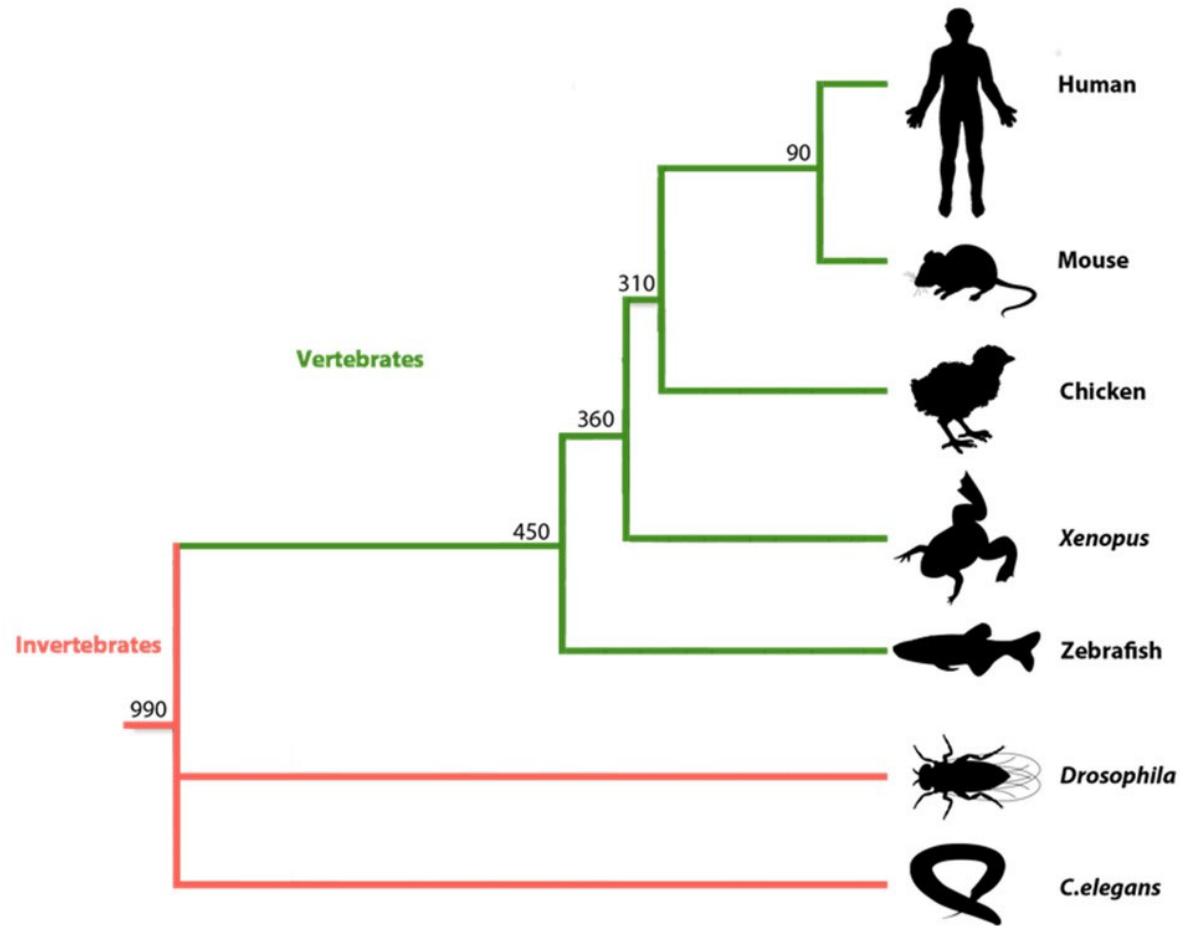


Model organisms and evolutionary conservation



Nobel Prize in Medicine 2026

From an algal protein to control of the brain



Karl Deisseroth



Peter Hegemann



Georg Nagel

“for their discoveries concerning light-gated ion channels and optogenetics”

