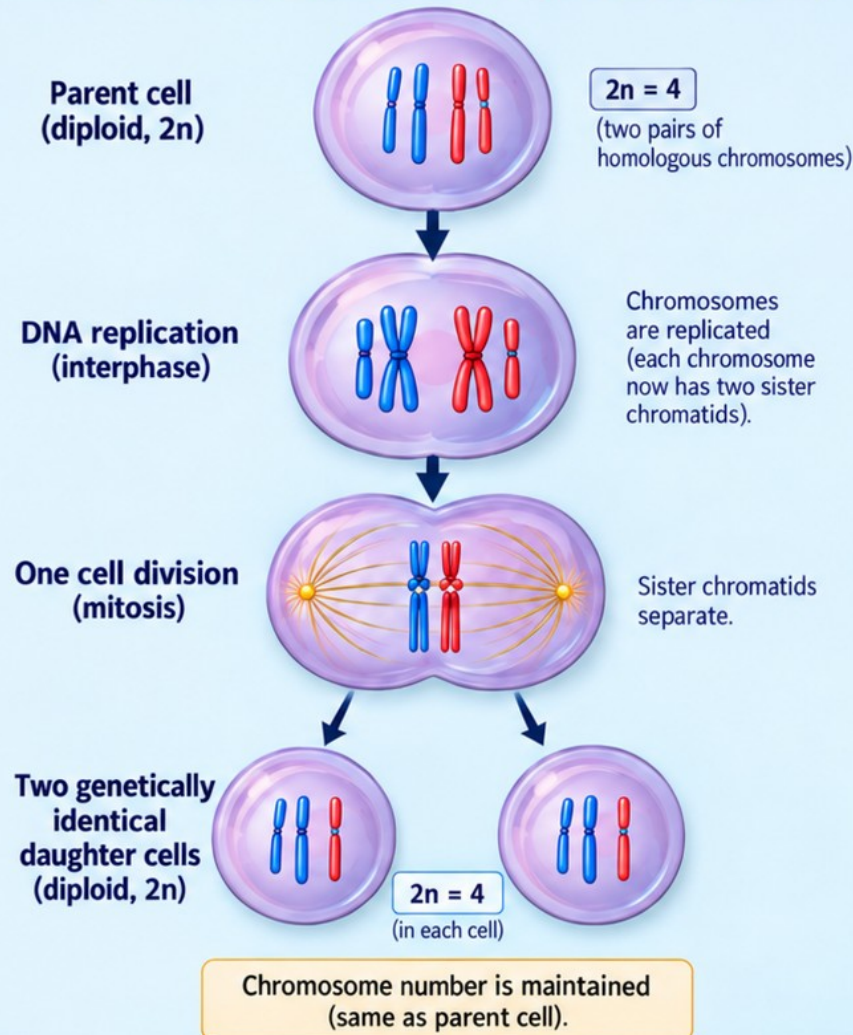


BMP blocked → neural fate



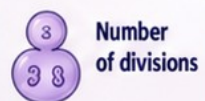
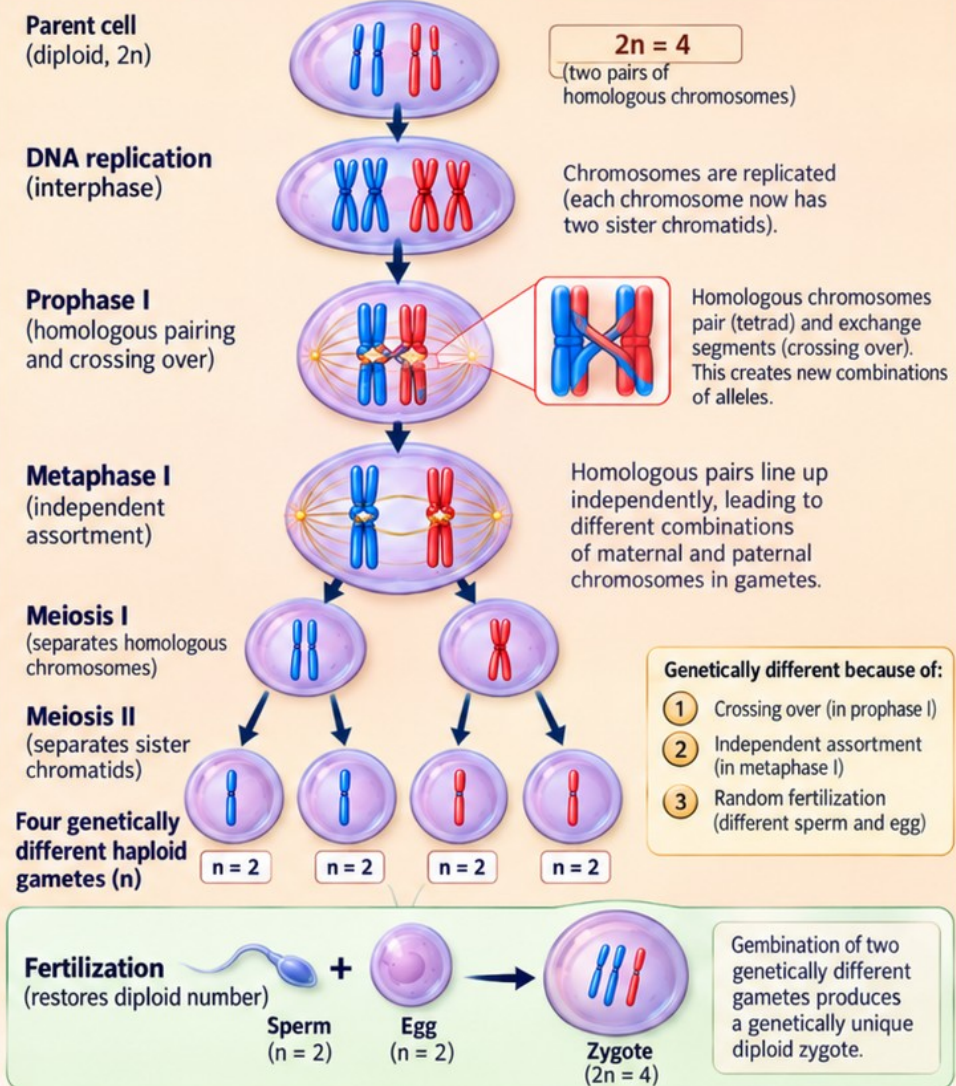
MITOSIS

