

Cells: Structure and function

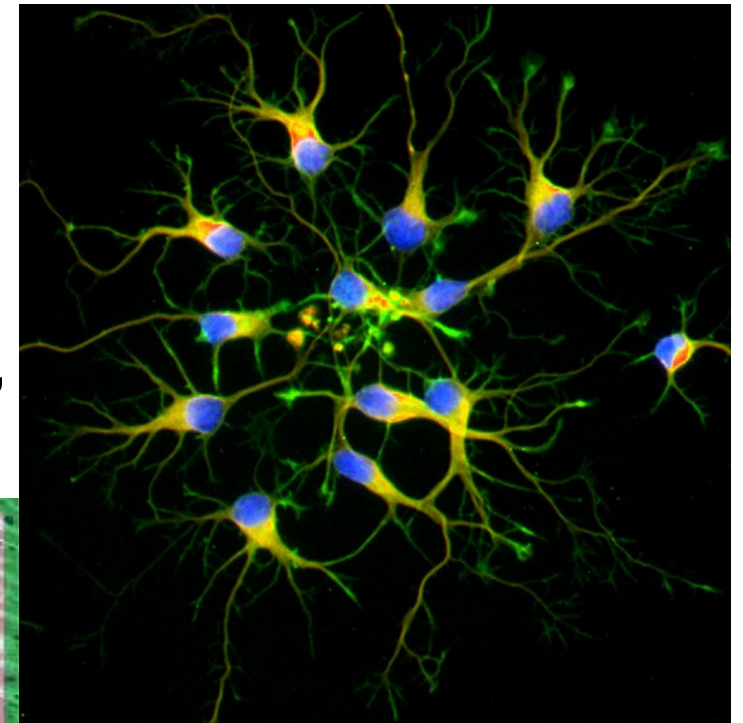
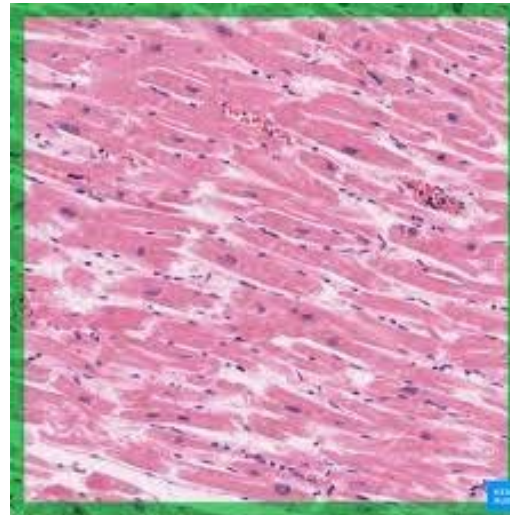
16.1.2024

Learning outcomes

- Recognize core features in cell structure and function
 - Stem cells
 - Cell structure and regulation of cell functions
 - Cell signaling
 - Cell division

Cell: The basic structural and functional unit of the body

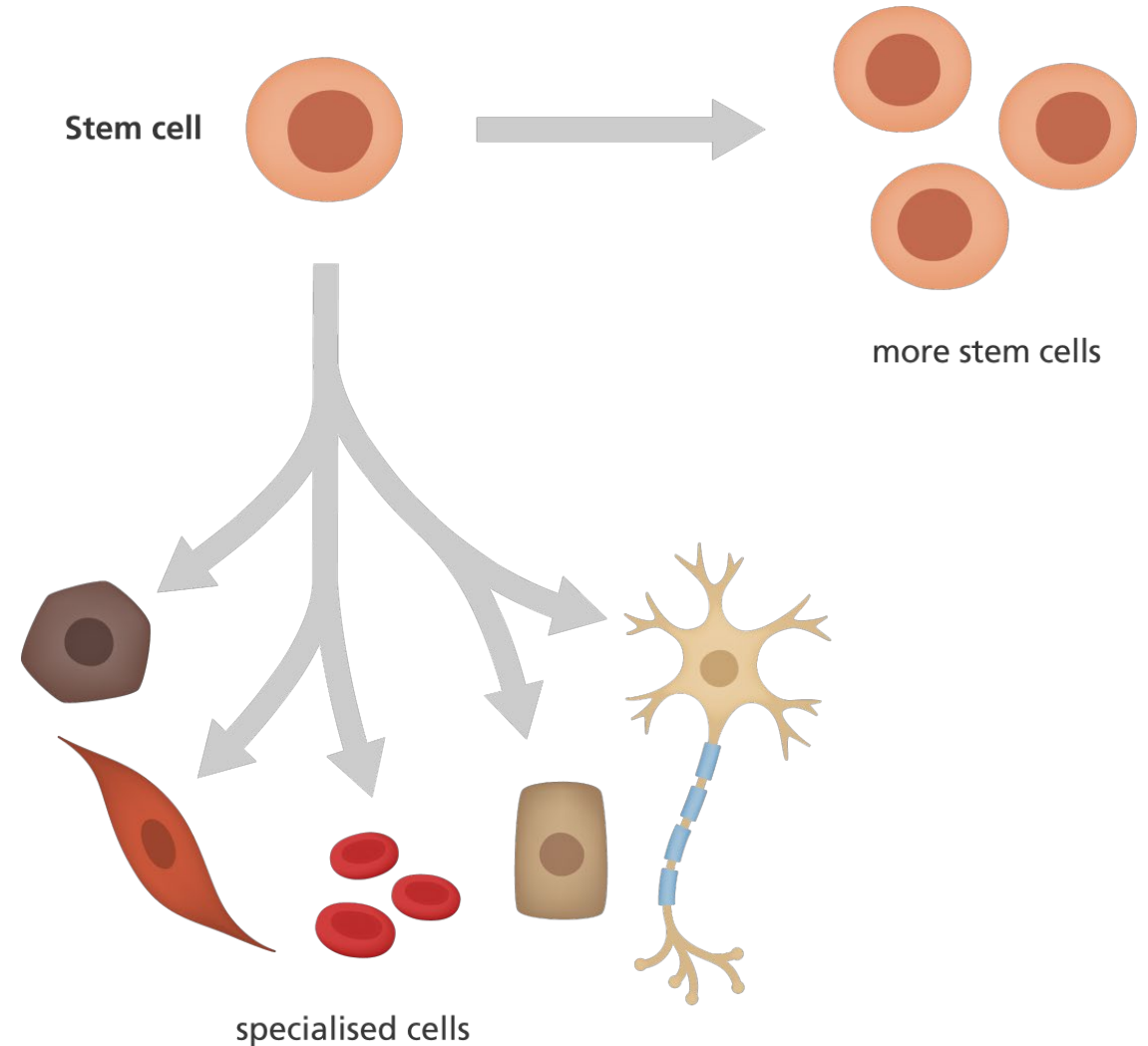
- Trillions of cell in the human body
- Cytology = Study of cells
- The size, shape, and other features highly variable: *e.g.*, red blood cell's diameter is 7- 8 μm , egg cell's 0.1 mm



Sciencellonline.com

Kenhub.com

- Stem cells → gametes (*i.e.*, reproductive cells) and somatic cells
- Cell ingredients
 - 80% water
 - Of dry weight, 80% proteins, 10% fat, and 1-2% carbohydrates and nucleid acids



CELLS

Basic units
Stem cells differentiate
into 200 cell types

STRUCTURE

Very similar for most cells
Red blood cells and
platelets have no cell
nucleus

FUNCTION

Transportation: cell/plasma
membrane
Energy production: mitochondria
Protein synthesis: ribosomes
Packaging and digestion: Golgi
complex, lysosomes
Control of cell functions: nucleus

SIZE

Red blood cells and sperm
cells smallest; muscle and
nerve cells, egg cells
largest

AGE

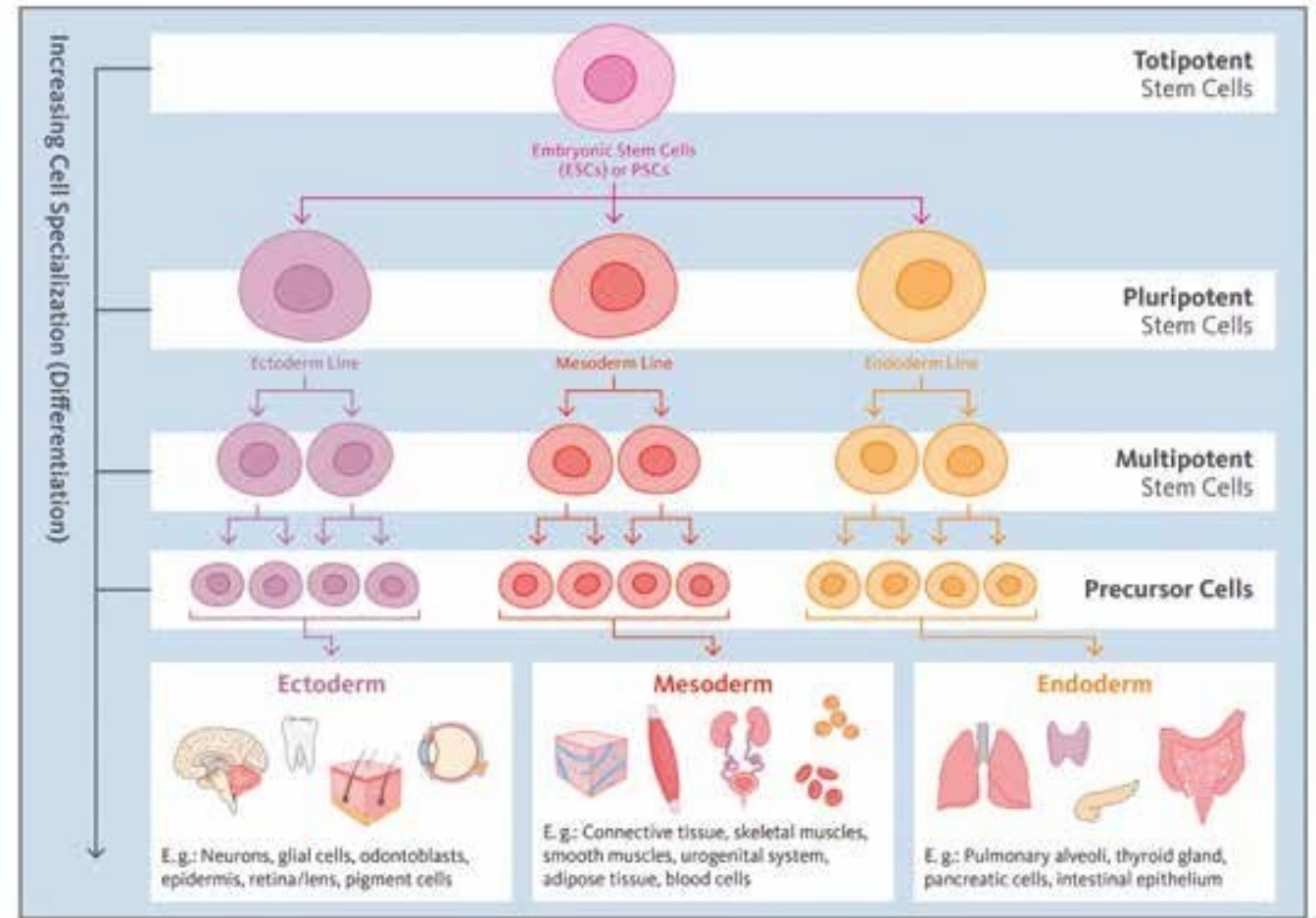
Days - weeks
Red blood cells 3-4 mths, white blood
cells days - months
Blood cells are constantly produced
from the stem cells in bone marrow
Nerve cells do not reproduce
Epithelium and connective tissue cells
do reproduce

SHAPE

Varies with task

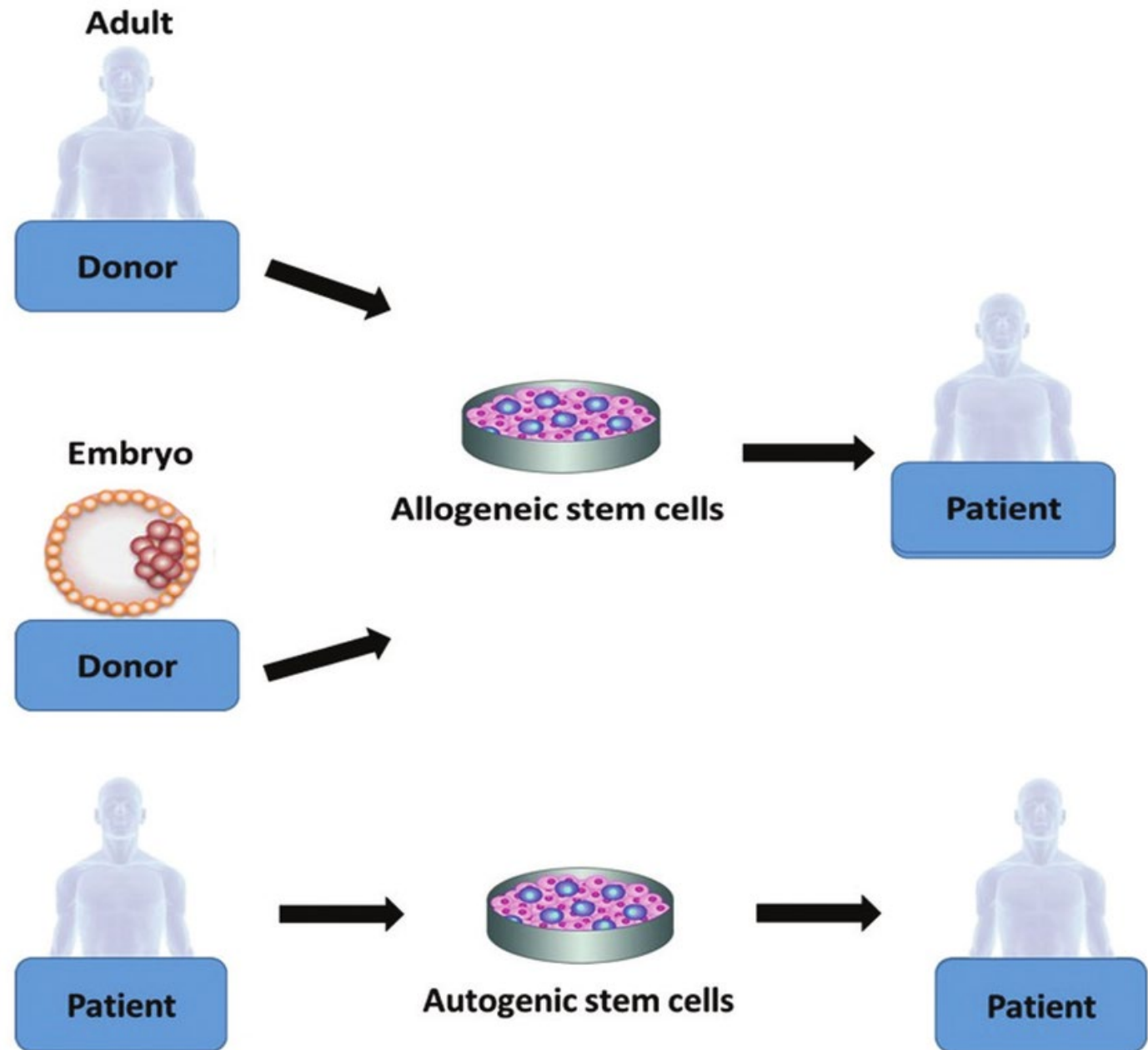
Cell differentiation

- Totipotent – pluripotent – multipotent – unipotent cells
- Stem cells continue to proliferate indefinitely
- Moderated by their surroundings: “stem cell niche”
- iPS = induced pluripotent stem cell