how nerve cells shape memories, feelings and behaviours in the living brain

Nobel Prize in Medicine 2026

From an algal protein to control of the brain



(B) *Chlamydomonas*

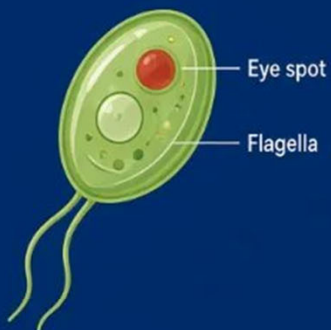


Channelrhodopsin — 2026 Nobel Prize in Medicine



1. DISCOVERED IN ALGAE

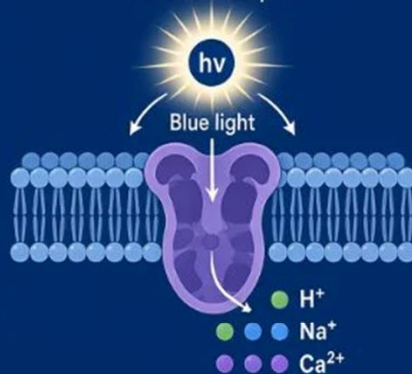
Chlamydomonas



Single-celled green alga
Chlamydomonas

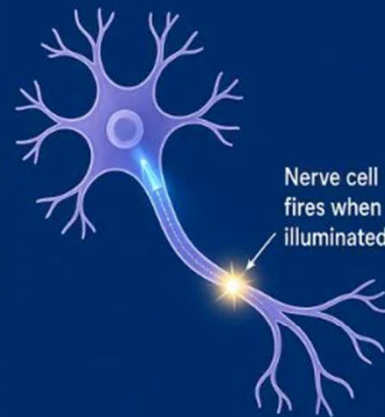
2. LIGHT-GATED ION CHANNEL

Channelrhodopsin



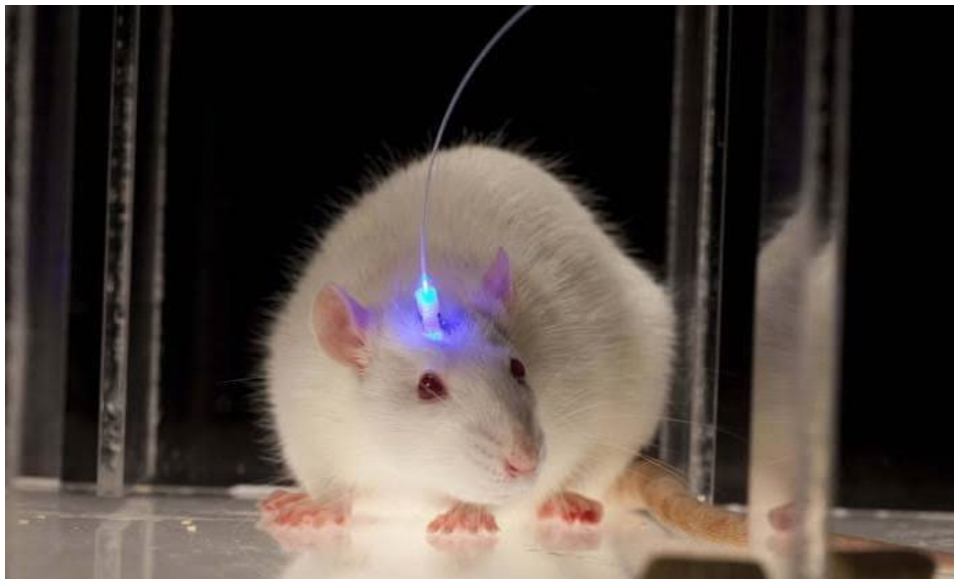
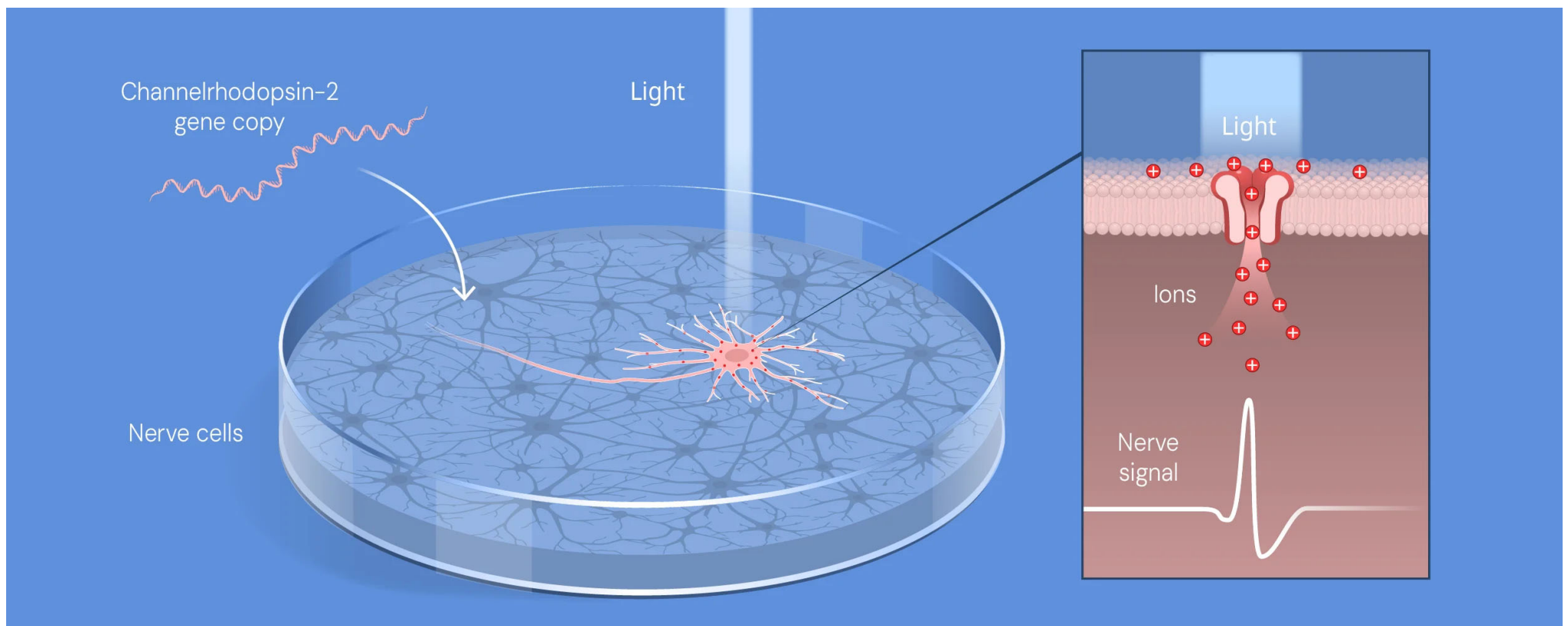
Light-gated ion channel