Asexual reproduction / growth / repair



MEIOSIS

Sexual reproduction



Number of divisions

Mitosis: 1

Meiosis: 2



Number of daughter cells

Mitosis: 2

Meiosis: 4



Ploidy of daughter cells

Mitosis: Diploid (2n)
same as parent

Meiosis: Haploid (n)
half the parent number



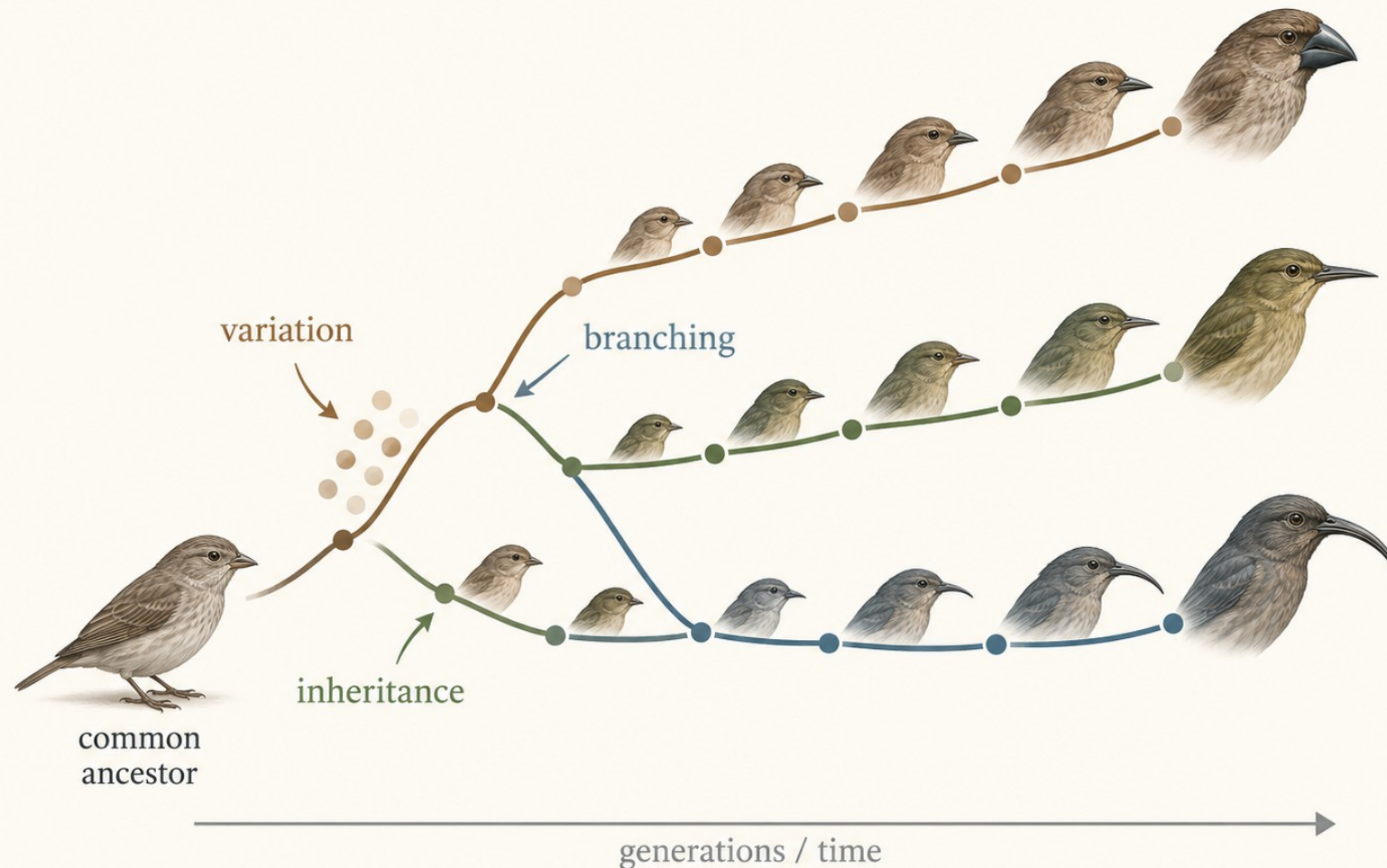
Genetic similarity of daughter cells

Mitosis: Genetically identical (clones)

Meiosis: Genetically different (unique combinations)

Evolution: descent with modification

Descent with Modification



Four evolutionary ideas