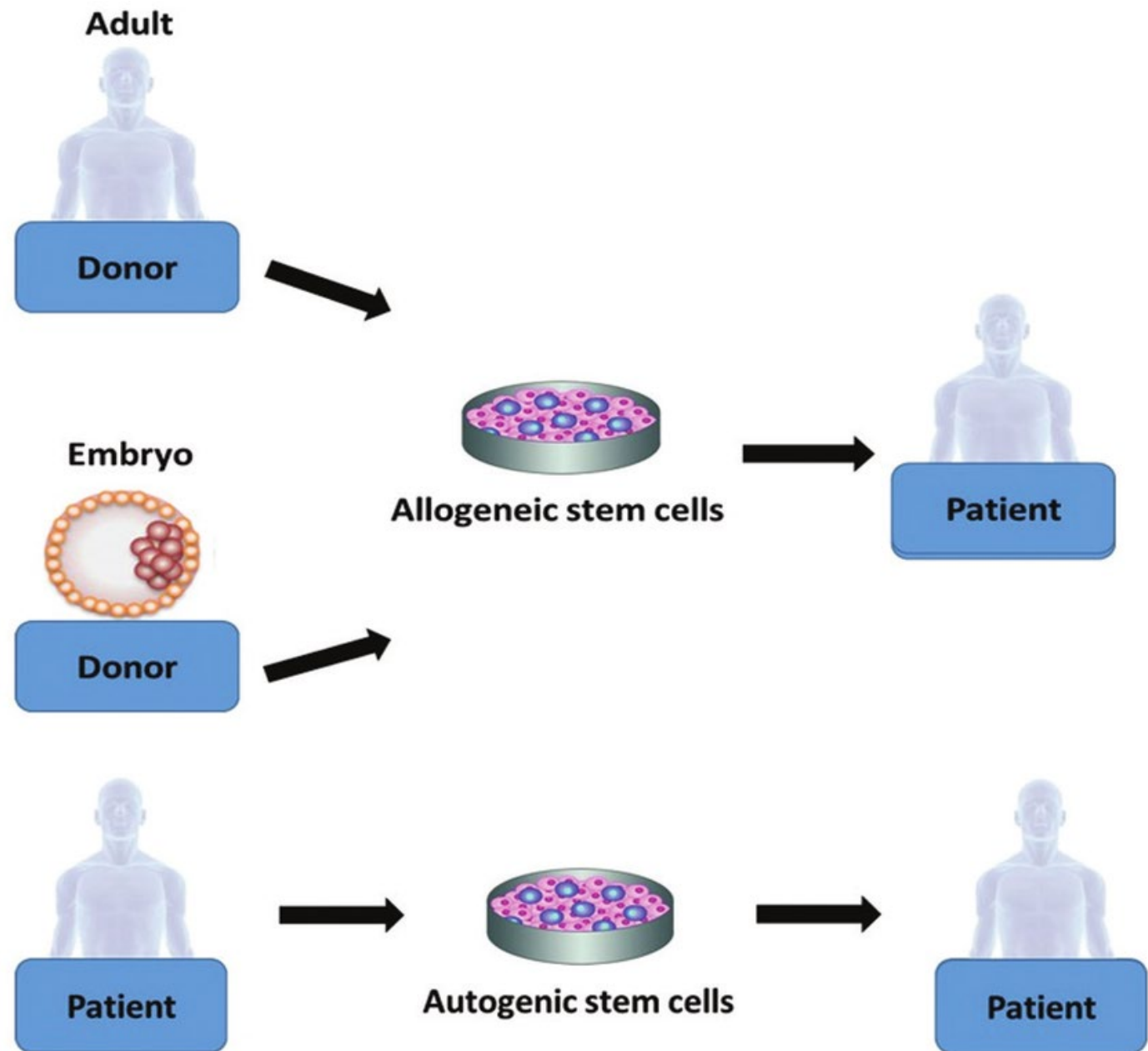
Allogeneic stem cell transplantation

- Patient's diseased bone marrow is destroyed
- Patient is given healthy stem cells which travel to the bone marrow and begin to grow



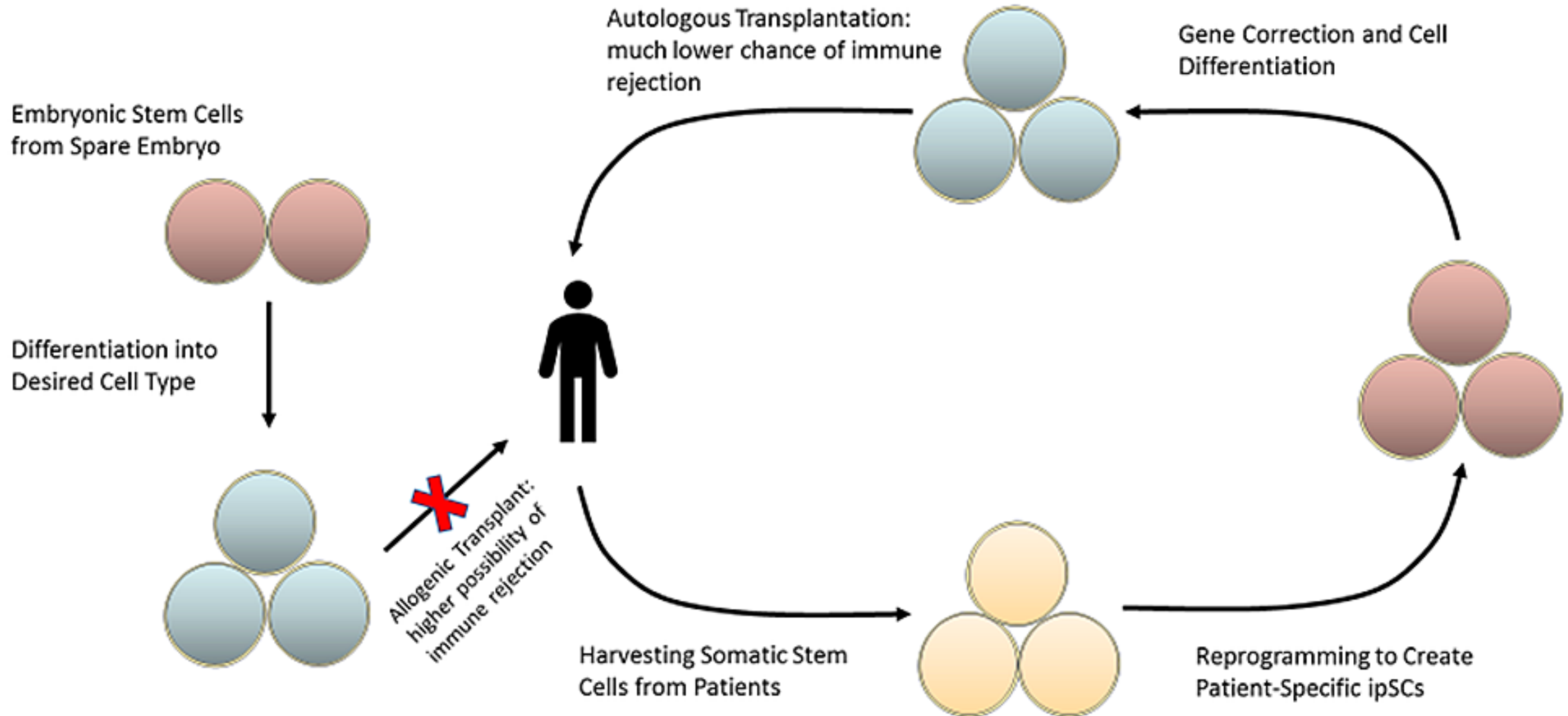
Autologous stem cell transplantation

- Patient's own stem cells are collected before a high-intensity treatment
- Following the treatment, the patient's stem cells are returned to the body