3. CONTROLLING NEURONS WITH LIGHT



Discovered in algae by Hegemann & Nagel.

Later used by Deisseroth to control neurons with light — foundation of optogenetics.



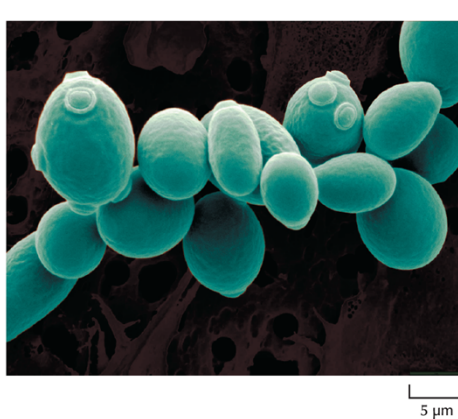
Memory, learning, feelings -
switched on by light



Gene therapy for blindness

Researchers study thousands of organisms

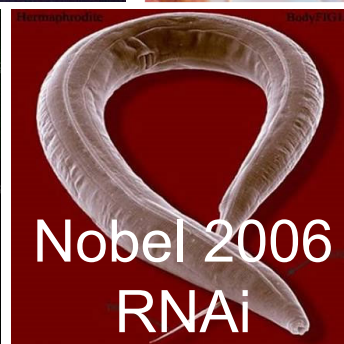
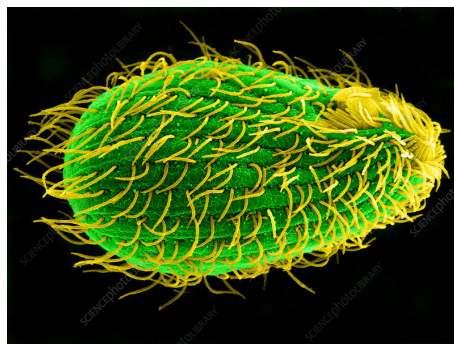
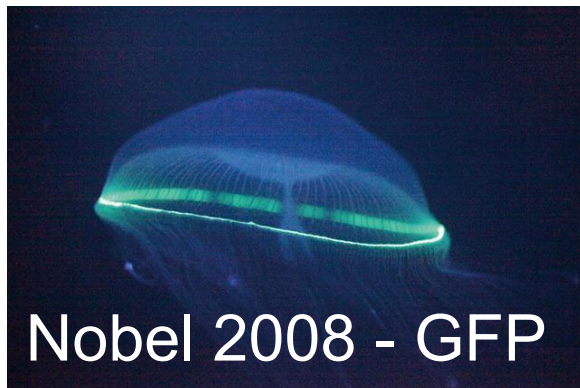
Why?



