Lectures 1-4

BT 632
Stem Cells, Cancer and Therapy
(3-0-0-6)

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Syllabus

- Introduction to stem cells: Types, characteristics, potency, differentiation; Stem cell isolation and culture; Embryonic, tissue specific and germ line stem cells; Induced pluripotent stem cells: direct reprogramming, transcription factors and RNAi, Stem cell specification and trans-differentiation; Stem cell niche, signaling and metabolism; Epigenetics; Ethical guidelines and issues: embryonic and induced pluripotent stem cells;

- Cancer types, oncogenes and tumor suppressor genes; Cancer origin, progression and relapse; Cancer stem cells; Cancer and normal stem cells: common and shared pathways; Cancer microenvironment; Cancer therapy: Chemotherapy, radiation, cell and integrative therapy; Cancer multidrug resistance; Stem cells for cancer therapy; Degenerative diseases; Tissue repair and regeneration; Disease modeling and drug discovery; Pharmacogenomics and Personalized medicine.

Texts and References

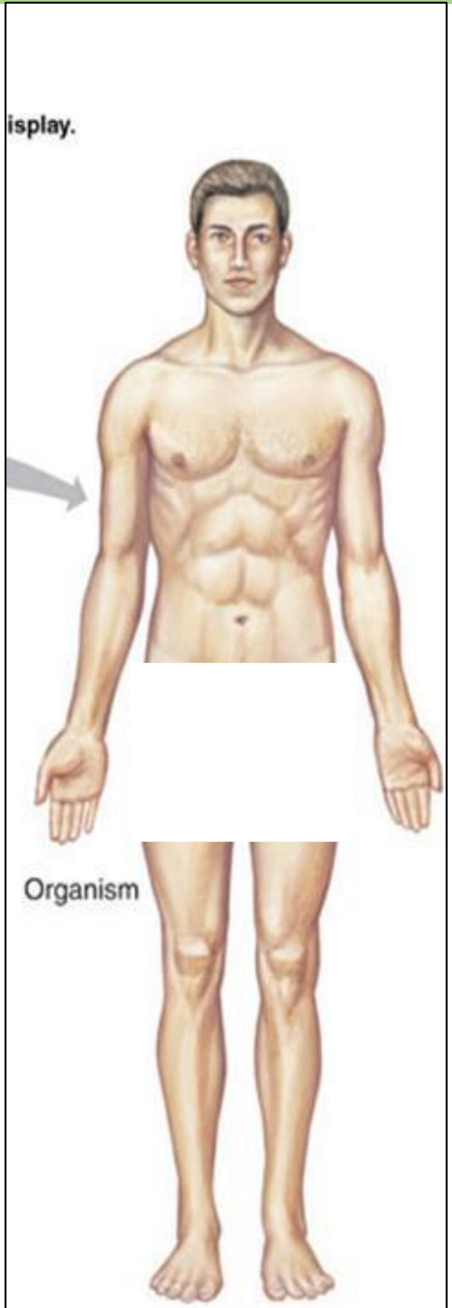
➢ Texts:

1. M. A. Hayat, Stem Cells and Cancer Stem Cells, Vol 2, Springer, 2012.
2. N. M. Bilko, B. Fehse, W. Osterta, C. Stocking and A.R. Zander, Stem Cells and their potential for clinical applications, Springer, 2008.
3. R. A. Weinberg, The Biology of Cancer, Garland Science, 2007.

➢ References:

1. R.G. Bagley, B.A. Teicher, Stem Cells and Cancer, Humana Press, 2009.
2. A. Bongso and E.H. Lee, Stem Cells: From bench to bedside, 2nd Edition, World Scientific, 2011.

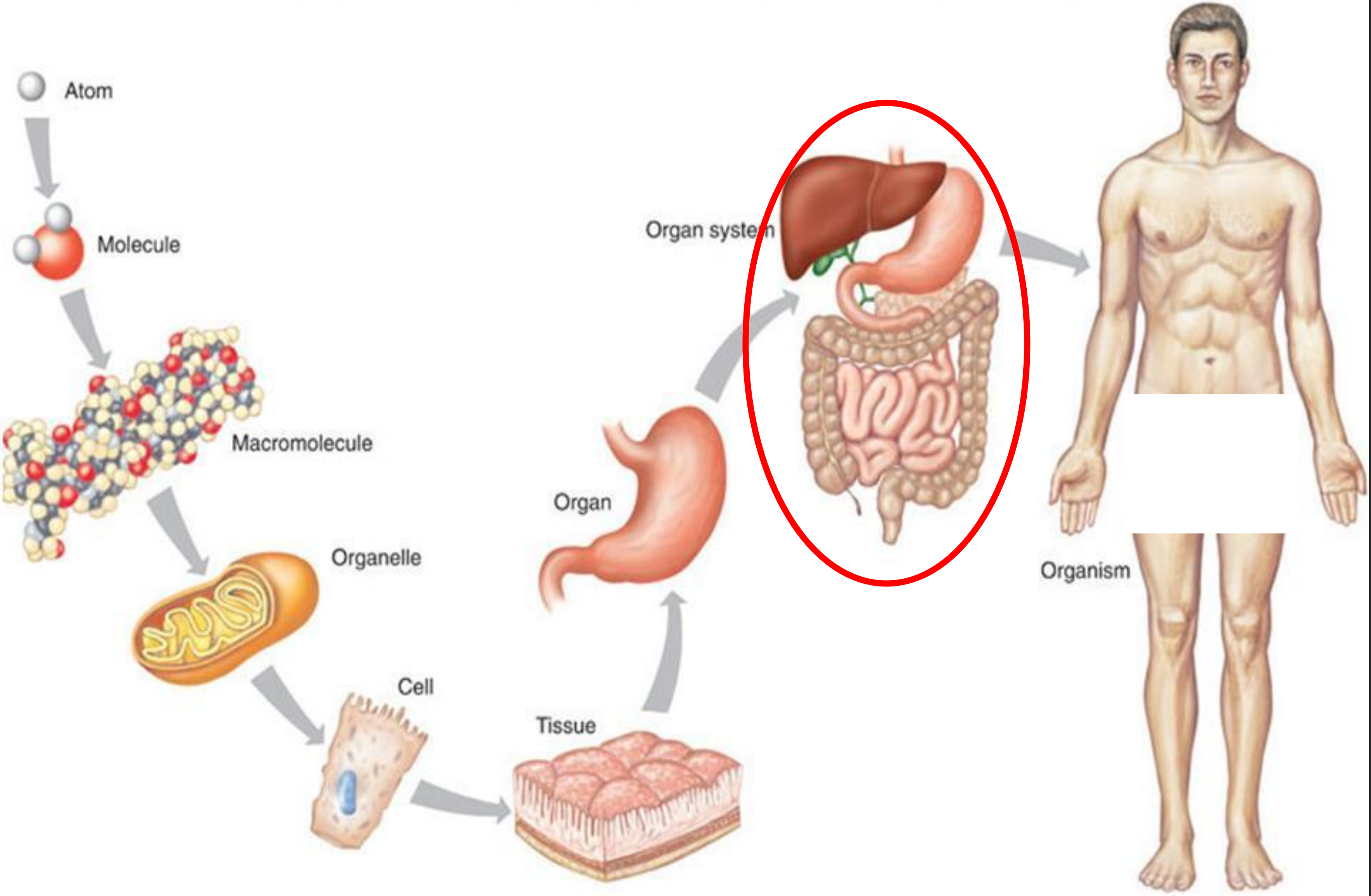
Eukaryote – Homo sapiens (Human)



- The human body is the structure of a human being.