New directions to stem cell treatments and research: iPS

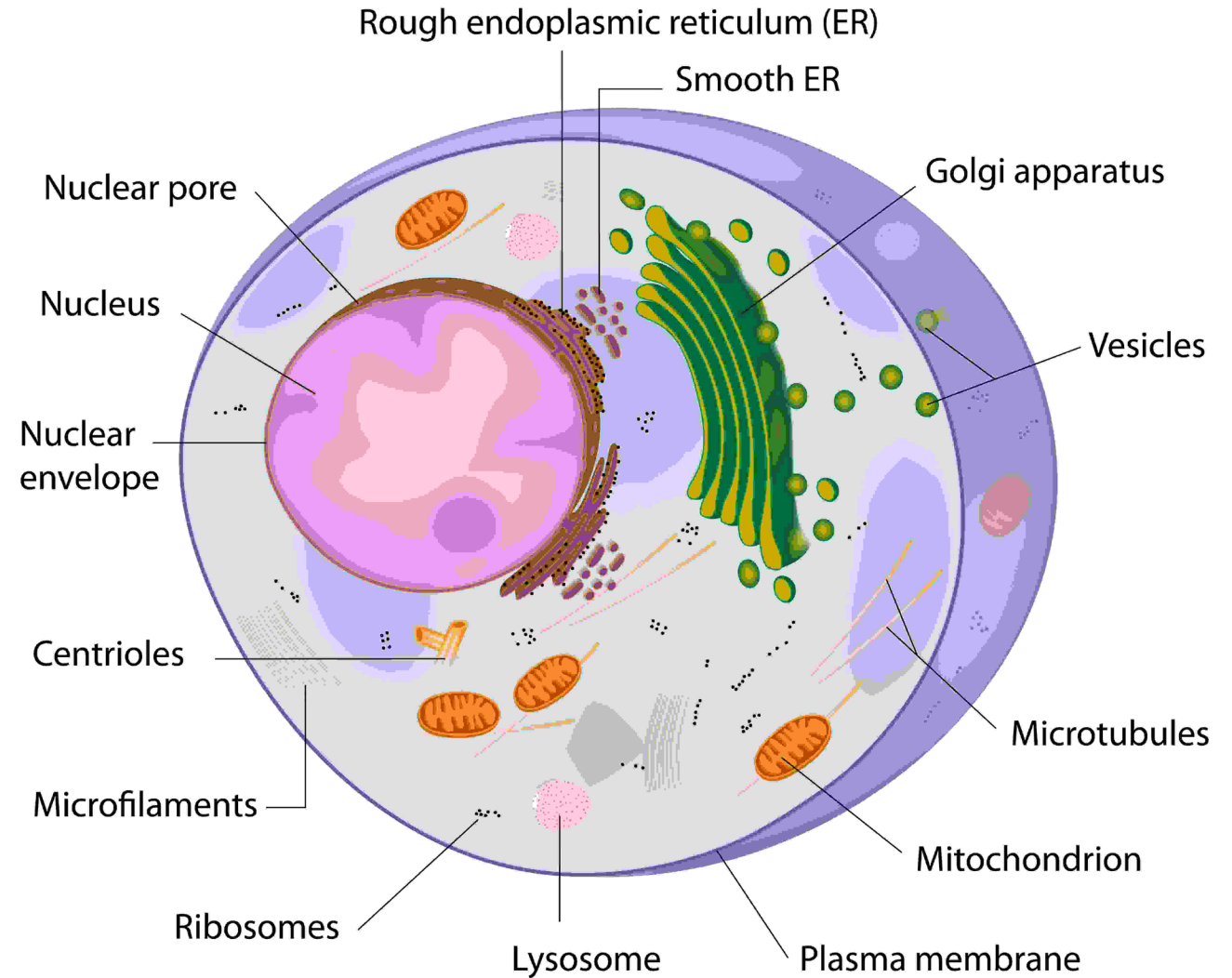
Patient-Specific Stem Cell Treatments



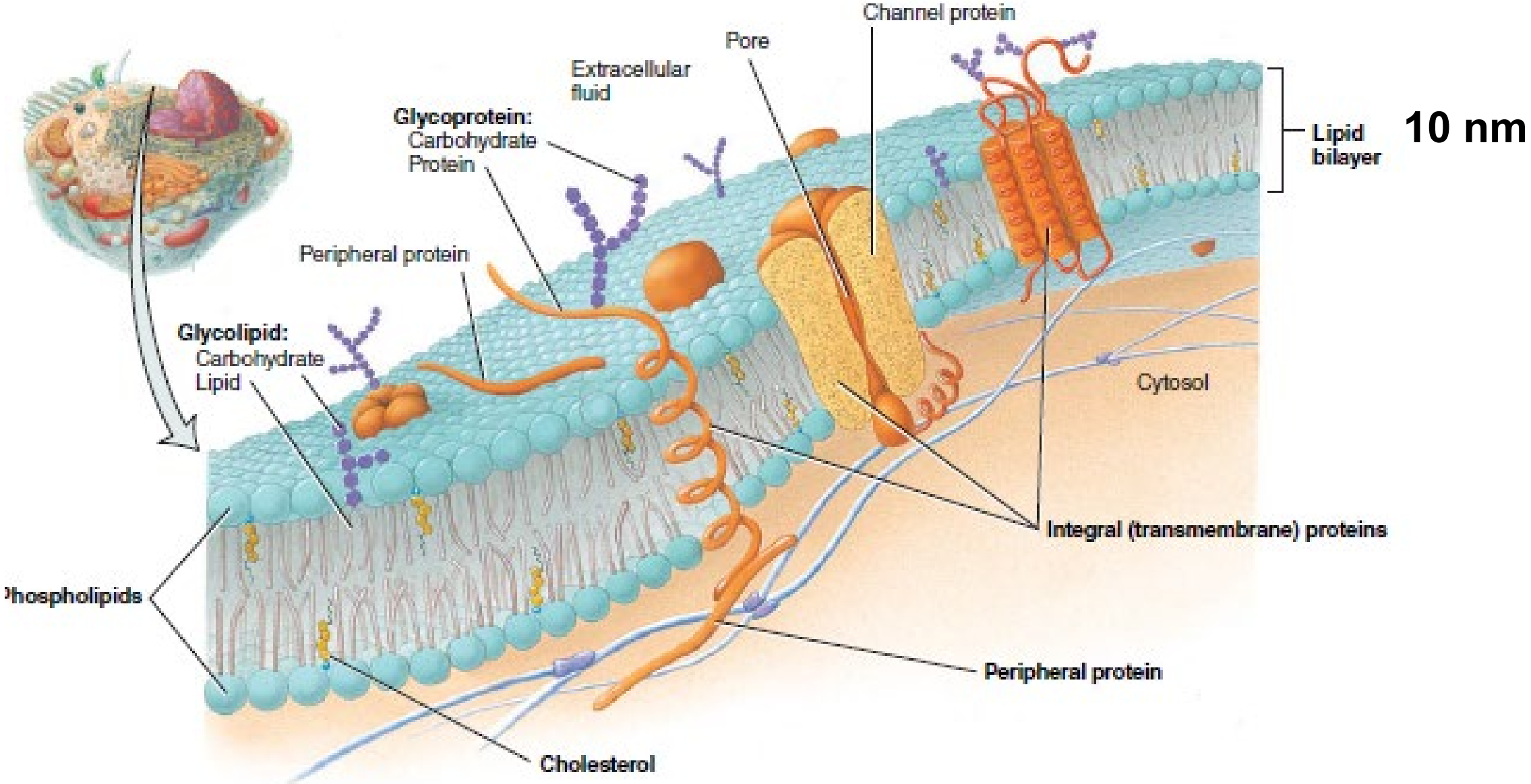
Cell structure and function

- 90% water and dissolved ions (see Lecture 1, water compartments)
- Cell organelles consist of organic molecules: proteins, fats, carbohydrates, nucleic acids

Structure of a Typical Animal Cell

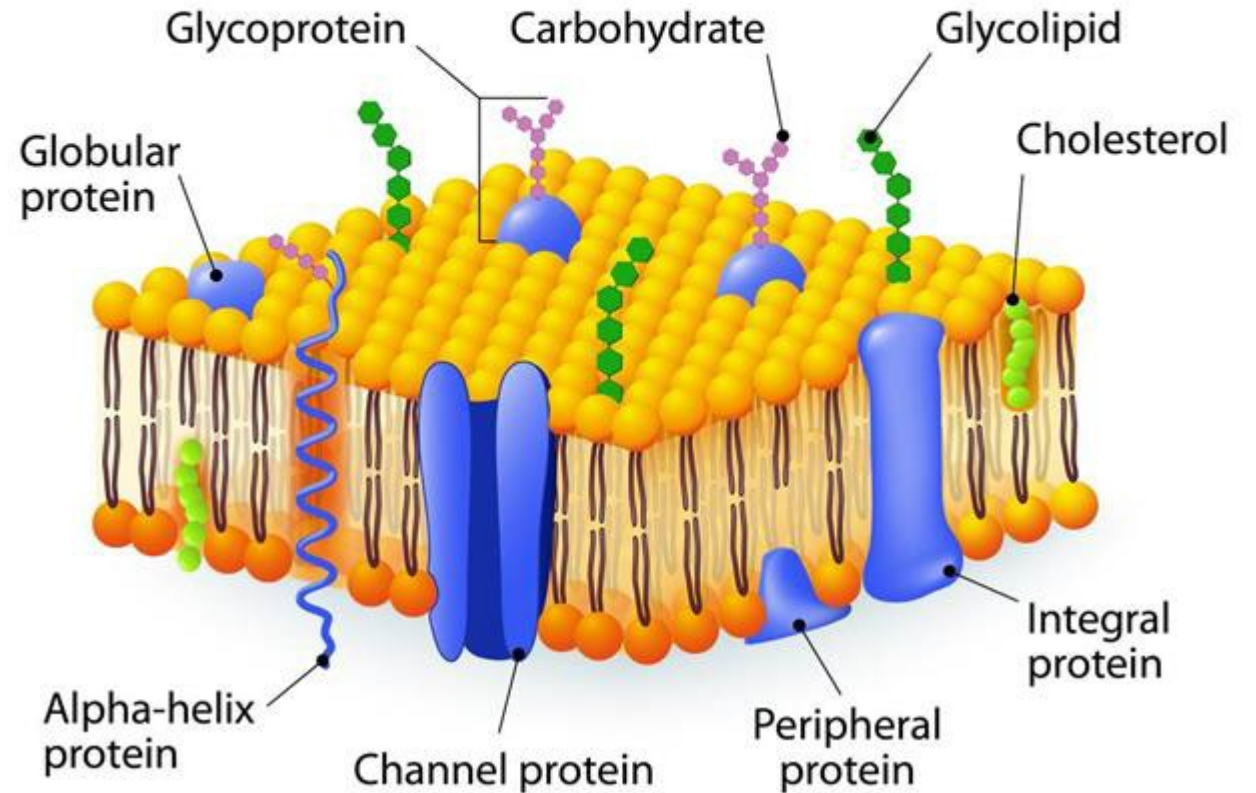


Cell/Plasma membrane



CELL MEMBRANE

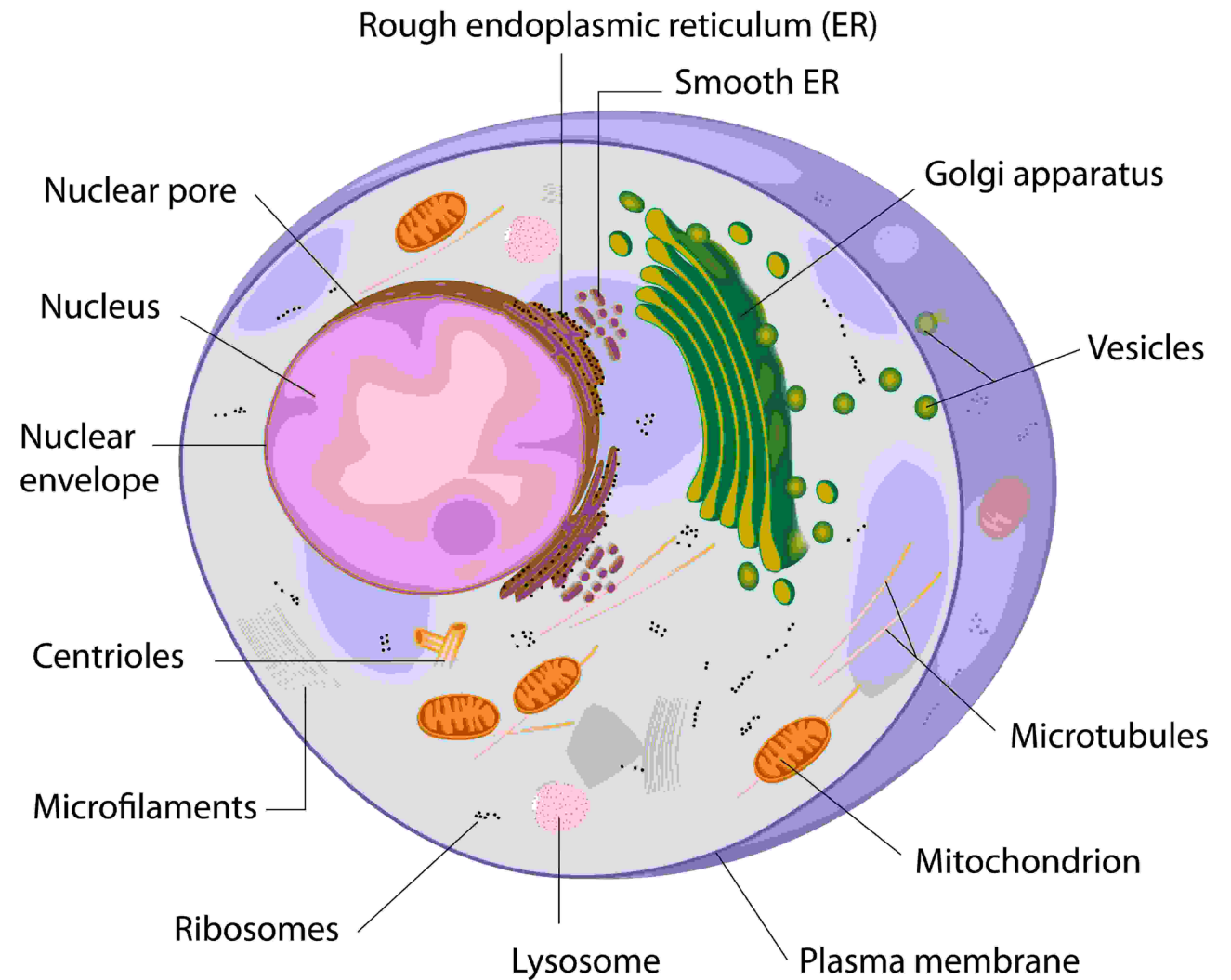
- Controls the flow and transportation of substances into and out of cell
- Links cells to other cells
- Includes membrane proteins: pumps, ion channels, structural proteins
- Na-K pump is the most important
- Active vs. passive transportation



Structure of a Typical Animal Cell

Cytoplasm

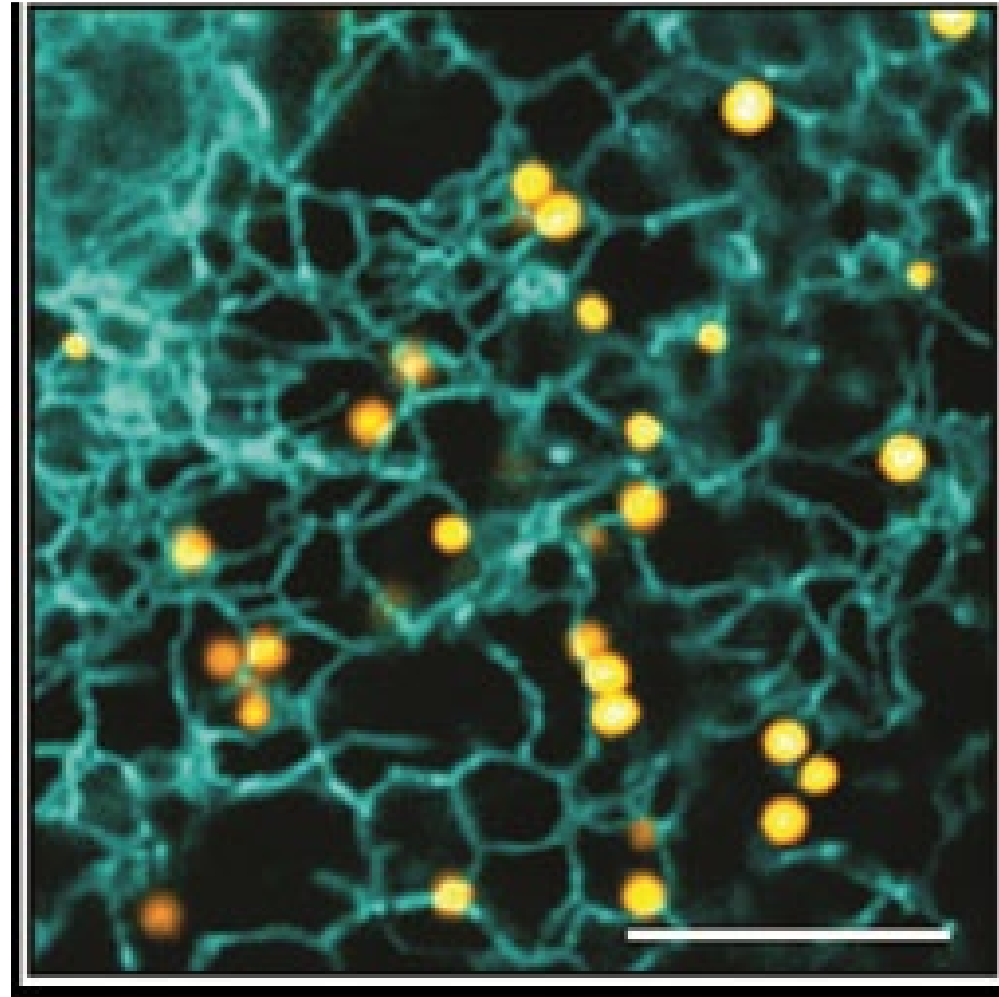
- Includes organelles, *i.e.*, structures to perform cell functions
- Includes the cytoskeleton: microfilaments, keratin (*e.g.*, in skin cells), microtubuli



Endoplasmic reticulum (ER)