(A) *Paramecium*

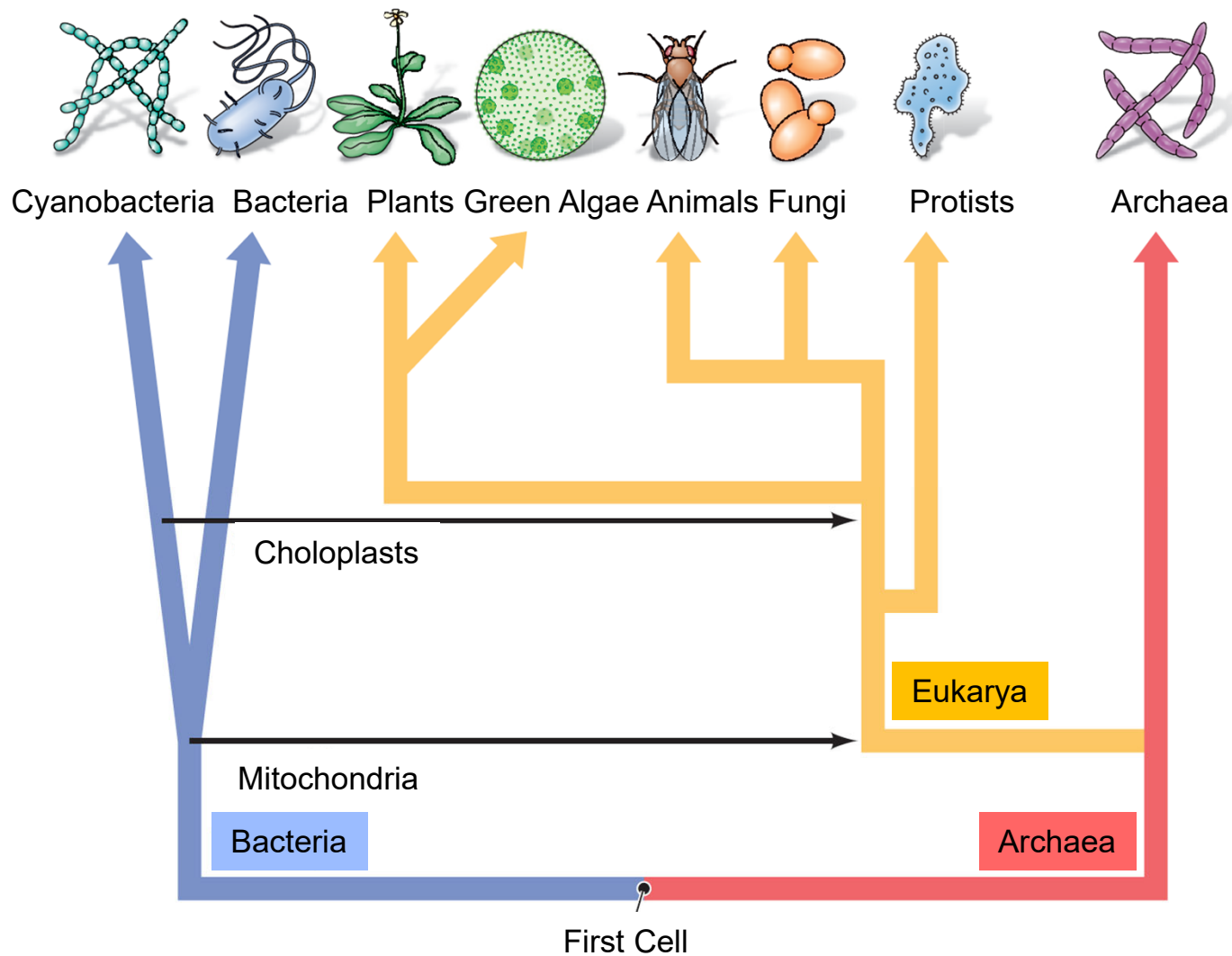


(B) *Chlamydomonas*



Remarkable biodiversity – powerful biotechnology tools

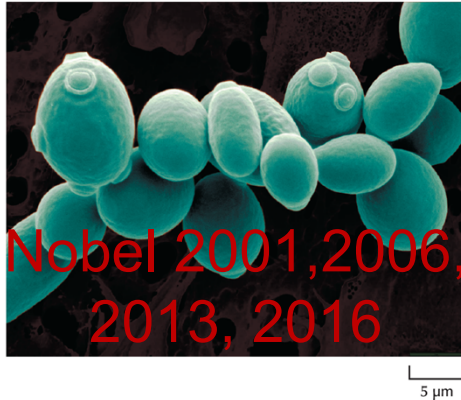
All organisms are evolutionarily connected and resemble one another in their basic mechanisms



Studying simple model organisms provides valuable information about the function and dysfunction of human cells

Researchers study thousands of organisms

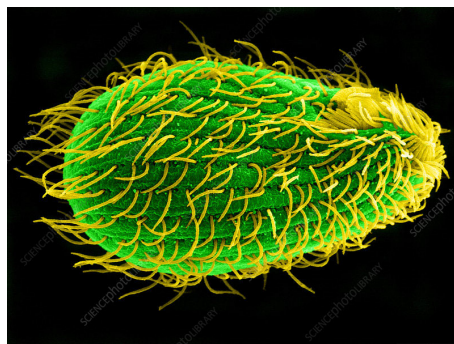
Why?



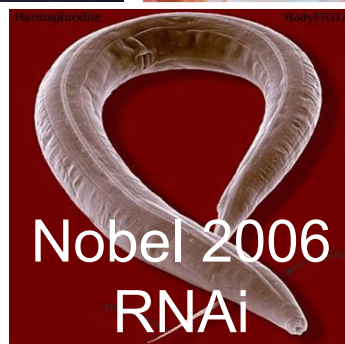
(A) *Paramecium*



(B) *Chlamydomonas*



Nobel 2020
telomerase



Nobel
2002, 2024



Nobel 1995
2011, 2017



Nobel 2001

Model organisms

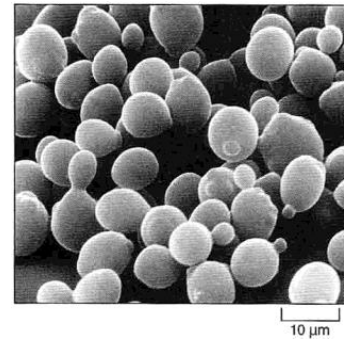
Advantages:

- Inexpensive, easy and rapid culture under controlled/simple laboratory conditions
- Short reproductive cycle
- Less complex genome
- Good genetic analysis
- Simpler structural organization & function
- No (or fewer) ethical issues in experimental manipulation

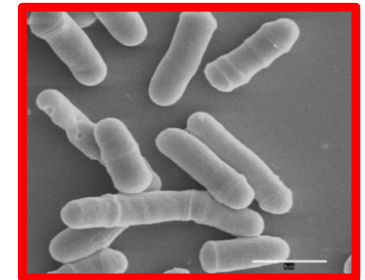
The bacterium *Escherichia coli*



The yeast *Saccharomyces cerevisiae*



Schizosaccharomyces pombe



The plant *Arabidopsis thaliana*



The nematode *Caenorhabditis elegans*



The insect *Drosophila melanogaster*

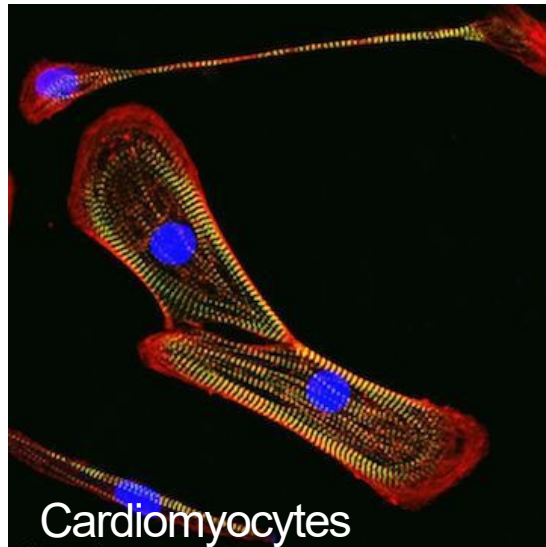


The mouse *Mus musculus*

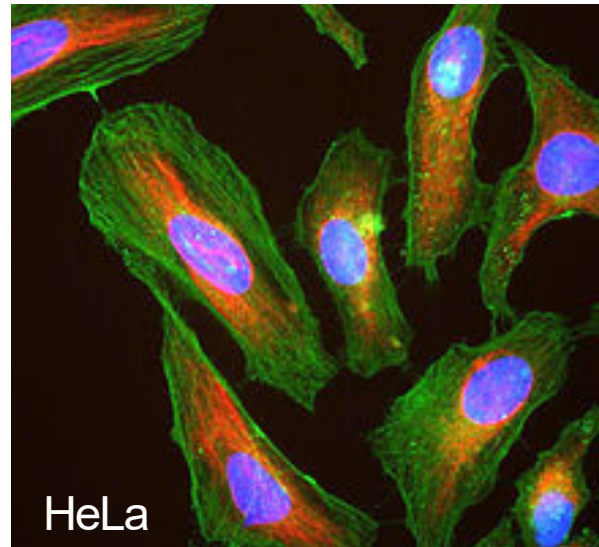
- Model organisms are our research tools for understanding the basic functions of life.
- They are useful experimental models for identifying genes associated with disease and for testing therapeutic protocols.

Human cells in culture

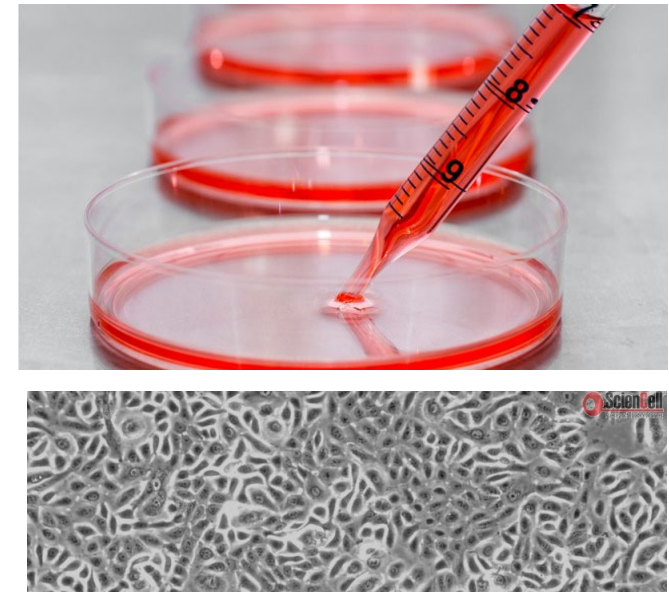
Normal cells



Cancer cells



Cell culture



Human populations — diseases



We have read the genetic material of thousands of organisms on Earth — including humans