Eukaryote – Homo sapiens (Human)

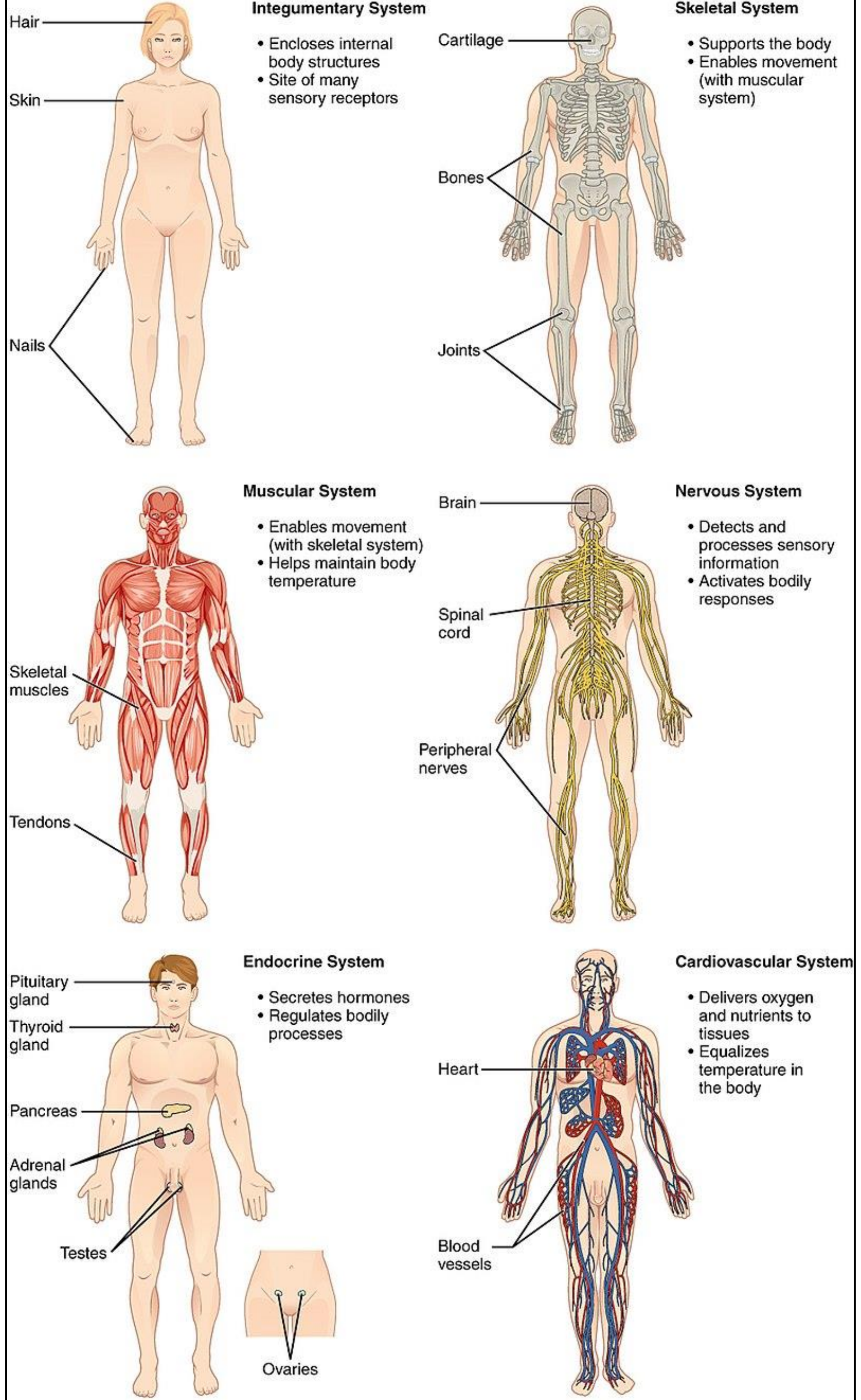
Fig. 1.03



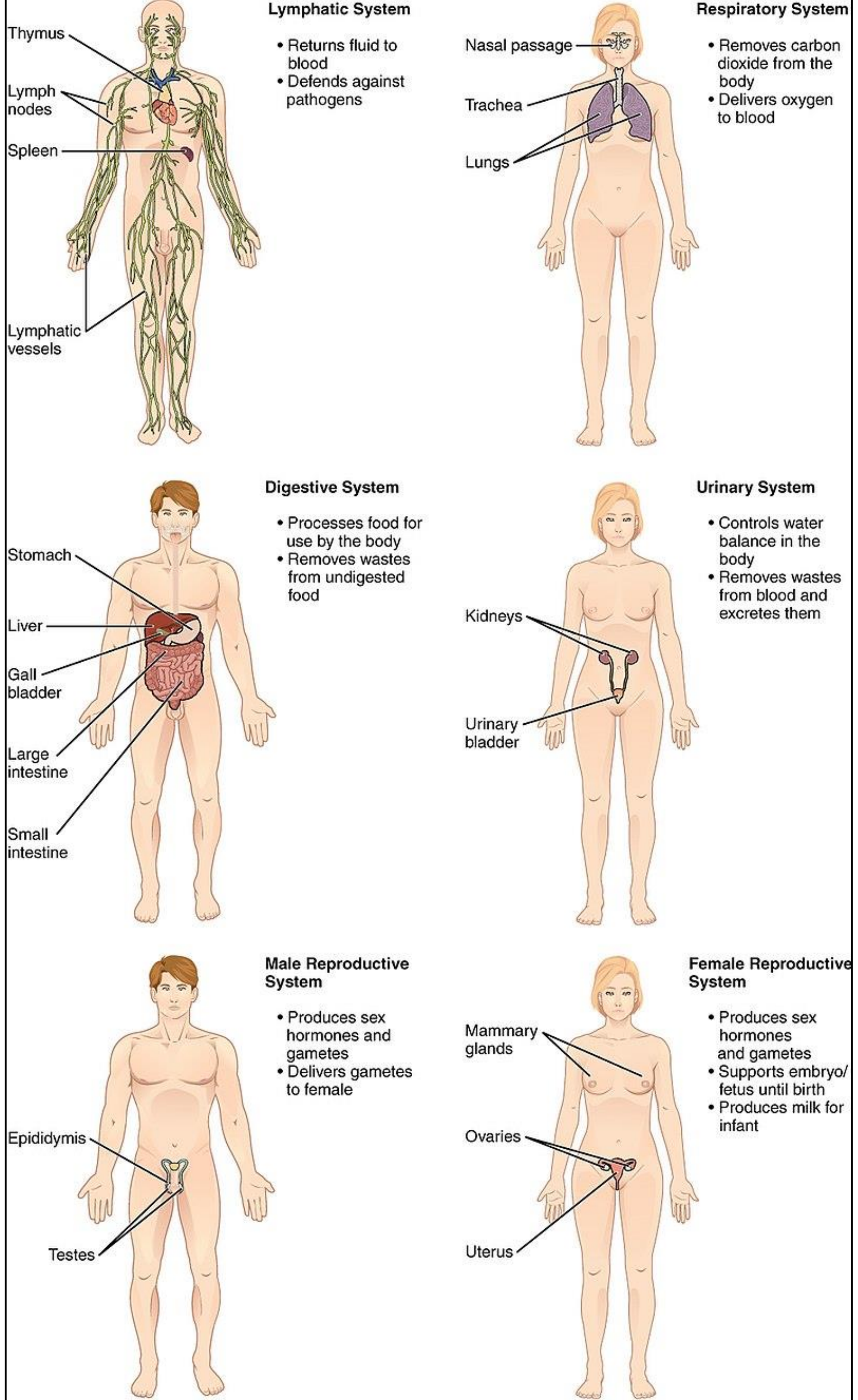
- The human body is the structure of a human being.
- It is composed of many different types organ systems.
- They ensure homeostasis and the viability of the human body.