1 Trade-off

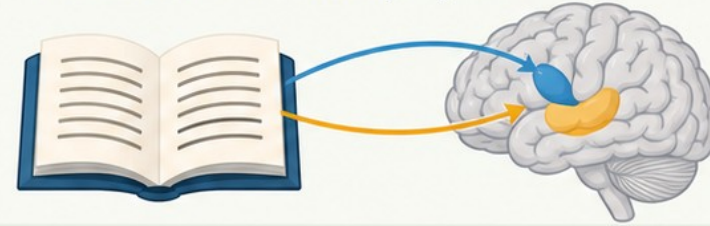
One trait brings both benefits and costs.



Example: Large brain → better cognition, but high metabolic cost and difficult childbirth.

2 By-product

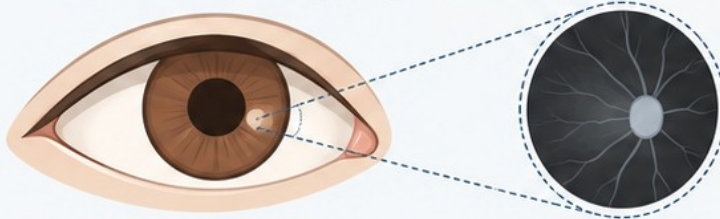
A feature or ability emerges from systems that evolved for other purposes.



Example: Reading → recruits visual and language systems that did not evolve specifically for reading.

3 Constraint

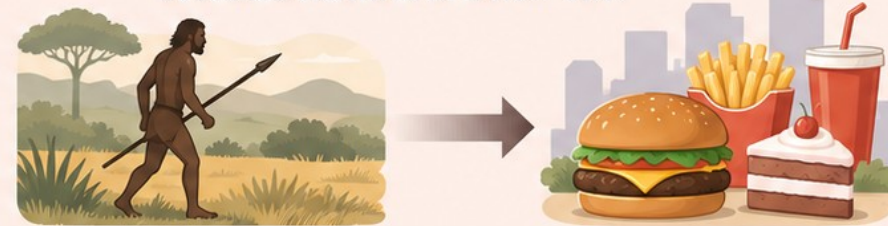
Evolution modifies inherited structures rather than designing from scratch.