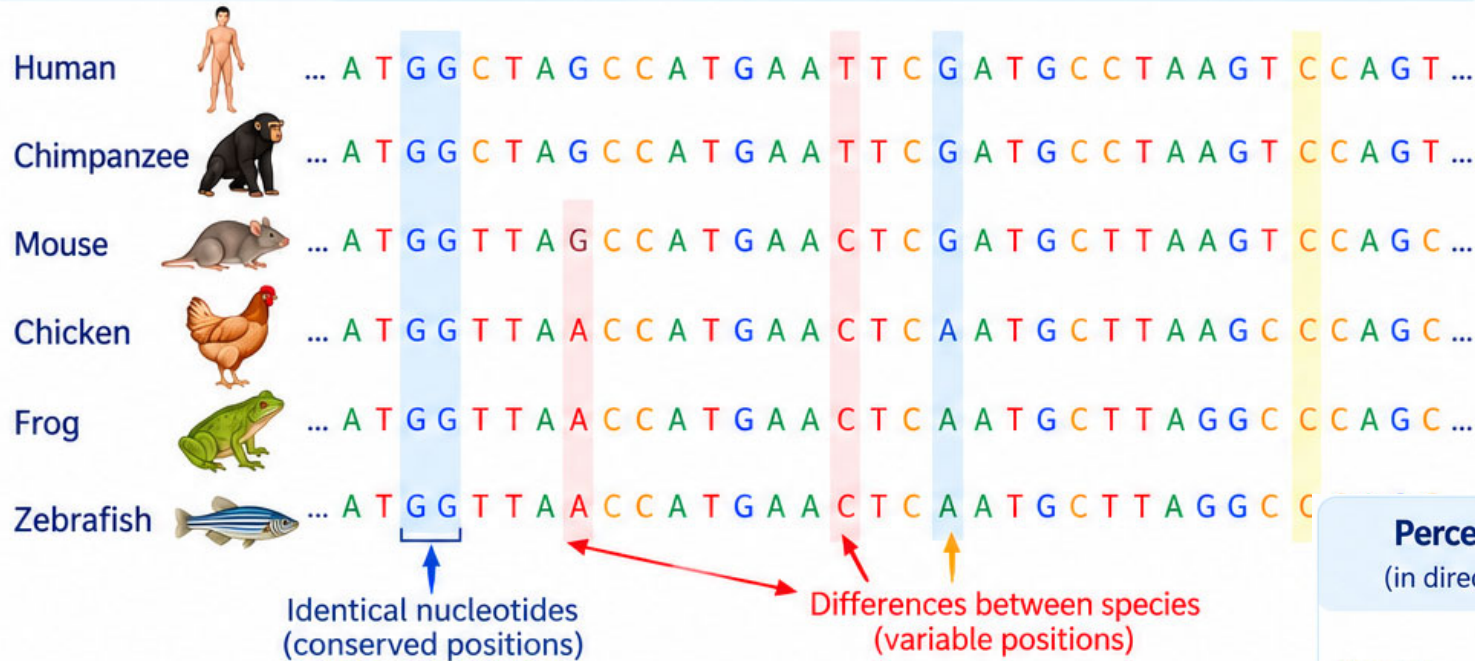
TABLE 1.2 DNA content of different cells

Organism	Haploid DNA content (million base pairs)	Number of protein-coding genes
Archaea		
<i>Methanococcus jannaschii</i>	1.7	1,700
Bacteria		
<i>Mycoplasma</i>	0.6	470
<i>Escherichia coli</i>	4.6	4,200
<i>Cyanobacterium</i>	3.6	3,200
Unicellular eukaryotes		
<i>Saccharomyces cerevisiae</i> (baker's yeast)	12	6,000
<i>Dictyostelium discoideum</i>	34	12,000
<i>Paramecium</i>	72	39,500
<i>Chlamydomonas</i>	118	14,500
<i>Volvox</i>	138	14,500
Plants		
<i>Arabidopsis thaliana</i>	125	26,000
Maize	2,200	33,000
Apple	740	57,000
Animals		
<i>Caenorhabditis elegans</i> (nematode)	97	19,000
<i>Drosophila melanogaster</i> (fruit fly)	180	14,000
Zebrafish	1,700	26,000
Mouse	3,000	20,000
Human	3,000	20,000

Comparison of genomic sequences between species reveals their genetic relatedness