Various body systems present in a human body

1. Respiratory system
2. Cardiovascular system (heart and circulatory system)
3. Digestive system
4. Nervous system
5. Lymphatic system (or Immune system)
6. Endocrine system
7. Integumentary system (or Exocrine system)
8. Musculoskeletal system
9. Urinary system (or Excretory system or Renal system)
10. Reproductive system



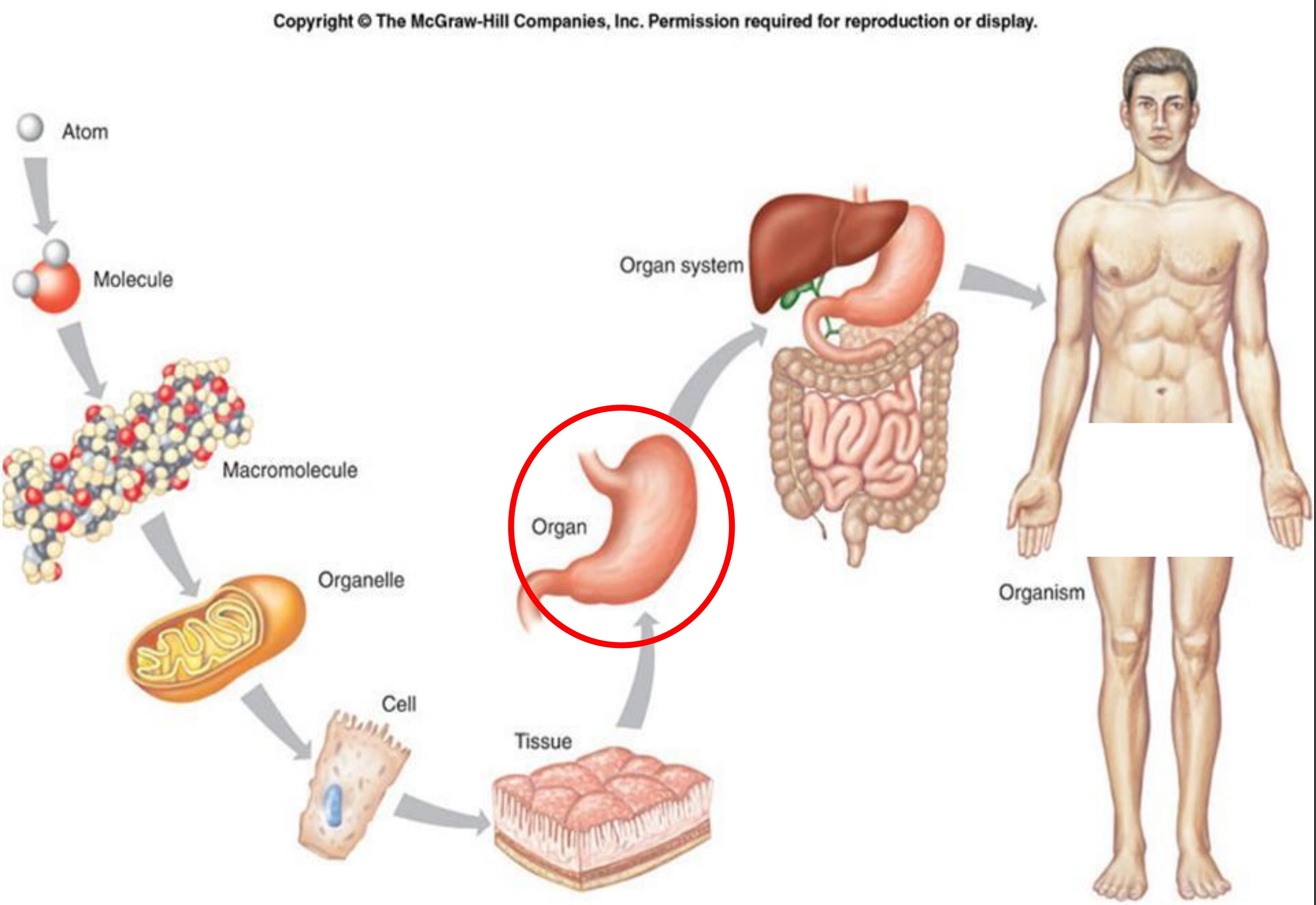
Integumentary System
• Encloses internal body structures
• Site of many sensory receptors
Hair
Skin
Nails
Skeletal System
• Supports the body
• Enables movement (with muscular system)
Cartilage
Bones
Joints
Muscular System
• Enables movement (with skeletal system)
• Helps maintain body temperature
Skeletal muscles
Tendons
Nervous System
• Detects and processes sensory information
• Activates bodily responses
Brain
Spinal cord
Peripheral nerves
Endocrine System
• Secretes hormones
• Regulates bodily processes
Pituitary gland
Thyroid gland
Pancreas
Adrenal glands
Testes
Ovaries
Cardiovascular System
• Delivers oxygen and nutrients to tissues
• Equalizes temperature in the body
Heart
Blood vessels



Lymphatic System
• Returns fluid to blood
• Defends against pathogens
Thymus
Lymph nodes
Spleen
Lymphatic vessels
Respiratory System
• Removes carbon dioxide from the body
• Delivers oxygen to blood
Nasal passage
Trachea
Lungs
Digestive System
• Processes food for use by the body
• Removes wastes from undigested food
Stomach
Liver
Gall bladder
Large intestine
Small intestine
Urinary System
• Controls water balance in the body
• Removes wastes from blood and excretes them
Kidneys
Urinary bladder
Male Reproductive System
• Produces sex hormones and gametes
• Delivers gametes to female
Epididymis
Testes
Female Reproductive System
• Produces sex hormones and gametes
• Supports embryo/fetus until birth
• Produces milk for infant
Mammary glands
Ovaries
Uterus

Eukaryote – Homo sapiens (Human)