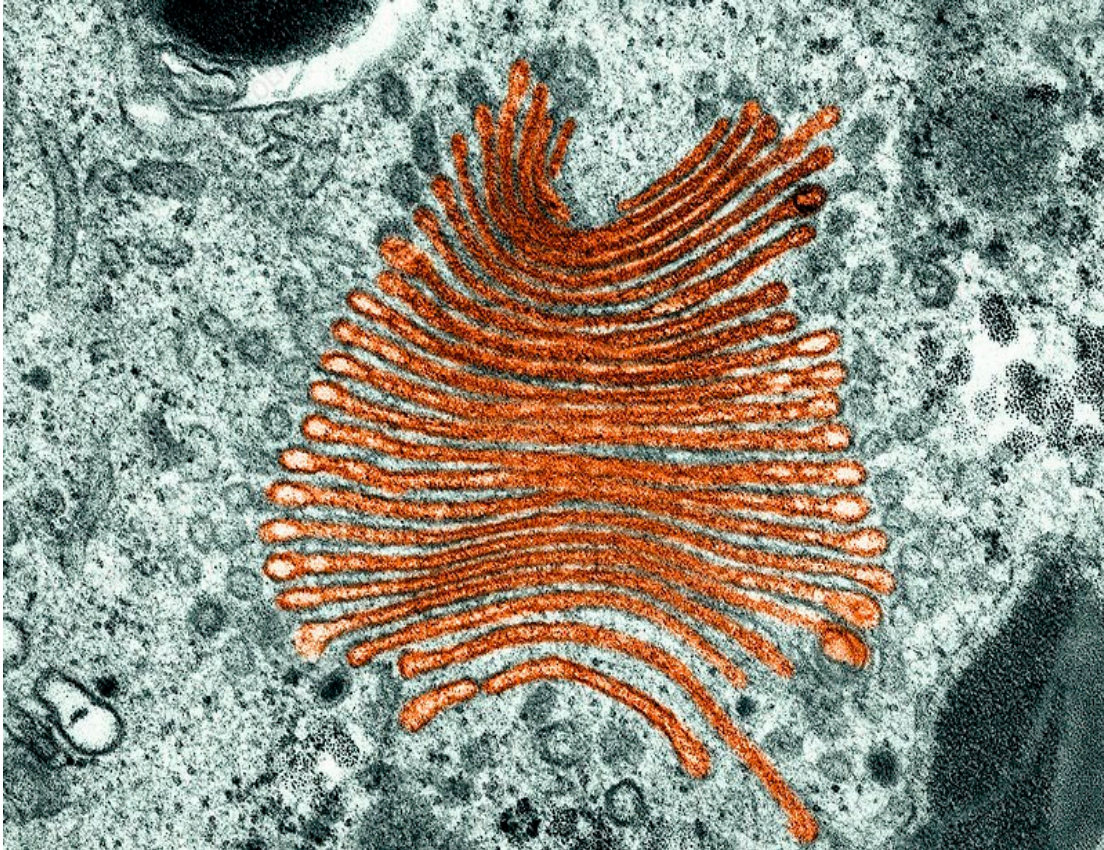
- Transportation of substances within cells
- In muscle cells ER also has a role in muscle contraction
- In ER, protein synthesis takes place on the surface of ribosomes

Fat droplets in ER



5 um

Golgi complex

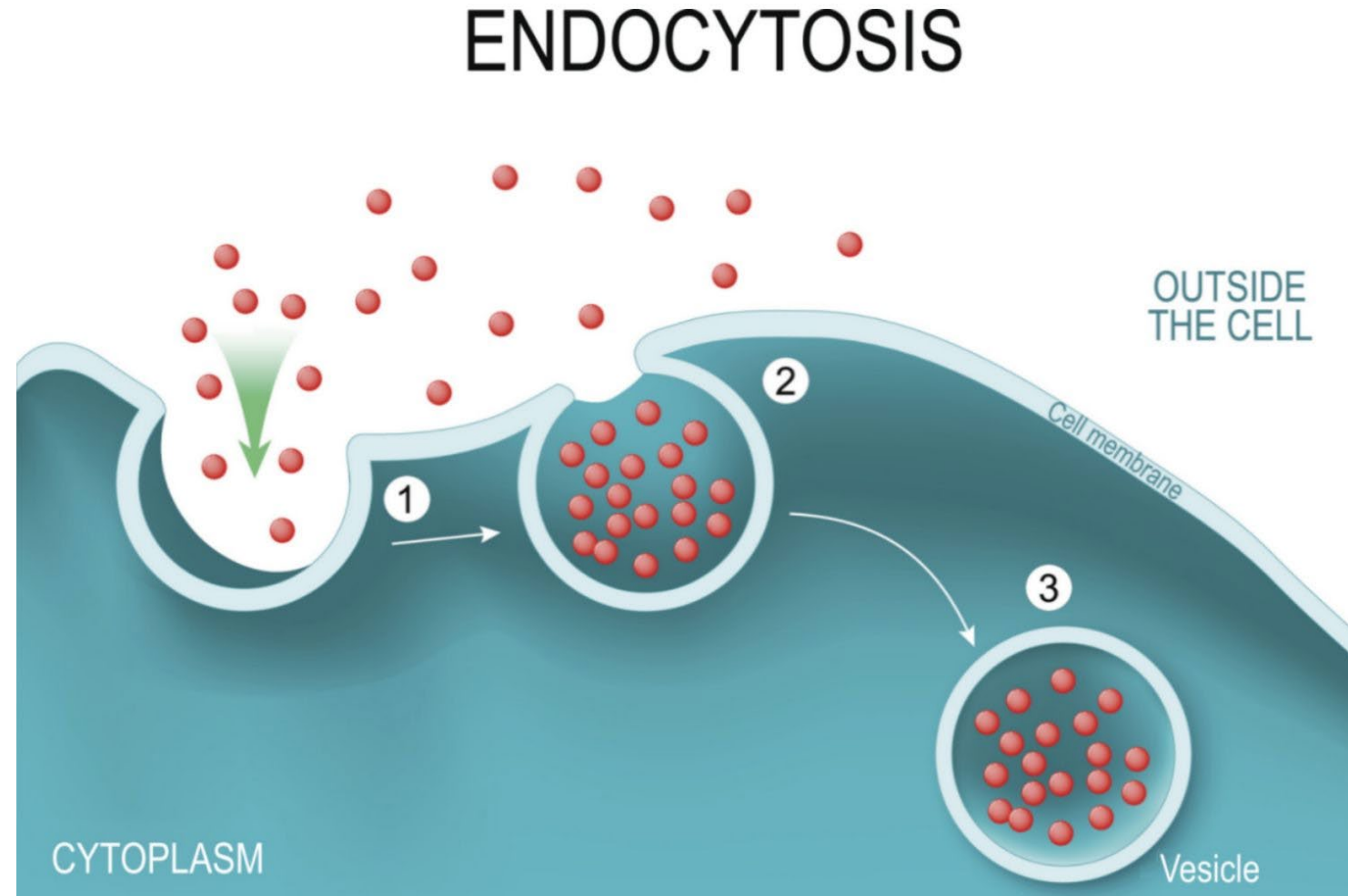


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- Modifies, sorts, packages and transports proteins and other molecules
- Forms secretory vesicles (lysosomes) to discharge processed proteins

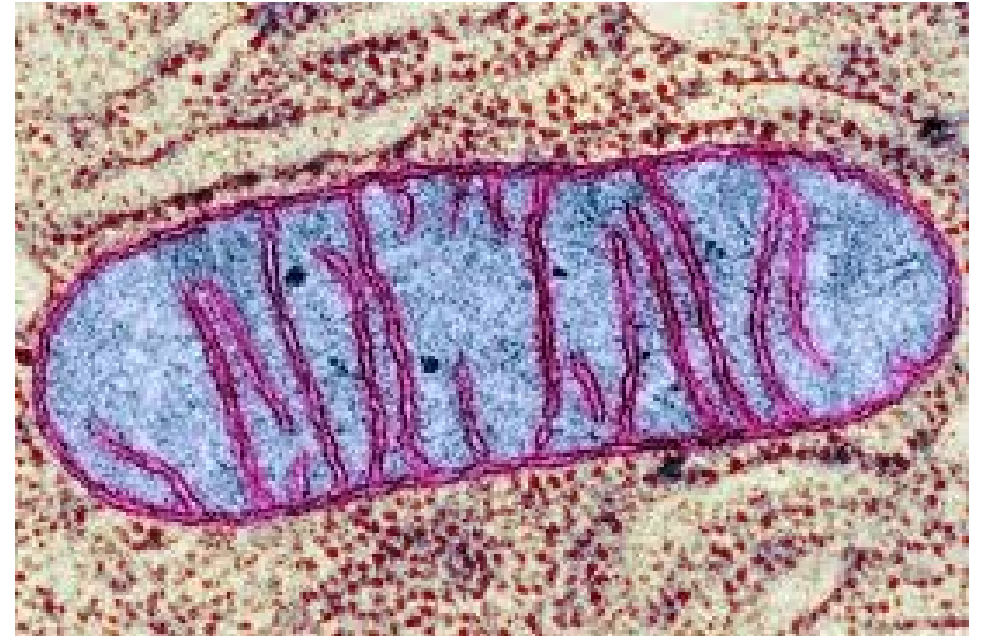
Endocytosis

- Cell membrane folds inward (1) – cell membrane folds back on itself and traps the fluid inside the vesicle (2) – vesicle is pinched off and is processed by the cell (3)
- Pinocytosis, phagocytosis, receptor-mediated endocytosis vs. exocytosis



Mitochondria

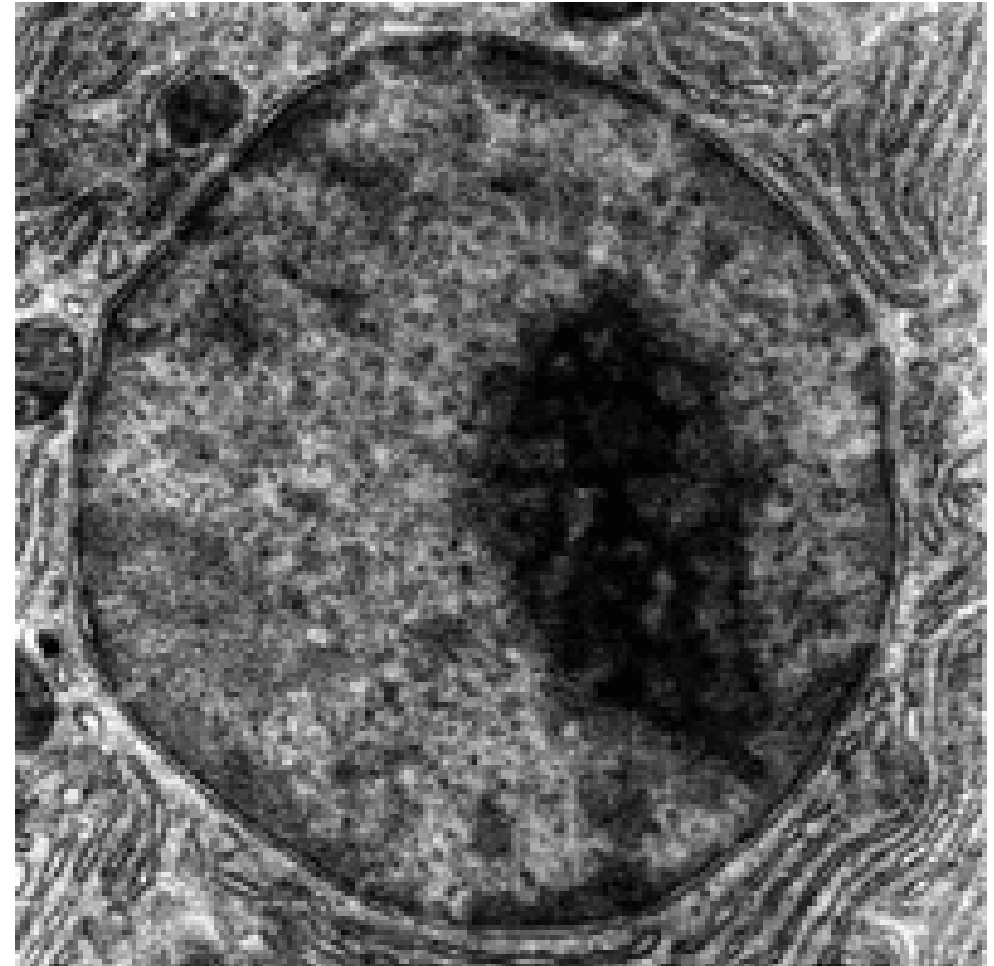
- Independent on moving and proliferation
- Possesses own DNA, inherited from the maternal side
- Responsible for aerobic respiration, *i.e.*, energy production within the cell:
ATP/adenosinetriphosphate
- Number within cells varies depending on the cells' energy consumption
- Mitochondrial diseases effect cells' energy production



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Nucleus

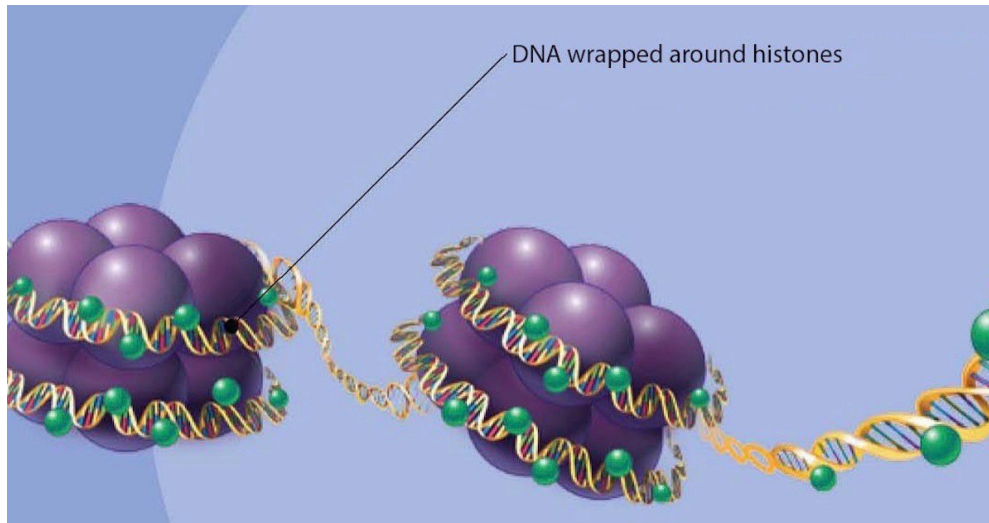
- In all other cells except red blood cells and platelets
- Surrounded by *nuclear envelope* with pores
- Usually 1-5 *nucleoli* = sites of RNA synthesis
- DNA is located within the nuclei as *chromatine* fibers around *histone* proteins