Example: Vertebrate blind spot → a consequence of retinal wiring.

4 Mismatch

A trait suited to an older environment becomes harmful in a new one.



Example: Calorie-seeking → obesity in calorie-rich environments.

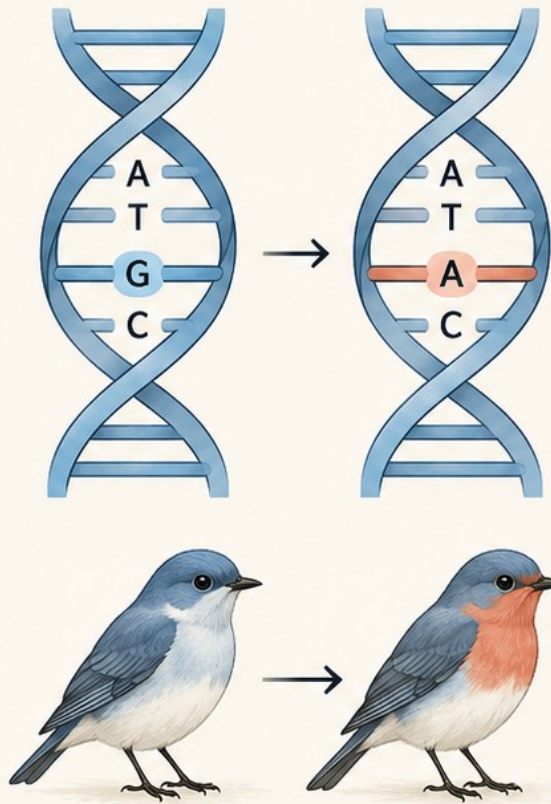


Evolution does not create perfect designs; it works through trade-offs, by-products, constraints, and mismatch.

Sexual Selection: Peacock Tail

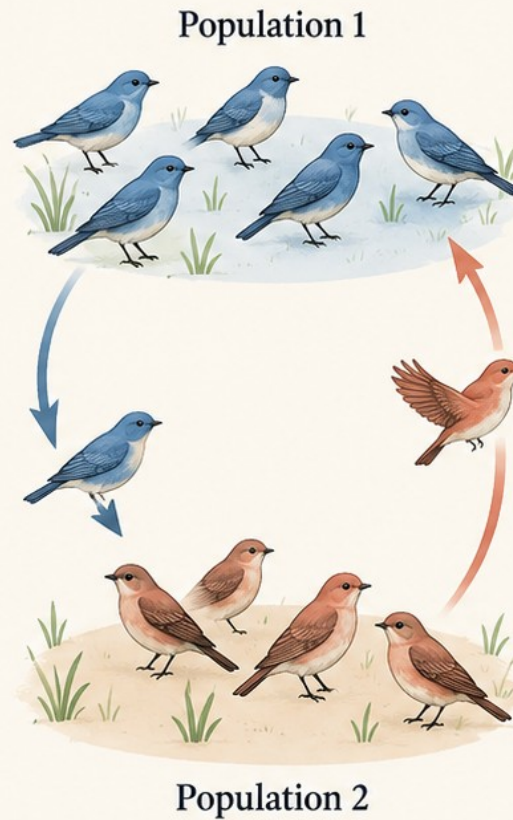


Mutation



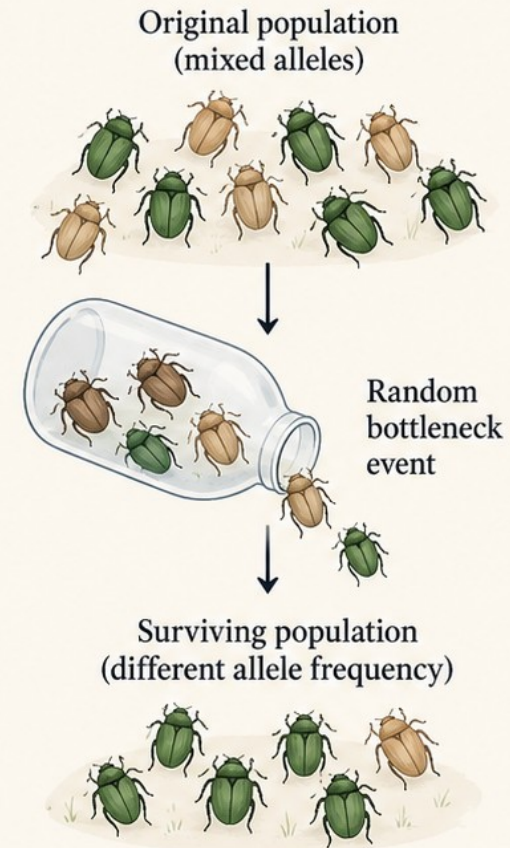
A change in DNA creates new variation.