Fig. 1.03



- The human body is the structure of a human being.
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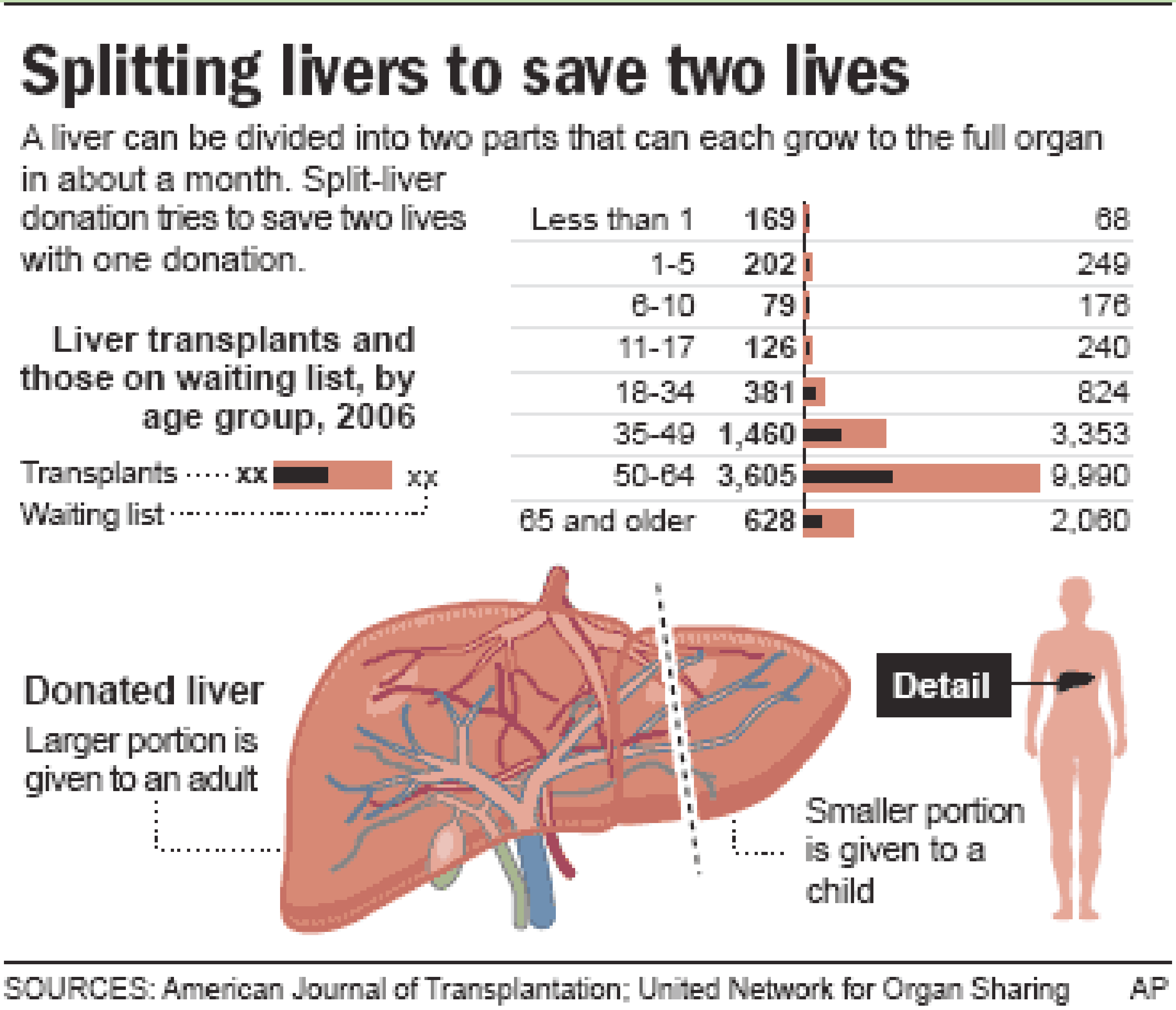
Number of organs present in a human body

- **79 organs** have been identified in the human body.
- **Skin** is the **largest and longest organ** according to its size and weight.
- **Pineal gland** near the center of the brain, in a groove between the hemispheres, is the **smallest organ**.
- **Liver** is the **largest internal** organ of the body.
- The **heart** is the **first major functional organ to develop** and starts to beat and pump blood at about three weeks into embryogenesis.
- The **last major organ** to develop and mature before birth are the **lungs**.
- The **brain** is the **last to reach its final mature** form and develops even after birth.

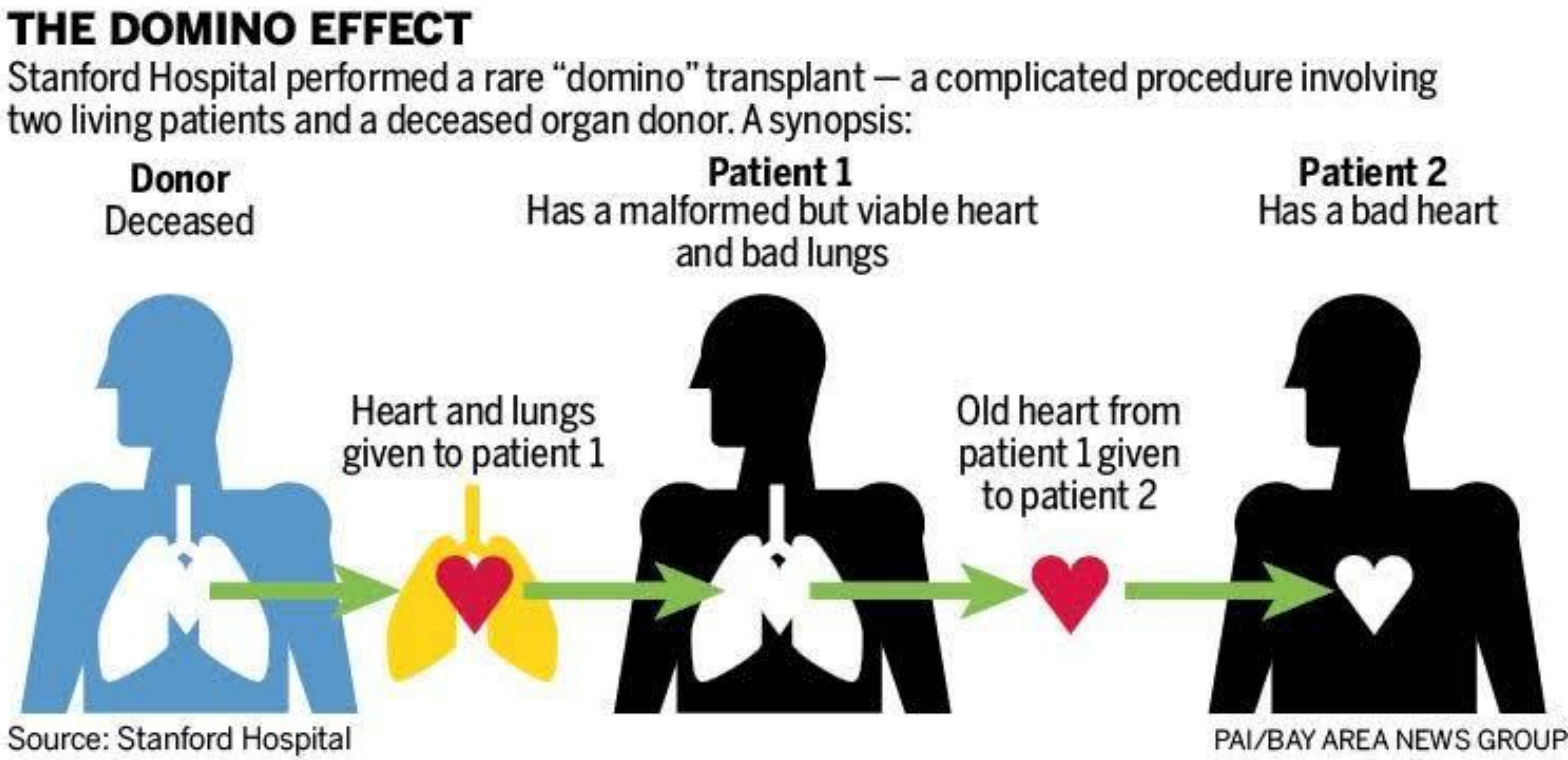
SENSORY ORGANS are as follows:-

- Eyes
- Ears
- Nose
- Tongue
- Skin

Split transplant



Domino transplant



Number of organs present in a human body

News > Science

Mesentery: New organ discovered inside human body by scientists (and now there are 79 of them)