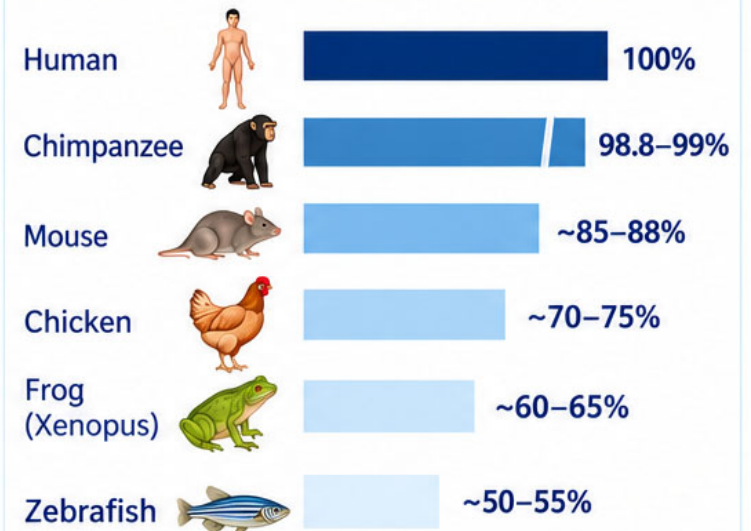
Example of a DNA sequence alignment

(human genomic region and corresponding sequences in other species)



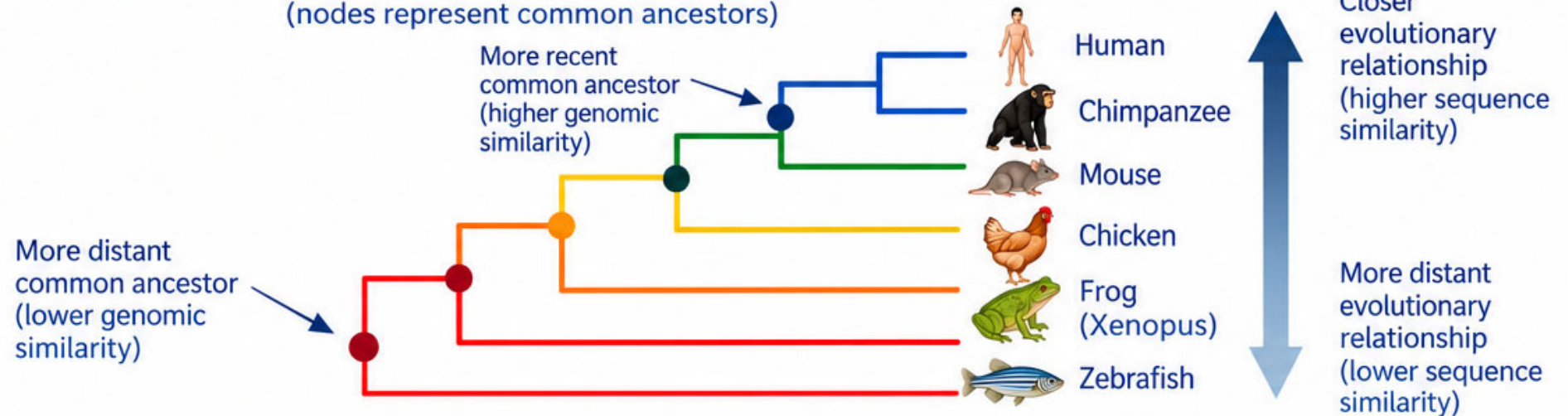
Percentage DNA identity with human

(in directly alignable bases, approximate values)



Phylogenetic tree based on DNA sequence comparisons

(nodes represent common ancestors)



The more identical sequences (and the fewer differences) two species have in the alignable regions of their genomes, the more recent their common ancestor and the more closely related they are.

Comparison of protein amino-acid sequences shows their evolutionary relationship

Human	FGLARAFGIPIRVYTHEVVTLWYRSPEVLLGS
<i>S. pombe</i>	FGLARSFGVPLRNYTHEIVTLWYRAPEVLLGS
<i>S. cerevisiae</i>	FGLARAFGVPLRAYTHEIVTLWYRAPEVLLGG
Human	ARYSTPVDIWSIGTIFAELATKLPLFHGDSEI
<i>S. pombe</i>	RHYSTGVDIWSVGCIFAENIRRSPLFPGDSEI
<i>S. cerevisiae</i>	KQYSTGVDTWSIGCIFAHCNRLPIFSGDSEI
Human	DQLFRIPRALGTPNNEVWPEVESLQDYKNTFP
<i>S. pombe</i>	DEIFKIPQVLGTPNEEVWPGVTLLQDYKSTFP
<i>S. cerevisiae</i>	DQIFKIPRVLGTPNEAIWPDIVYLPDFKPSFP

Comparison of the same protein (Cdc2) in humans and in two yeast species involved in the cell cycle.

Despite the large evolutionary distance between humans and yeast, the proteins show extensive conservation.

(Amino acids are represented by one-letter codes, e.g. methionine = M, phenylalanine = F)

Comparison of protein sequences shows their evolutionary relationship

Homologous proteins (homologues): substantial structural and functional similarity due to common evolutionary origin.

The degree of amino-acid conservation indicates evolutionary divergence and/or a sequence essential for survival.