Migration (Gene flow)



Alleles move between populations.

Genetic drift



Random sampling changes allele frequencies.

Evolution can change through new variation, movement of alleles, and random sampling.

Artificial Selection: Samurai Crab

<https://www.crabmuseum.org/blog/the-mystery-of-the-samurai-crab>



Aging as a Side Effect

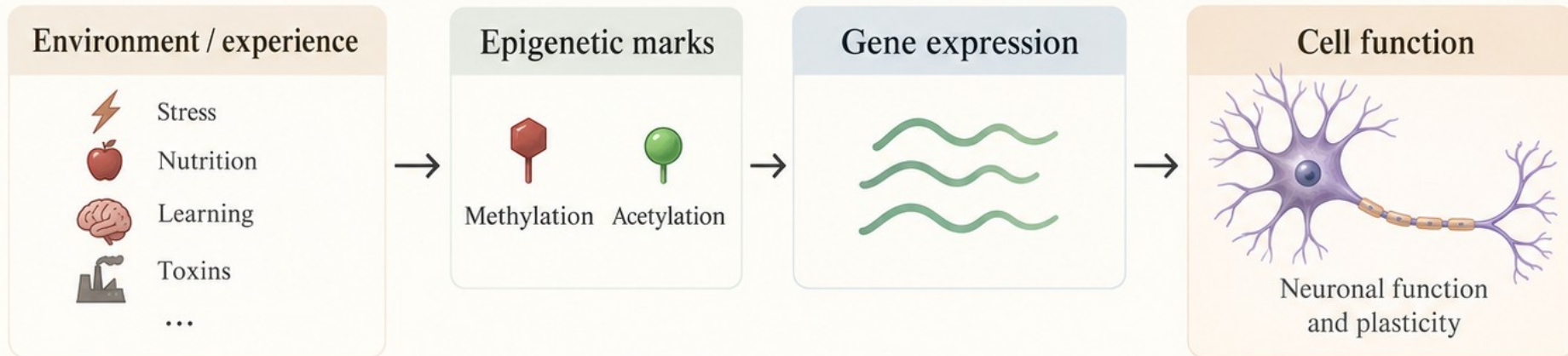
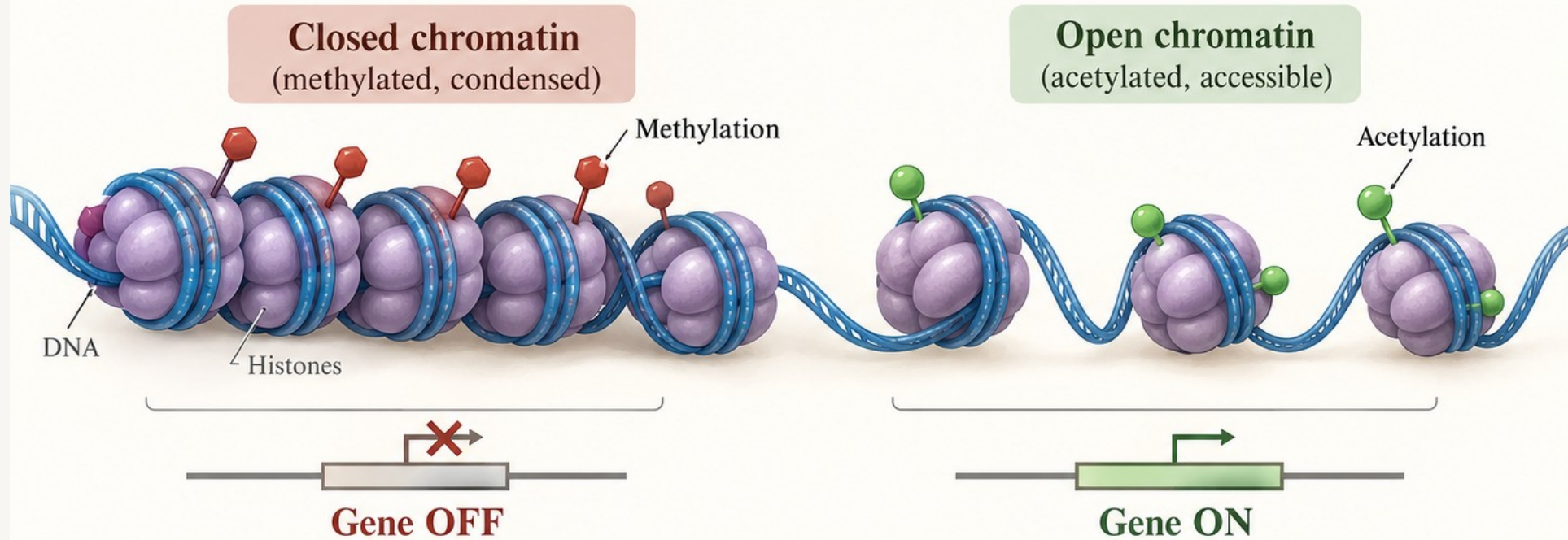
Cancer cells don't die : HeLa line of cells