The finding opens up 'a whole new area of science'

Tom Embury-Dennis | @tomemburyd | Tuesday 3 January 2017 17:27 |
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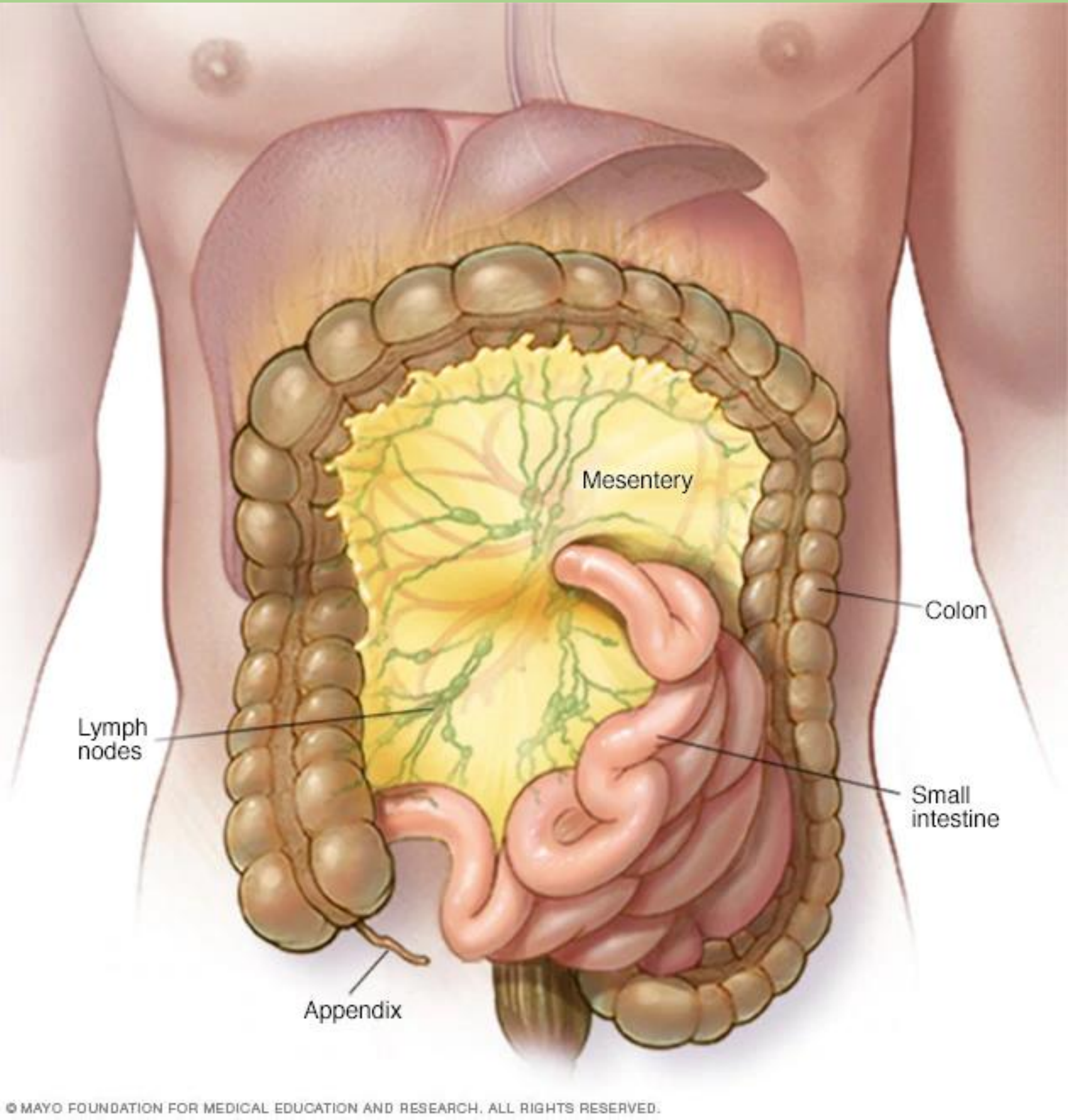
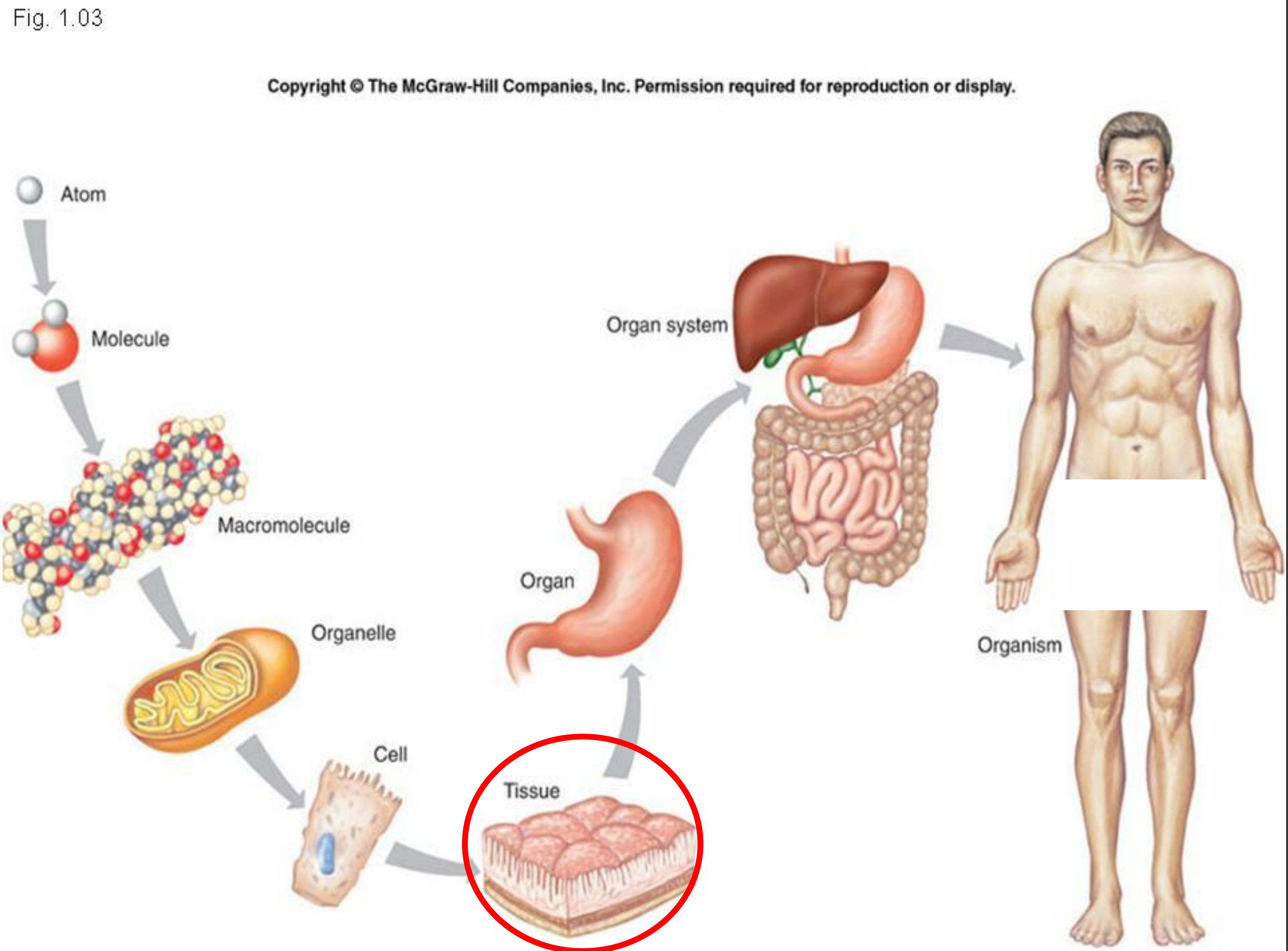
- **Large single continuous stretch of tissue that support and position all the digestive organs in the abdomen.**
- **The organ is responsible for transporting blood and lymphatic fluid between the intestine and the rest of the body.**