Orthologous proteins (orthologues): a category of homologous proteins

Corresponding proteins in different species,
derived from a common gene in an ancestral species and performing similar functions
E.g. human and mouse β -globin

Paralogous proteins (paralogues): a category of homologous proteins

Homologous proteins within the same species;
in an ancestral species, **an original gene was duplicated**.
They have similar structure and often perform similar functions
E.g. human α - and β -globin

Critical thinking question

When is, in your opinion, a mutation in a human gene more likely to lead to disease:

- if it changes an amino acid that has been conserved during evolution, or
- if it changes an amino acid found only in the human protein?

Key concepts

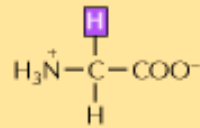
- Studying different organisms provides valuable biotechnology tools
- Studying model organisms helps us understand the basic molecular mechanisms of human cells and their dysfunction in disease
- Comparing the genomes of different organisms provides valuable information about the evolutionary relationships between species
- Comparing different proteins provides valuable information about their functionally important regions

For the tutorial

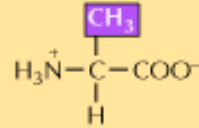
1. Read Chapter 1 of Essential Albers
2. Take the test on eClass (without assistance)
(formative = it does not affect your grade; it is for your own improvement)
3. Read the “How to...” guides: How to read, take notes, follow lectures, and prepare for exams

20 different amino acids in proteins

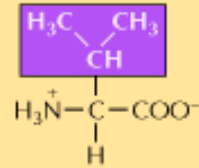
Nonpolar amino acids



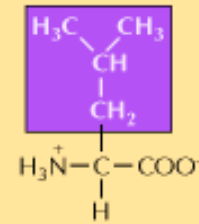
Glycine (Gly) G



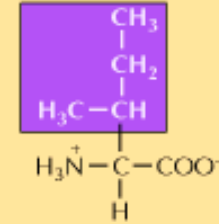
Alanine (Ala) A



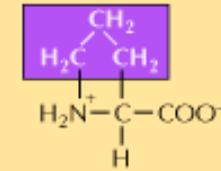
Valine (Val) V



Leucine (Leu) L



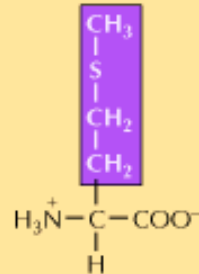
Isoleucine (Ile) I



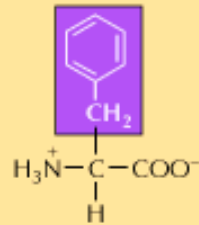
Proline (Pro) P



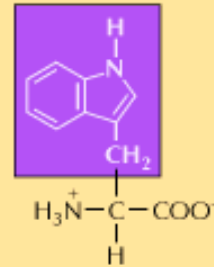
Cysteine (Cys) C



Methionine (Met) M

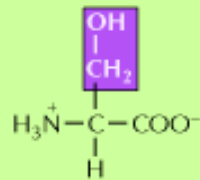


Phenylalanine (Phe) F

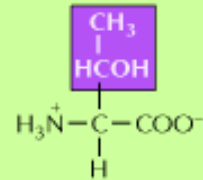


Tryptophan (Trp) W

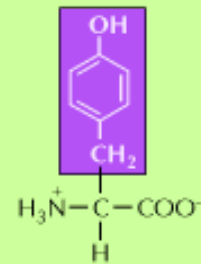
Polar amino acids



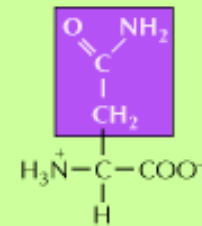
Serine (Ser) S



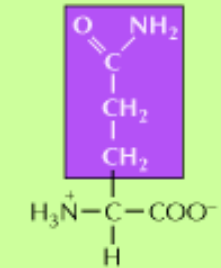
Threonine (Thr) T



Tyrosine (Tyr) Y

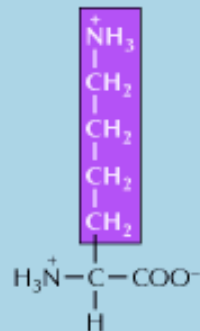


Asparagine (Asn) N

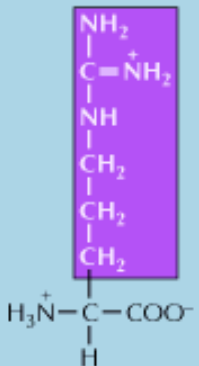


Glutamine (Gln) Q

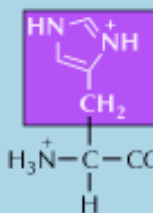
Basic amino acids



Lysine (Lys) K

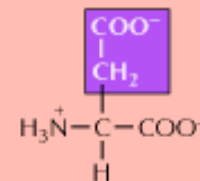


Arginine (Arg) R

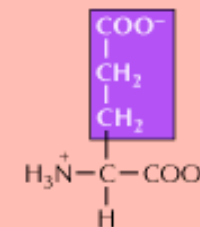


Histidine (His) H

Acidic amino acids



Aspartic acid (Asp) D



Glutamic acid (Glu) E