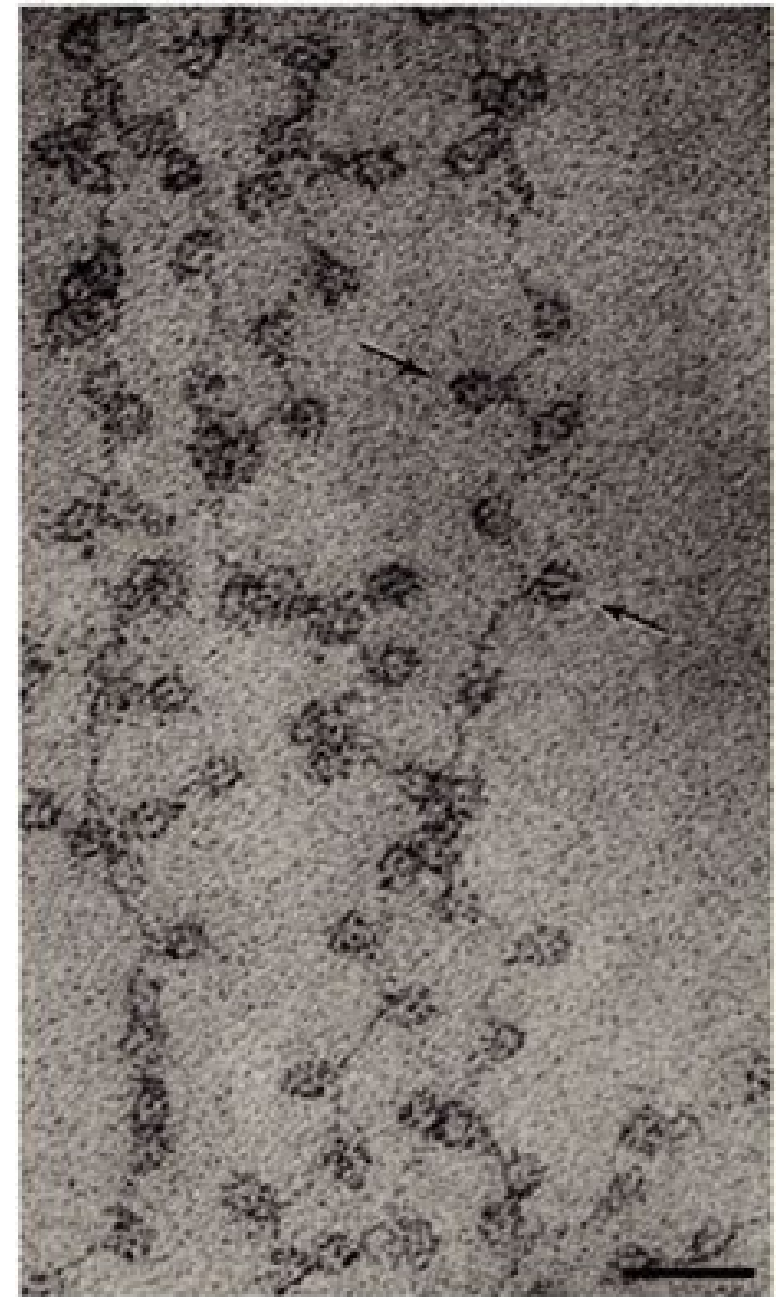
Wikipedia

Chromosomes

- Consist of DNA and histone proteins
- Histones provide structural support and affect gene expressions
- Nucleosome is the basic unit of chromatine



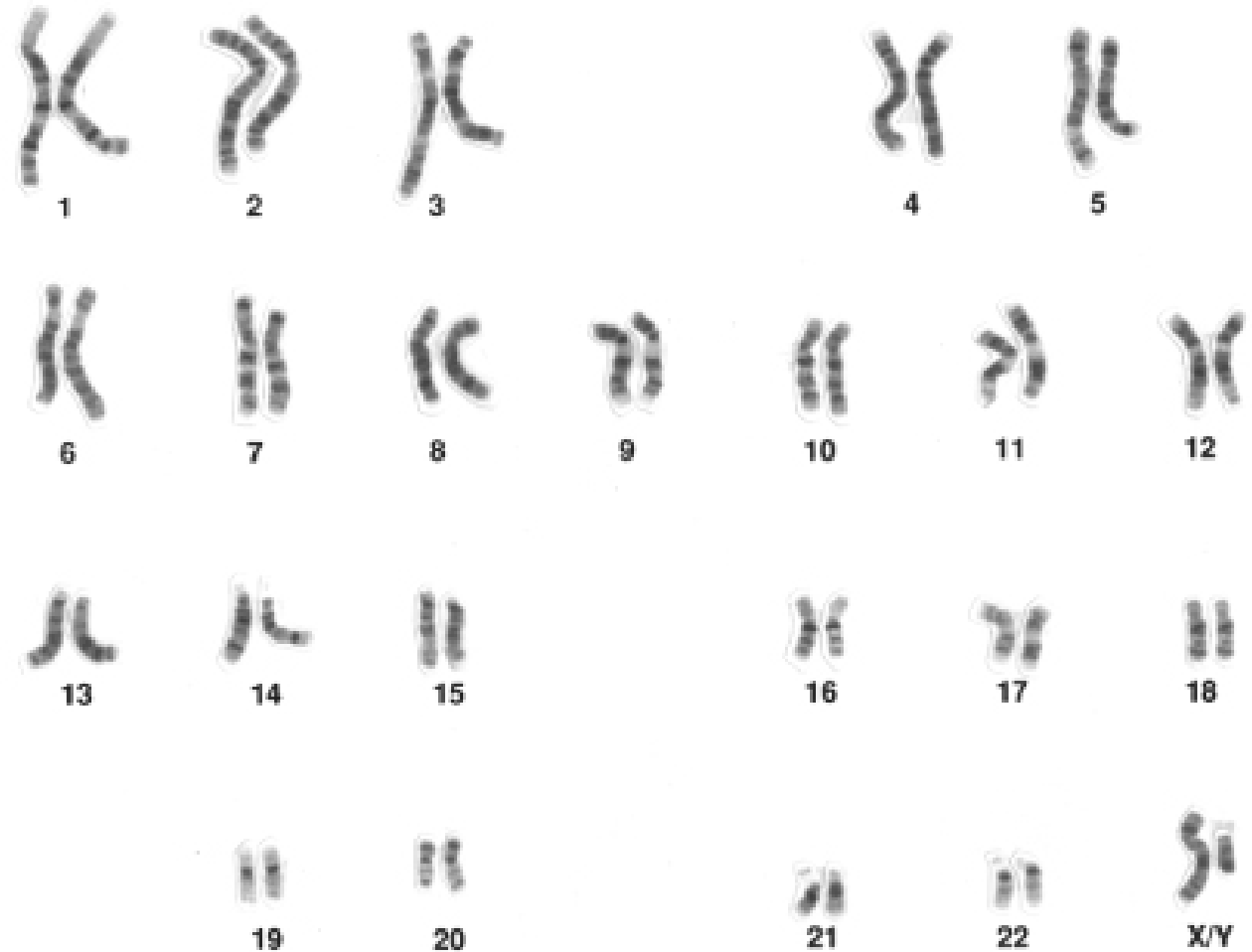
evolutionnews.org/2019/02/histone-code-a-challenge-to-evolution-an-inference-to-design/



Nature Reviews Molecular Cell Biology **4**, 811 (2003)

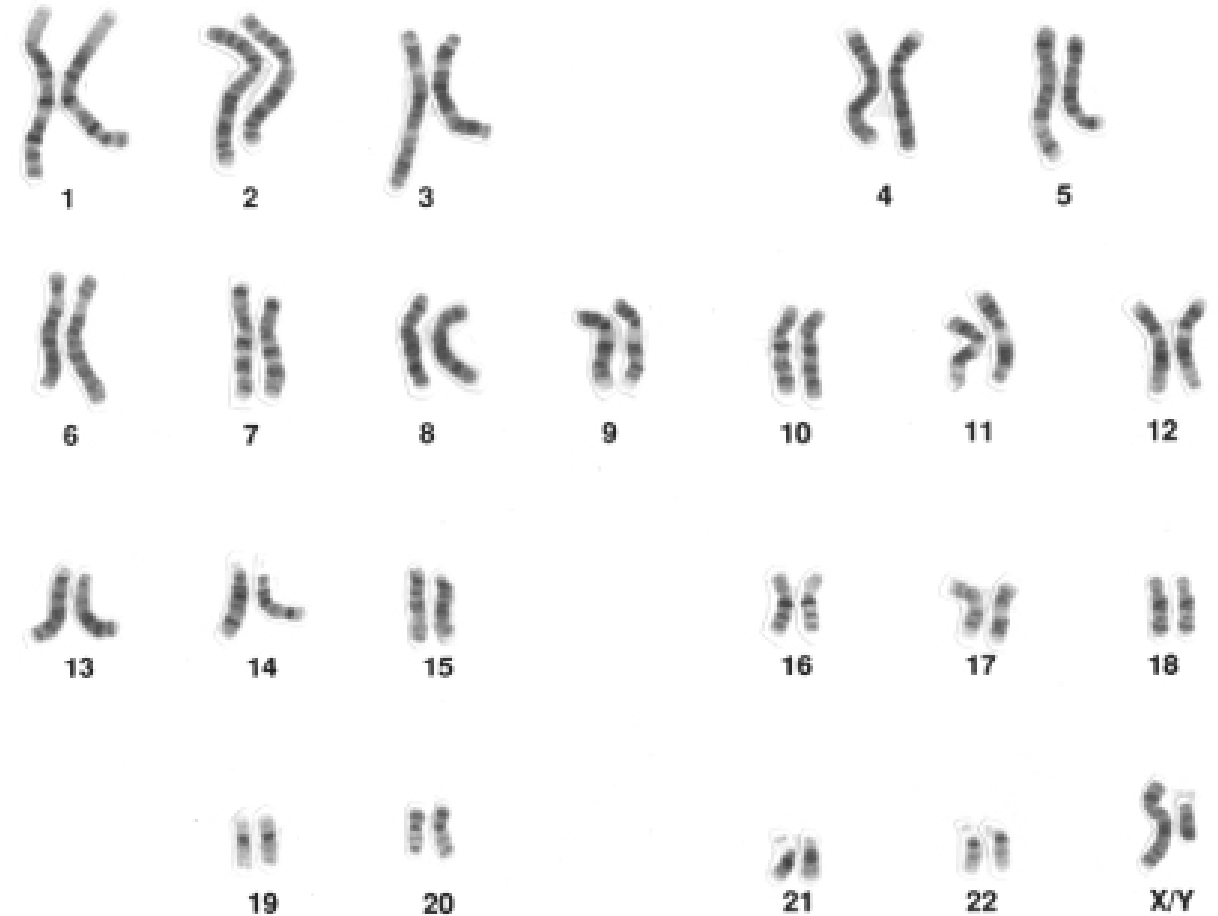
Chromosomes contain genes that modulate cell functions

- Appr. 20000-25000 genes
- During intervals outside cell division, chromosome resides in nucleus as > 1 m ribbon
- Before cell division, the chromatides condense
- *Gametes have a single set of chromosomes (haploid cells) 22+1*
- Other cells (somatic) have *diploid* number of chromosomes $2 \times 23 = 46$



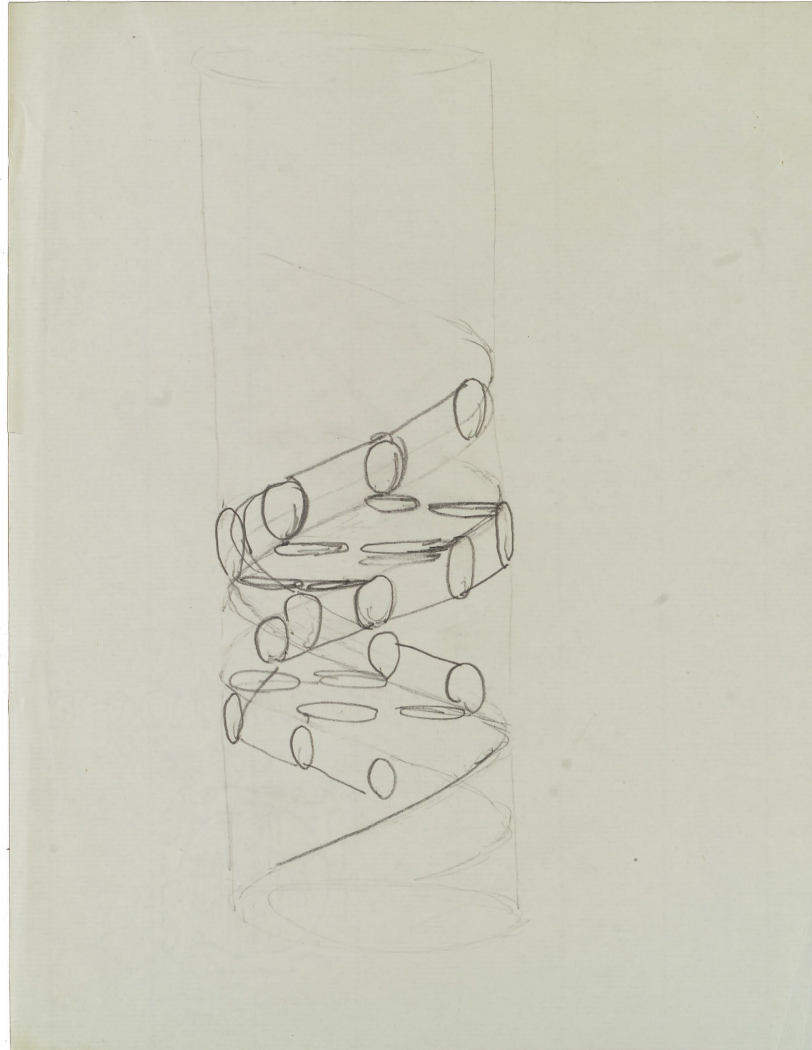
Gene terminology

- DNA, deoxynucleic acid
- Gene = Part of DNA that encodes the synthesis of a protein
- Homologous chromosomes/genes
- Dominant/recessive genes: one variant of a gene masks the other

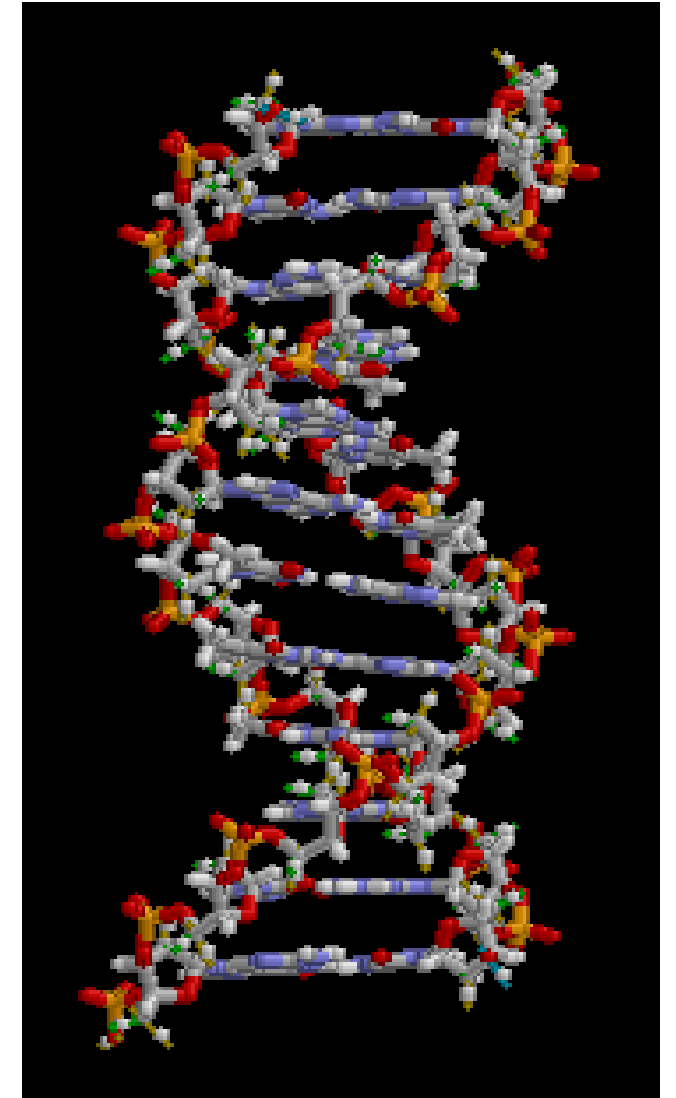


DNA double helix

- Structure described in 1953 by Watson and Crick
- Consists of
 - Pentose sugar
 - Nitrogenous base: adenine (A), guanine (G), cytosine (C), thymine (T)
 - Phosphate group
- Sugar + nitrogenous base + phosphate = *nucleotide*