Eukaryote – Homo sapiens (Human)



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Different types of tissues present in a human body

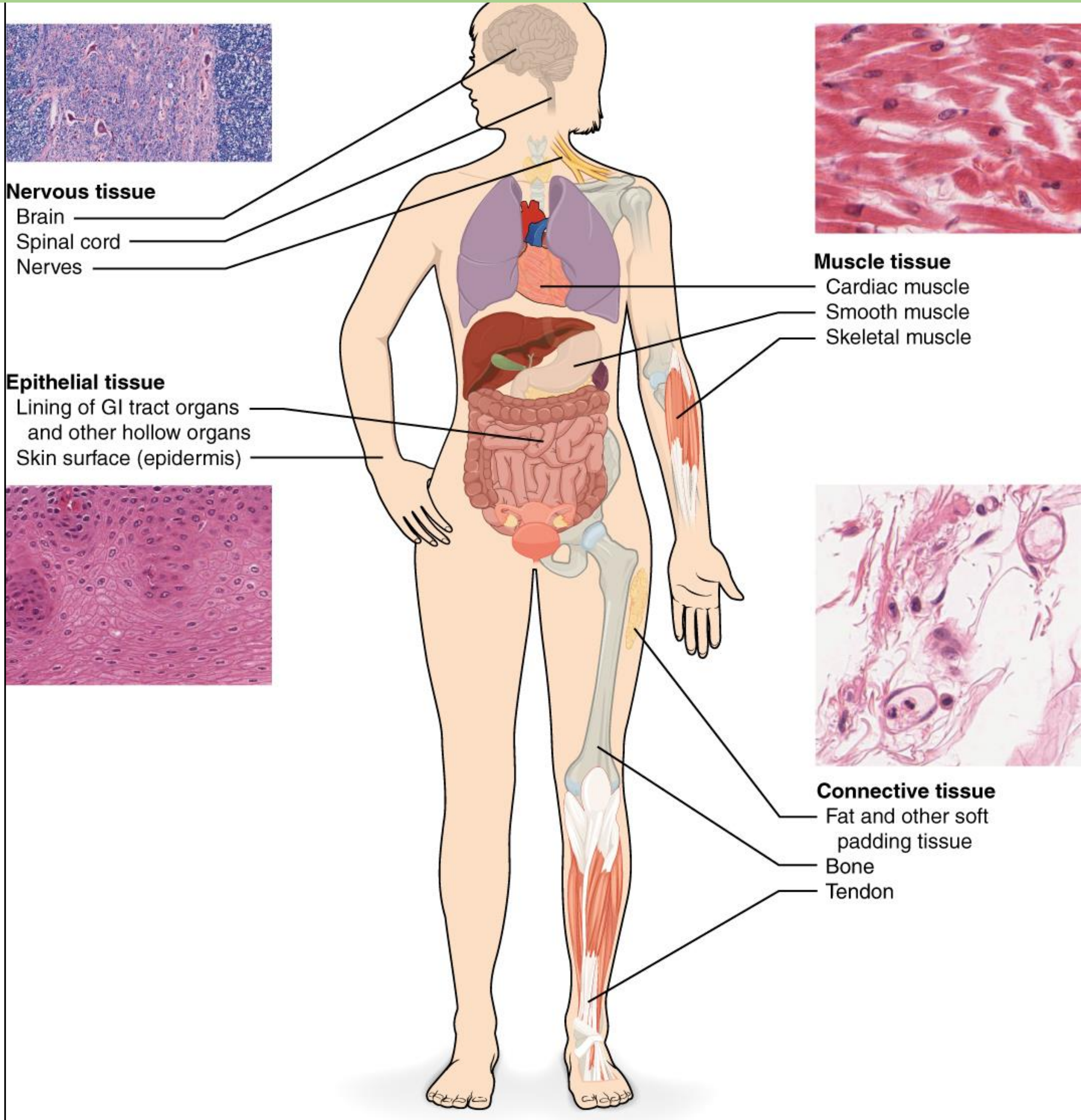
Human body tissue consists of groups of cells with a similar structure working together for a specific function. There are four main types of tissues in a body.

Epithelial tissue (epithelium)
- is made of layers (sheets) of cells that cover the surfaces of the body that come into contact with the exterior world, lines internal cavities and passageways, and form glands.