Peter Medawar's 'mutation accumulation theory' states that the force of natural selection remains high until the first reproduction [[Medawar 1952](#)]. It then declines with age. Therefore, deleterious mutations whose effects occur late in life can accumulate because they are not selected against. This is known as the 'selection shadow'. This means that the primary goal of an organism is reproduction, and until that time natural selection ensures the maintenance of cellular processes that are essential for survival. After reproduction, there is no evolutionary pressure to ensure the continued survival of the organism. Cellular processes decline, the organism ages and eventually dies.

George Williams' theory of 'antagonistic pleiotropy' states that natural selection can favour gene variants with beneficial effects early in life, even if the same variants have deleterious effects later [[Williams 1957](#)]. Because the deleterious effects of these genes occur in old age, after the reproductive phase, they have little evolutionary impact. Nature cannot directly select against a gene or its mutation that causes the death of an individual in old age if its deleterious effects do not occur before the end of the reproductive phase.

Epigenetics

Same DNA, different gene expression



Examples and the Eight Criteria of Life

✓ = meets criterion ~ = partially or context-dependent ✗ = does not meet criterion

01

Example	Cellular organization	Metabolism (energy use)	Homeostasis (regulation)	Growth & development	Response to stimuli	Reproduction (self-replication)	Heredity (genetic info)	Capacity for evolution*	Considered alive?
Cancer cell 	✓	✓	✓	✓	✓	✓	✓	✓	Yes (cell)
Frozen embryo 	✓	~	~	~	~	✗	✓	✓	Yes (dormant)
Worker ant 	✓	✓	✓	✓	✓	✗	✓	✓	Yes (organism)
Fire 	✗	✗	✗	~	~	~	✗	✗	No
Dry kidney bean 	✓	~	~	~	~	~	✓	✓	Yes (dormant)
Postmenopausal woman 	✓	✓	✓	✓	✓	✗	✓	✓	Yes (organism)
Fungus (e.g., mushroom) 	✓	✓	✓	✓	✓	✓	✓	✓	Yes (organism)
Sperm cell 	✓	✓	~	✗	✓	✗	✓	✗	Yes (cell, not an organism)
Bacteria 	✓	✓	✓	✓	✓	✓	✓	✓	Yes (organism)
Virus 	✗	✗	✗	✗	~	✓ [†]	✓	✓	Not typically considered alive (acellular)

* Individuals do not evolve; populations and lineages evolve. A ✓ here means the example belongs to a lineage capable of Darwinian evolution.

† Viruses can replicate, but only inside a host cell by using the host's machinery.

Worker ants typically do not reproduce, yet they are clearly alive.

§ Fire consumes fuel and releases energy, but this is not metabolism in the biological sense (i.e., organized, enzyme-mediated biochemical reactions).

¶ For postmenopausal women, growth and development do not mean continual increase in size. Development has occurred, and biological remodeling/turnover continues.

A sperm cell is a living cell, but it is not an independent organism and does not reproduce itself; it contributes genetic material to reproduction of the organism.

What is **life? When is something **alive**?**
Organism vs. **Living thing**
Properties of a **cell**
Gene Expression and Translation
Mitosis and Miosis
Evolution