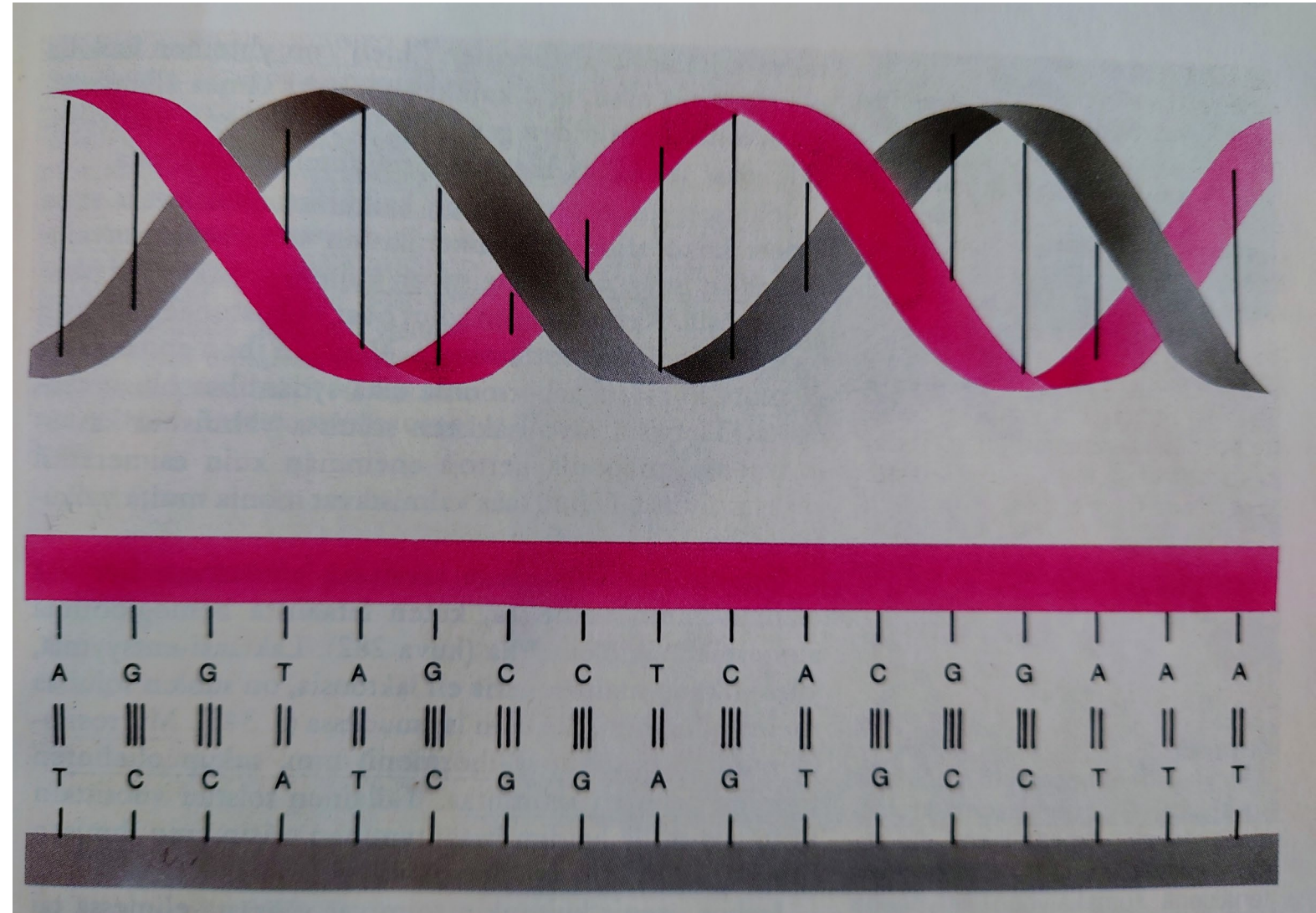
Crick, appr. 1953



Wikipedia

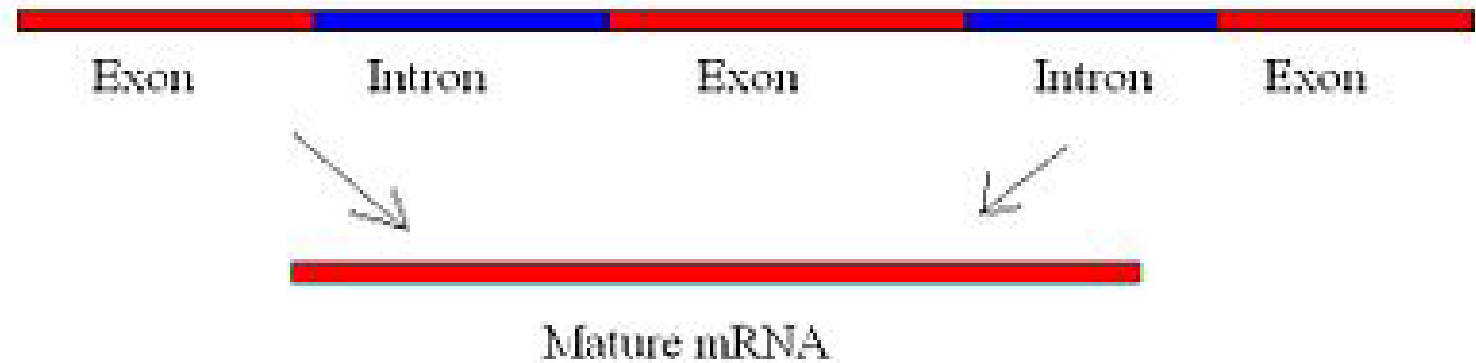
Transcription phase

- One of the DNA strands is copied into single sequence of ribonucleic acid (messenger-RNA, mRNA)
- mRNA is a “negative copy” of the original template
- mRNA travels outside of the nucleus to ribosomes



Introns and exons

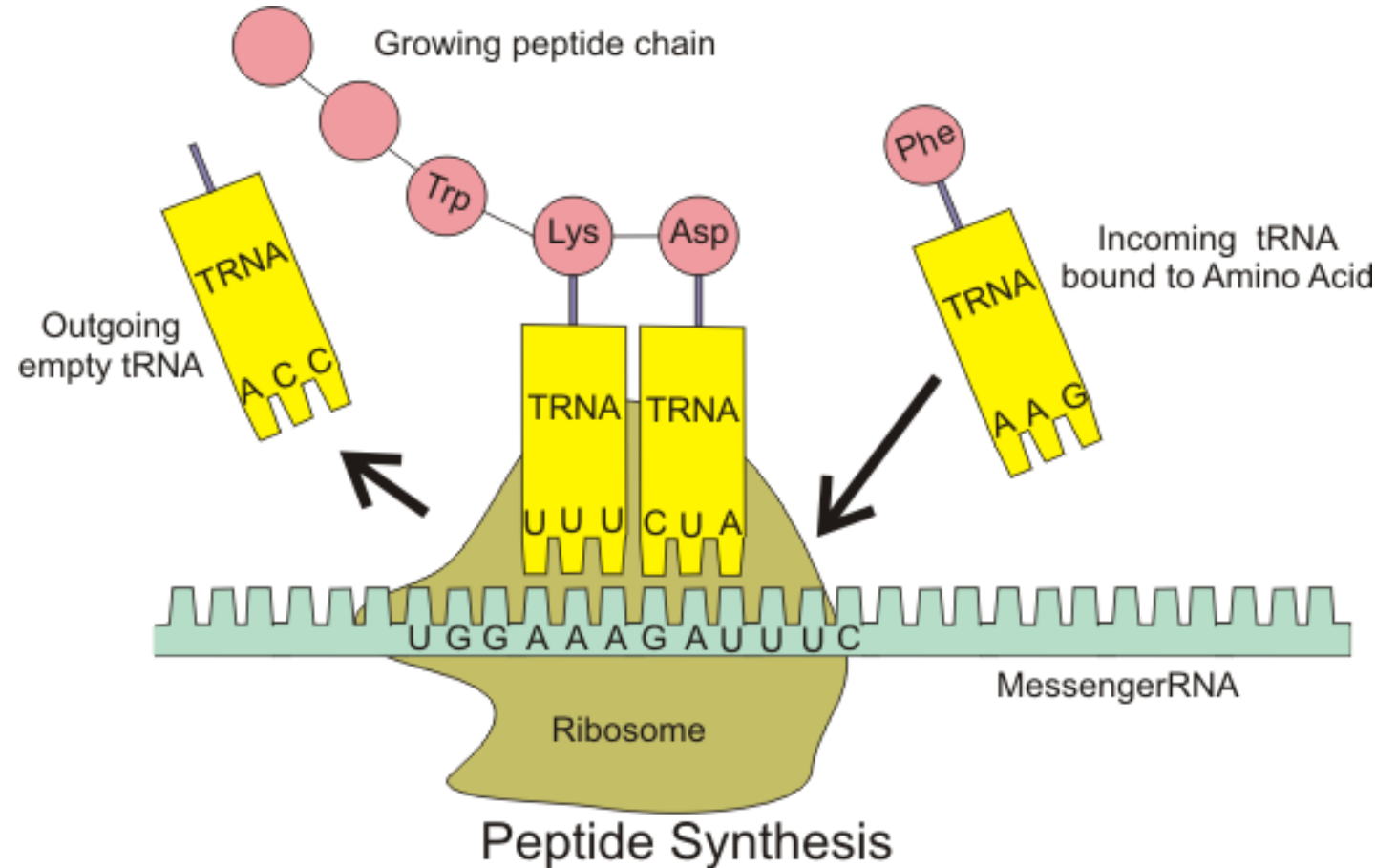
- Introns do not code proteins, and they are cut away from the mature mRNA
- Role unclear: alternative splicing, effective gene expression?
- Example of SARS-CoV-2



Wikipedia

Translation phase

- mRNA is translated 3 bases at a time
- Transfer RNA (tRNA) brings the corresponding amino acids (20 different ones)
- Similar in all animals
- Rate appr. 15 peptide bonds per second

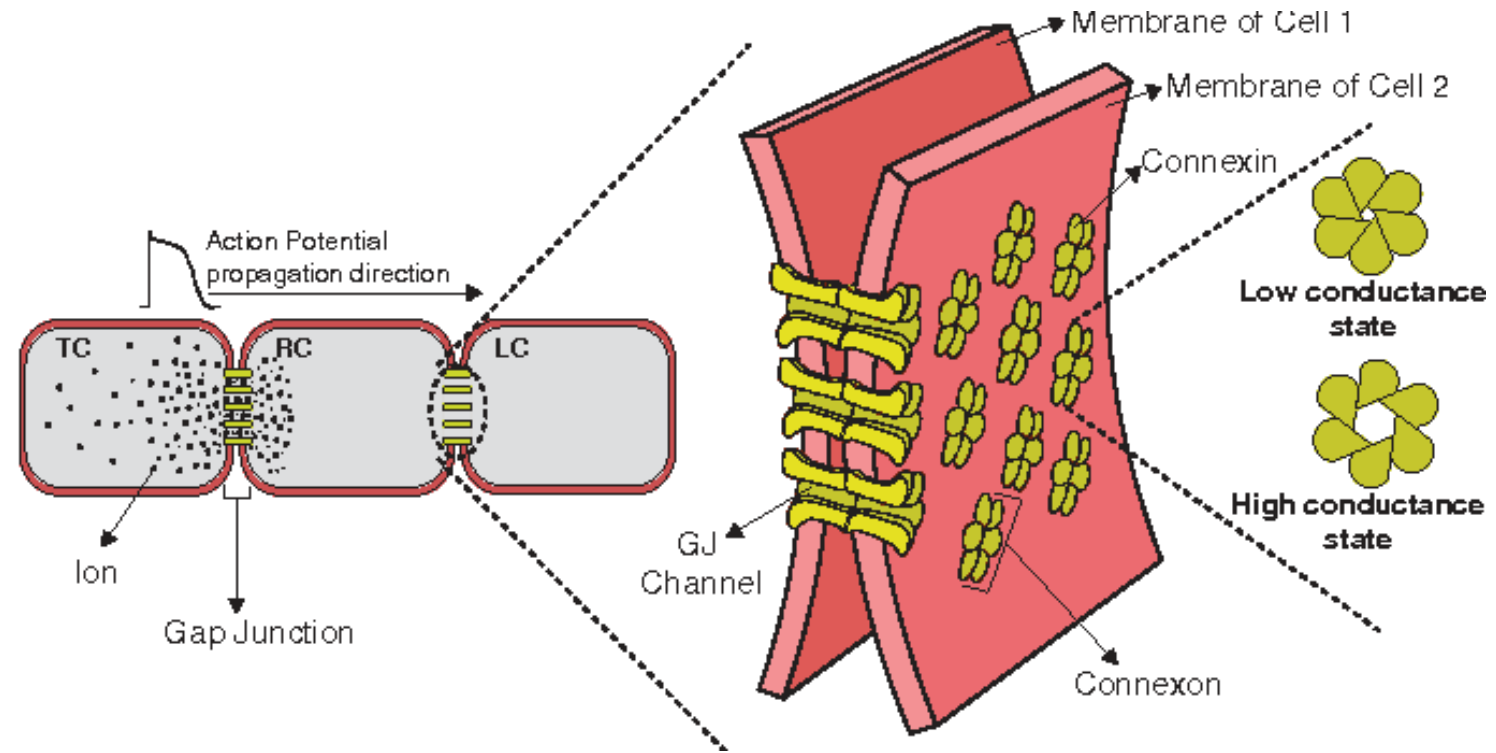


Cell functions: Summary

- Cell transform its **genetic information** forward with DNA synthesis: nucleus
- Cell **directs its own functions** via RNA synthesis: nucleus
- Cell maintains its **chemical composition** stable: cell membrane
- Cell **breaks down** nutrients: mitochondria, cytoplasm, lysosomes
- Cells bind the **energy** (ATP) released from nutrients: mitochondria
- Cell **produces** protein, fat, carbohydrates: ribosomes, endoplasmic reticulum, Golgi complex