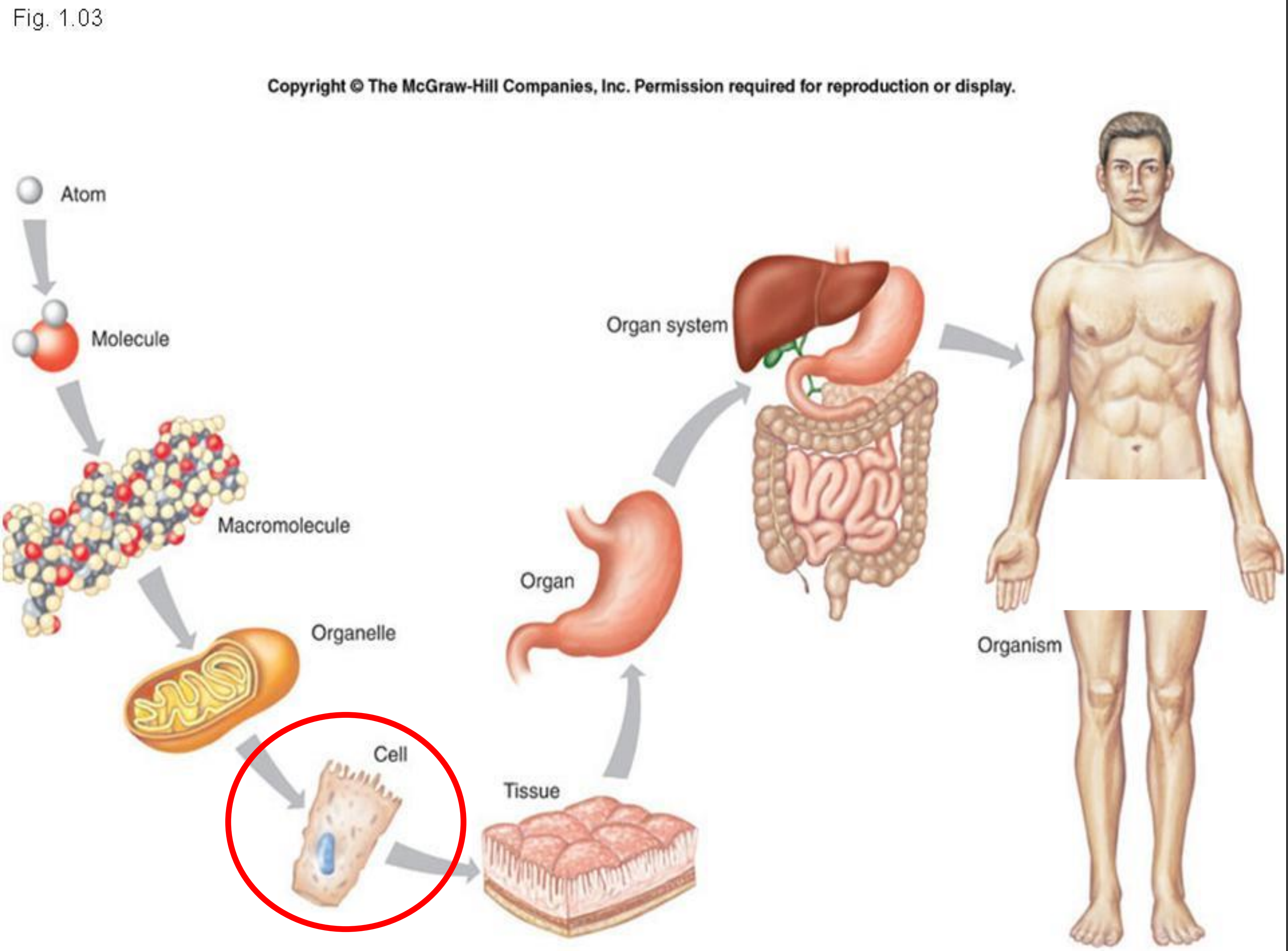
Connective tissue
- binds the cells and organs of the body together and performs many functions, especially in the protection, support, and integration of the body.

Muscle tissue
- is excitable, responds to stimulation and contracts to provide movement.
- occurs as three major types: skeletal (voluntary) muscles, smooth muscles, and the cardiac muscle in the heart.

Nervous tissue
- is also excitable, allows the body to receive signals and transmit information as electric impulses from one region of the body to another.



Eukaryote – Homo sapiens (Human)



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Number of cells / different cell types present in a human body

Total number of human cells present in a human body:

- **There are 37.2 Trillion Cells in Your Body**
- **1 trillion = 1,000,000,000,000 (1 x 10^{12}); so 37,200,000,000,000**

> **Note: This does not include any of the millions of microbes living inside our body**

Total number of different human cell types present in a human body:

- **200-220 cell types**
- (neuron, cardiomyocyte, beta-cell, hepatocyte, fibroblast, keratinocyte, RBC, T lymphocyte, B lymphocyte, natural killer cell, etc.)

Ann Hum Biol. 2013 Nov-Dec;40(6):463-71. doi: 10.3109/03014460.2013.807878. Epub 2013 Jul 5.

An estimation of the number of cells in the human body

Eva Bianconi [1], Allison Piovesan, Federica Facchin, Alina Beraudi, Raffaella Casadei, Flavia Frabetti, Lorenza Vitale, Maria Chiara Pelleri, Simone Tassani, Francesco Piva, Soledad Perez-Amodio, Pierluigi Strippoli, Silvia Canaider

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1 Department of Experimental, Diagnostic and Specialty Medicine, University of Bologna , Bologna , Italy .

PMID: 23829164 DOI: 10.3109/03014460.2013.807878
Free article

Erratum in

Ann Hum Biol. 2013 Nov-Dec;40(6):471

Abstract

Background: All living organisms are made of individual and identifiable cells, whose number, together with their size and type, ultimately defines the structure and functions of an organism. While the total cell number of lower organisms is often known, it has not yet been defined in higher organisms. In particular, the reported total cell number of a human being ranges between 10(12) and 10(16) and it is widely mentioned without a proper reference.

Aim: To study and discuss the theoretical issue of the total number of cells that compose the standard human adult organism.

Subjects and methods: A systematic calculation of the total cell number of the whole human body and of the single organs was carried out using bibliographical and/or mathematical approaches.

Results: A current estimation of human total cell number calculated for a variety of organs and cell types is presented. These partial data correspond to a total number of 3.72 × 10(13).

Conclusions: Knowing the total cell number of the human body as well as of individual organs is important from a cultural, biological, medical and comparative modelling point of view. The presented cell count could be a starting point for a common effort to complete the total calculation.

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> PLoS Biol. 2016 Aug 19;14(8):e1002533. doi: 10.1371/journal.pbio.1002533. eCollection 2016 Aug.

Revised Estimates for the Number of Human and Bacteria Cells in the Body

Ron Sender [1], Shai Fuchs [2], Ron Milo [1]

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PMID: 27541692 PMCID: PMC4991899 DOI: 10.1371/journal.pbio.1002533

Abstract

Reported values in the literature on the number of cells in the body differ by orders of magnitude and are very seldom supported by any measurements or calculations. Here, we integrate the most up-to-date information on the number of human and bacterial cells in the body. We estimate the total number of bacteria in the 70 kg "reference man" to be 3.8·1013. For human cells, we identify the dominant role of the hematopoietic lineage to the total count (≈90%) and revise past estimates to 3.0·1013 human cells. Our analysis also updates the widely-cited 10:1 ratio, showing that the number of bacteria in the body is actually of the same order as the number of human cells, and their total mass is about 0.2 kg.