Cell signaling

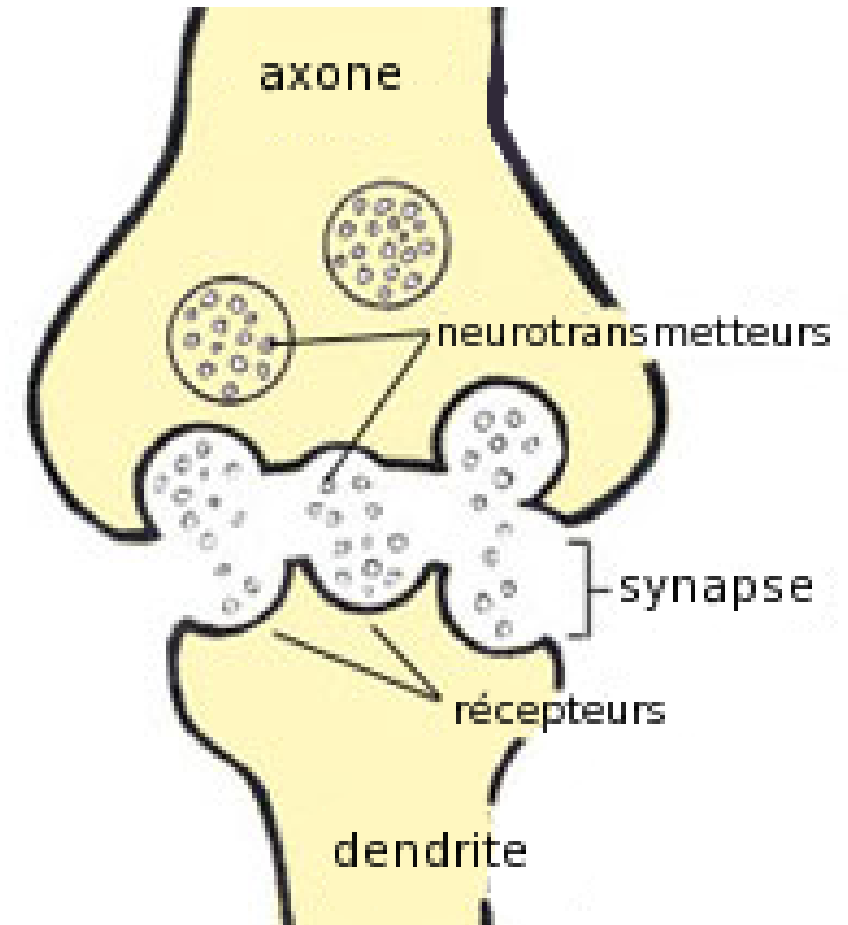
- Electric action potential directly from one cell to another via gap junction: in smooth muscle and cardiac muscle tissues



Kilinc ja Akan, 2013

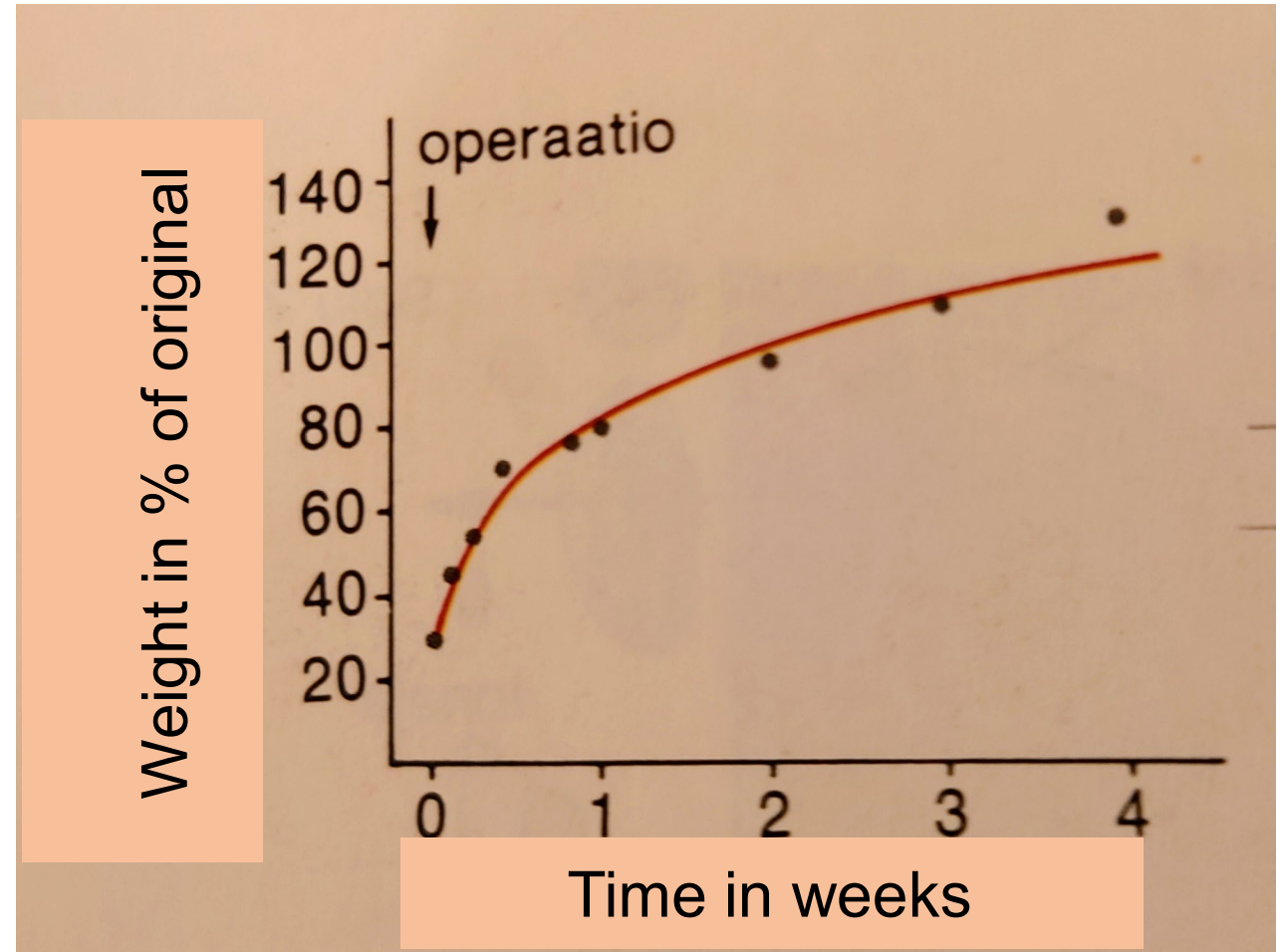
Cell signaling

- Chemical *transmitters* either directly from cell to another or via space between cells (e.g., synapses between nerve cells)
- *Hormones* travel far with circulation; *paracrine hormones* affect close-by cells (e.g., immune system, local dilation of blood vessels)



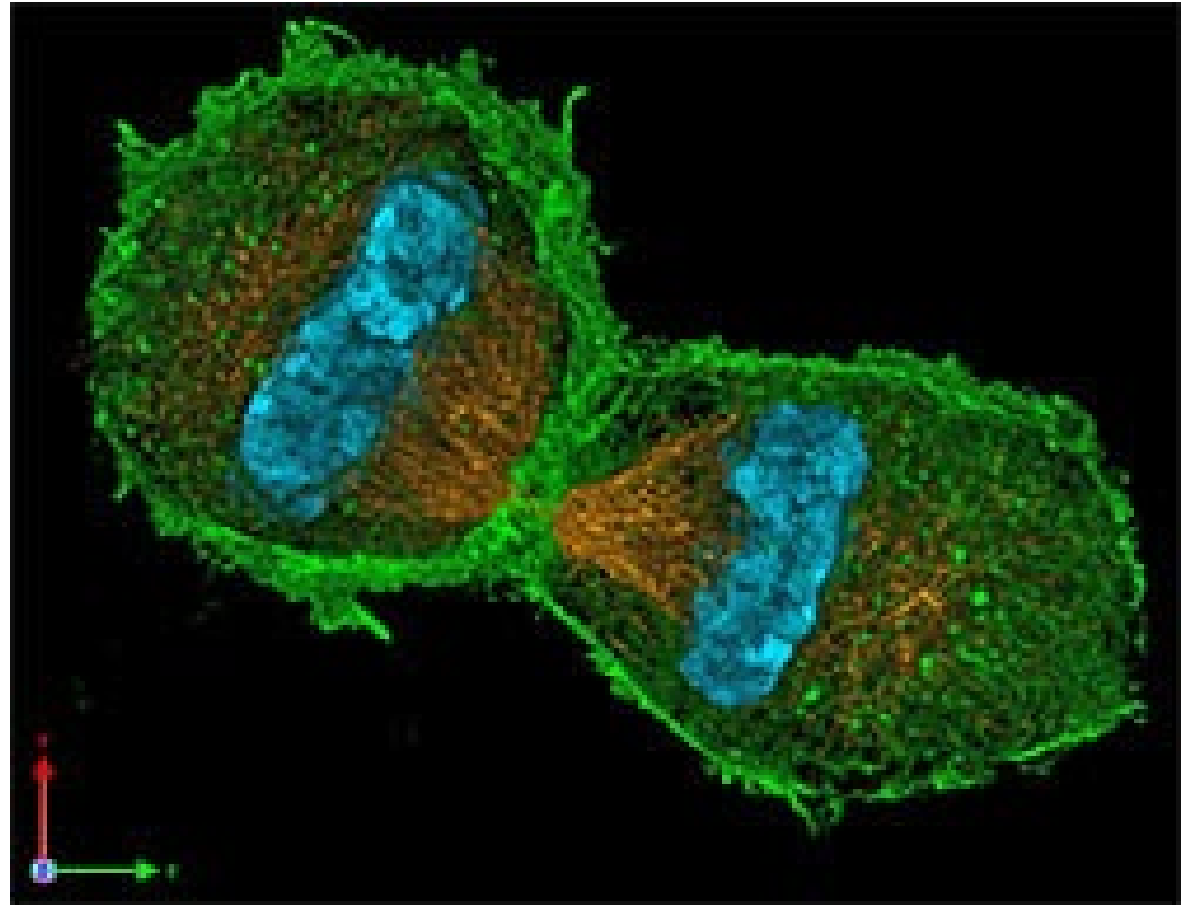
Number of cells is regulated

- The development of organisms = cell growth, cell division, cell differentiation
- In the fetal period, all divisions are fast – after that, big differences between cells
 - ✓ Epithelial cells in intestines – 5 d
 - ✓ Liver cells – month
 - ✓ Nerve cells – never
- Growth factors in significant role in different organ systems

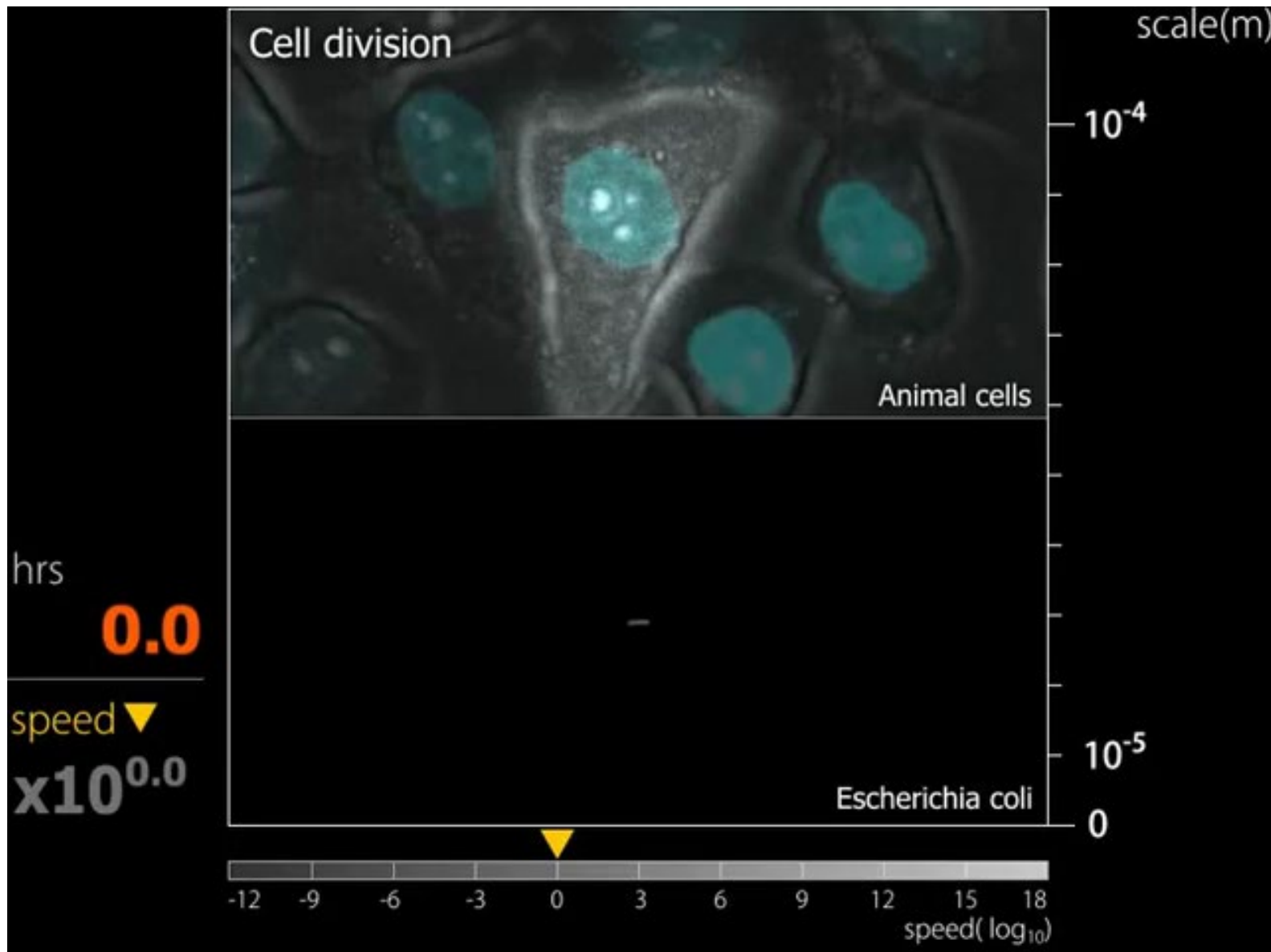


Mitotic phase

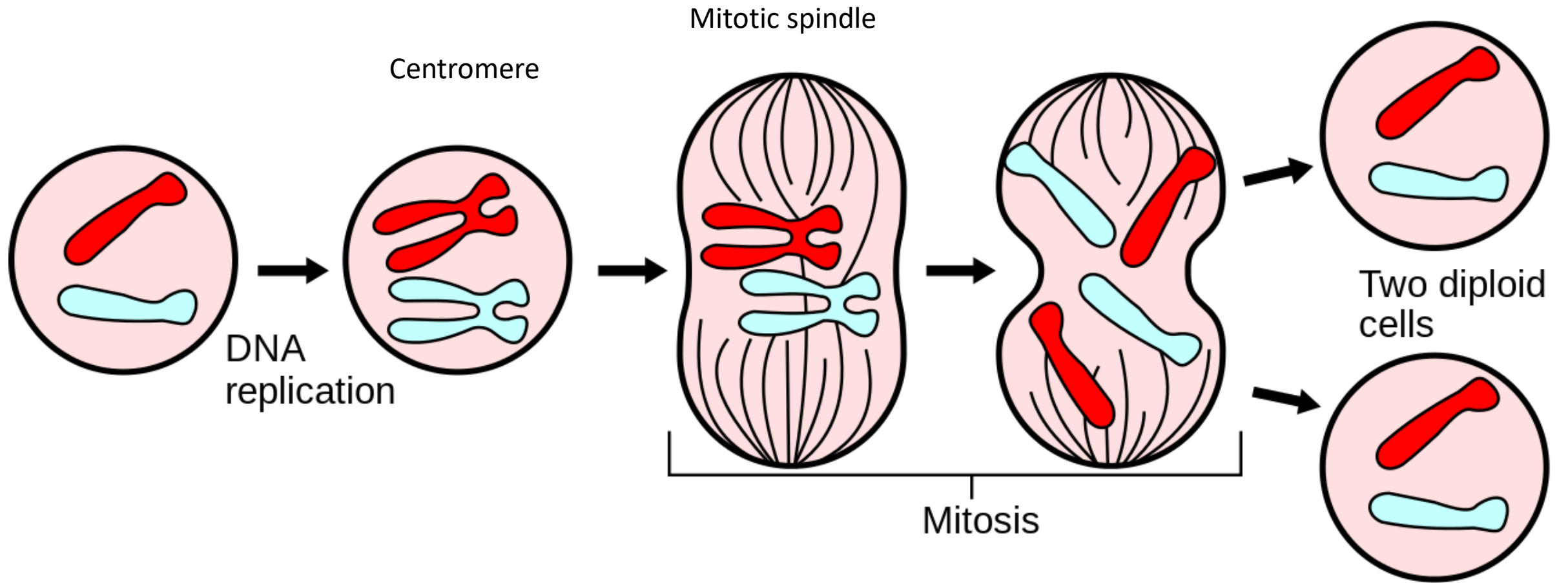
- Formation of two identical cells, consisting of a nuclear division and cytoplasmic division

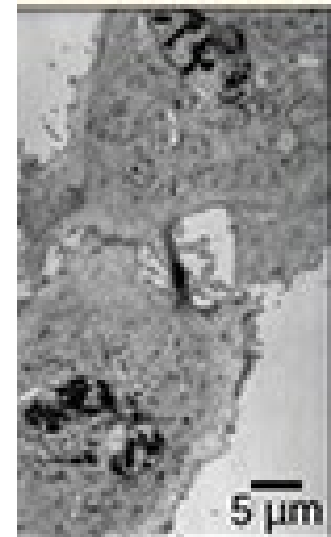
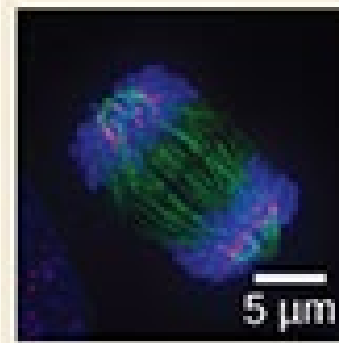
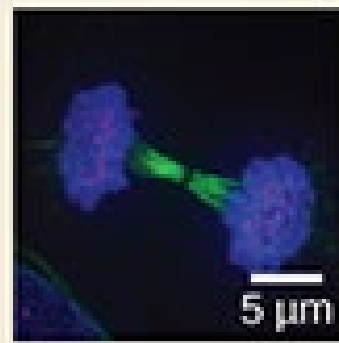
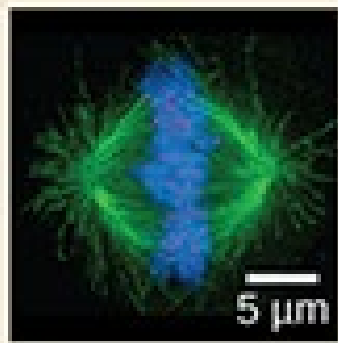
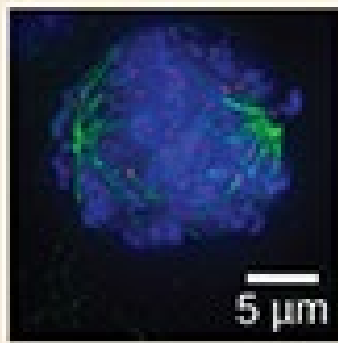
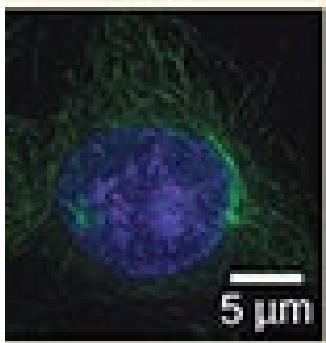
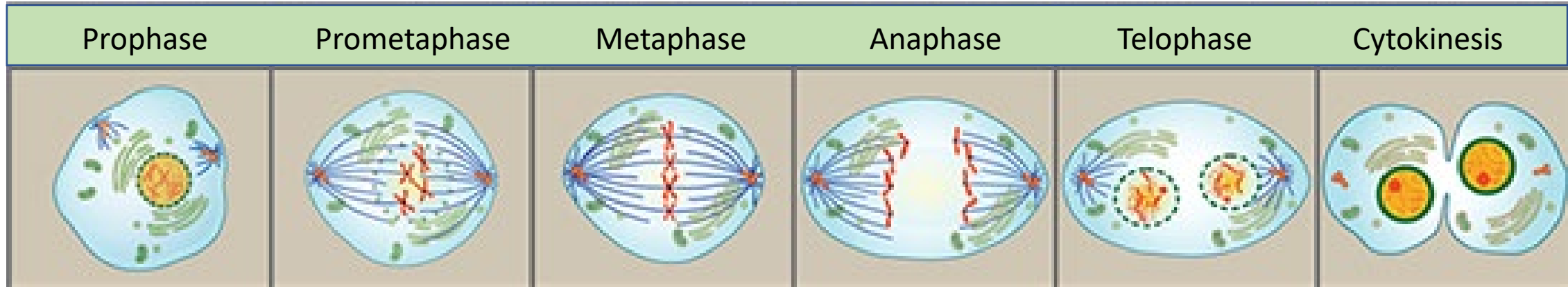


Mitosis in a mouse cell (Photo: Lothar Schermelleh)



Mitotic phase



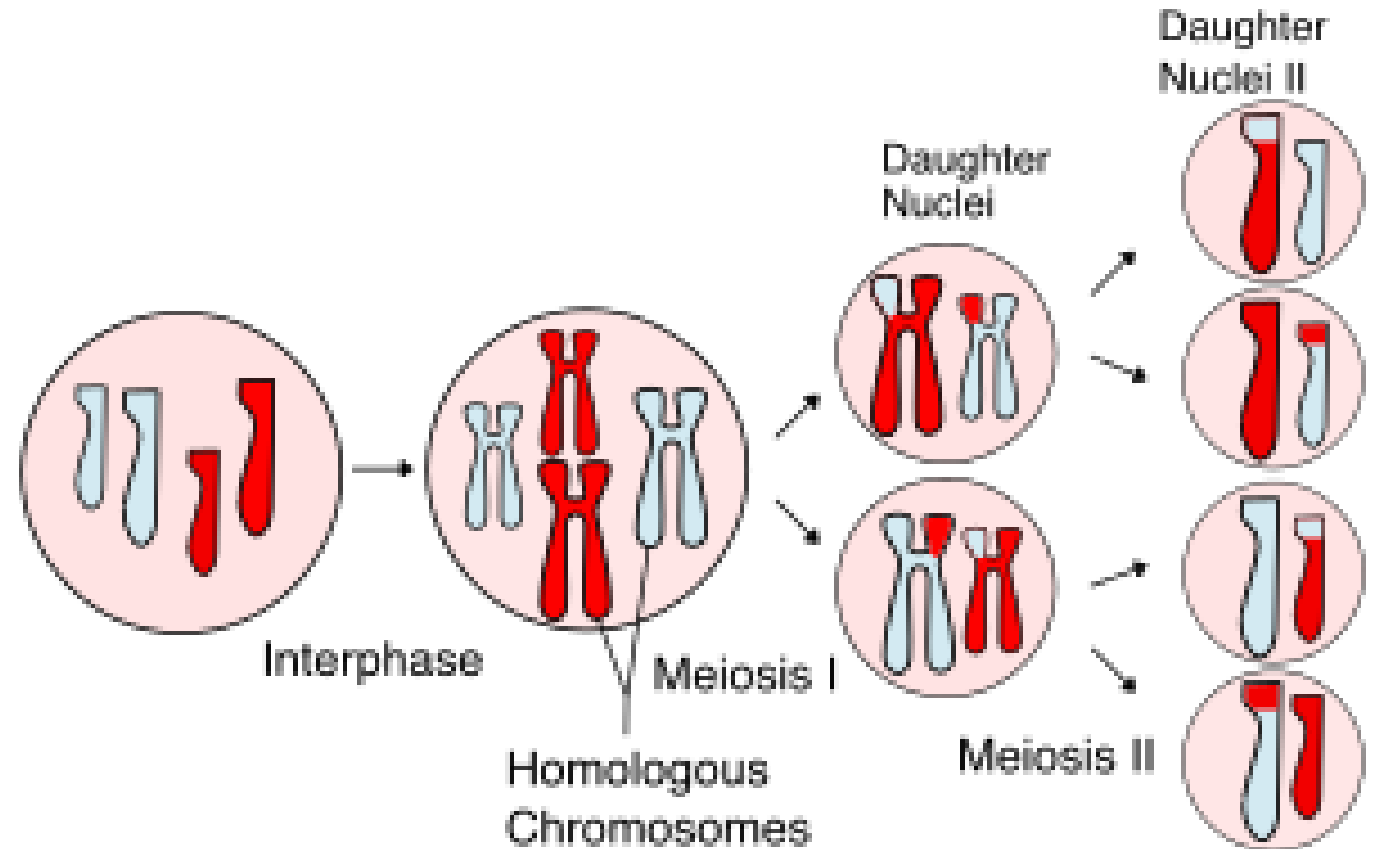


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Modified Mariana Ruiz Villareal, Roy van Heesbeen, the Wadsworth Center

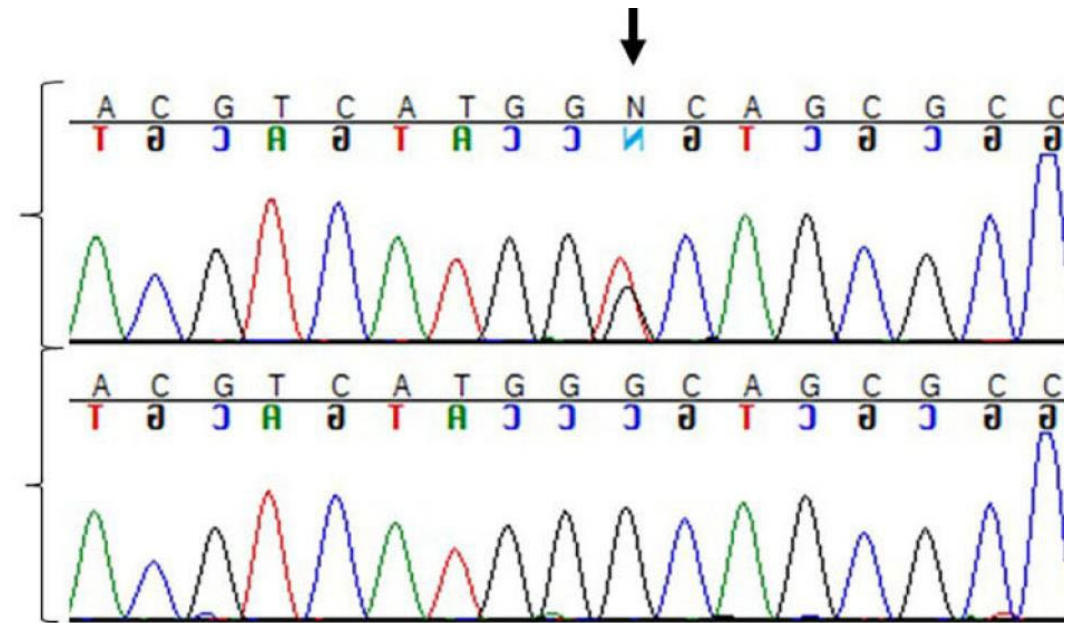
Meiosis

- Production of gametes
- Gametes are haploid cells (23 chromosomes)
- Two successive division rounds → 4 cells
- Crossing-over = exchange of genes between chromatids
- The resulting gametes are genetically different from the original ones



Mutations

- Only mutations in gametes are inheritable
- In somatic cells, mutations can associate with increased risk of disease
- Reasons: False DNA replication, physical/chemical/biological factors
- Genetic mutations
- Chromosomal mutations: loss, duplication, multiplication, turning



Sini Penttilä