PLOS BIOLOGY

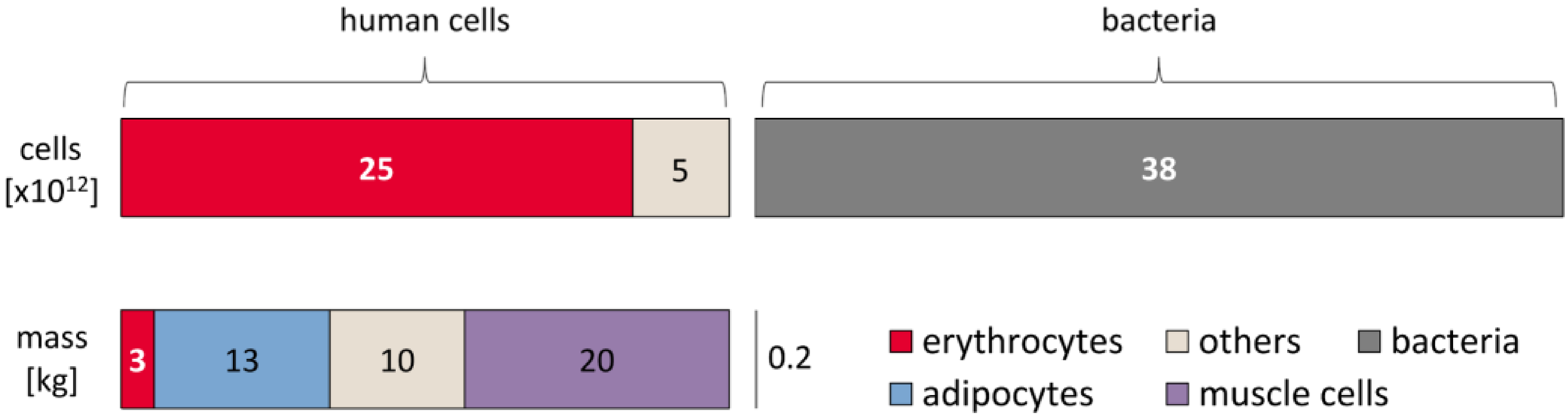

Fig 3. Distribution of cell number and mass for different cell types in the human body (for a 70 kg adult man). The upper bar displays the number of cells, while the lower bar displays the contribution from each of the main cell types comprising the overall cellular body mass (not including extracellular mass that adds another ≈24 kg). For comparison, the contribution of bacteria is shown on the right, amounting to only 0.2 kg, which is about 0.3% of the body weight.

doi:10.1371/journal.pbio.1002533.g003

https://pubmed.ncbi.nlm.nih.gov/27541692/

PLOS BIOLOGY

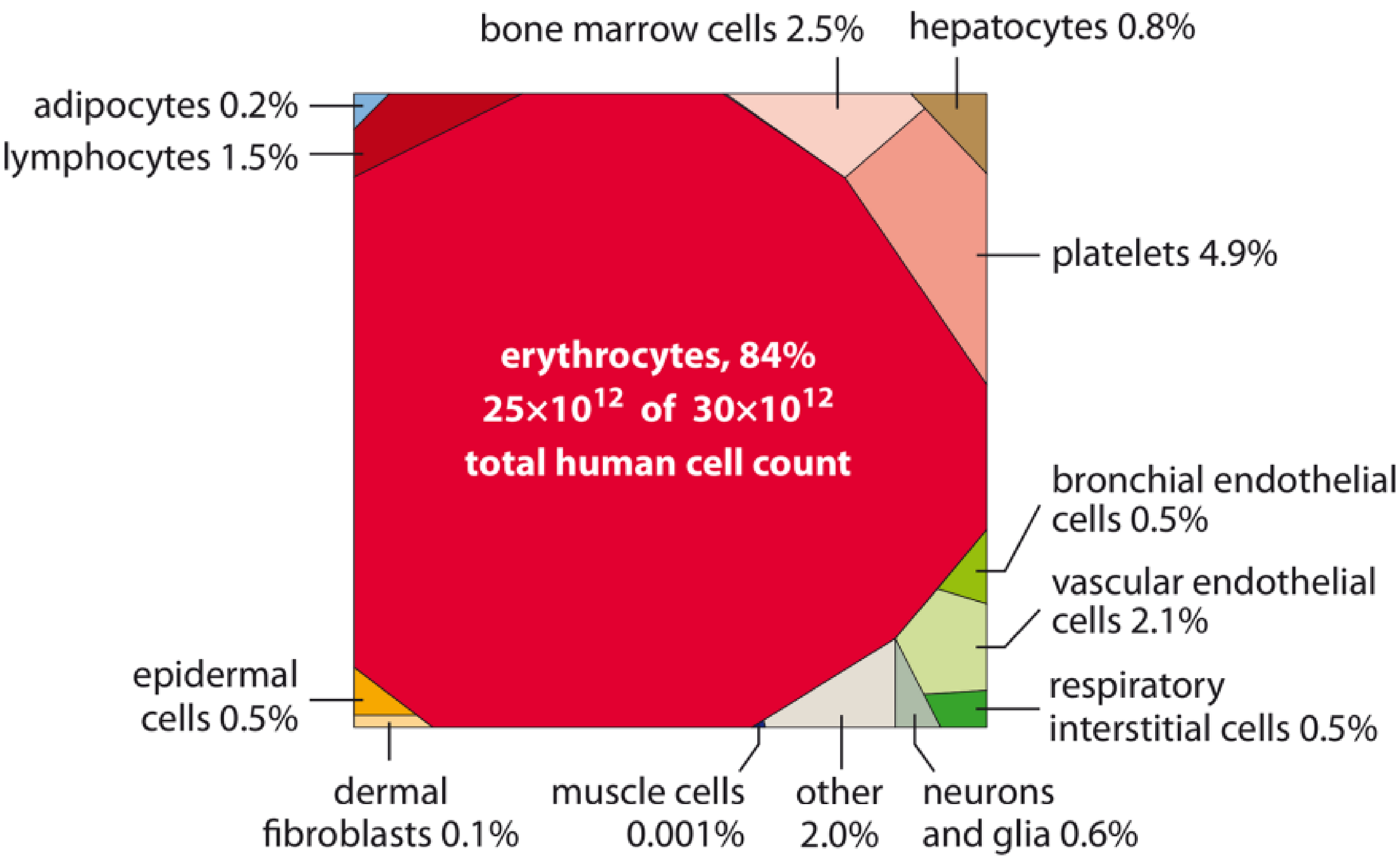

Fig 2. The distribution of the number of human cells by cell type. Representation as a Voronoi tree map where polygon area is proportional to the number of cells. Visualization performed using the online tool at http://bionic-vis.biologie.uni-greifswald.de/.

doi:10.1371/journal.pbio.1002533.g002

https://pubmed.ncbi.nlm.nih.gov/27541692/

PNAS RESEARCH ARTICLE | CELL BIOLOGY OPEN ACCESS

The human cell count and size distribution

Ian A. Hatton[a,b,1], Eric D. Galbraith[b,c], Nono S. C. Merleau[a,d], Teemu P. Miettinen[e], Benjamin McDonald Smith[f,g], and Jeffery A. Shander[h]

Edited by Jan M. Skotheim, Stanford University, Stanford, CA; received February 22, 2023; accepted July 24, 2023 by Editorial Board Member Rebecca Heald

September 18, 2023 | 120 (39) e2303077120 | https://doi.org/10.1073/pnas.2303077120

Significance

A consistent and comprehensive quantitative framework of the cells in the human body could benefit many areas of biology. We compile data to estimate cell mass, size range, and cell count for some 1,200 cell groups, from the smallest red blood cells to the largest muscle fibers, across 60 tissues in a representative male, female, and 10-y-old child. We find large-scale patterns revealing that both cellular biomass in any given logarithmic cell-size class and the coefficient of cell-size variation are both approximately independent of cell size. These patterns are suggestive of a whole-organism trade-off between cell size and count and imply the existence of cell-size homeostasis across cell types.

PNAS RESEARCH ARTICLE | CELL BIOLOGY OPEN ACCESS

The human cell count and size distribution

Ian A. Hatton[a,b,1], Eric D. Galbraith[b,c], Nono S. C. Merleau[a,d], Teemu P. Miettinen[e], Benjamin McDonald Smith[f,g], and Jeffery A. Shander[h]

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https://www.pnas.org/doi/epub/10.1073/pnas.2303077120
https://humancelltreemap.mis.mpg.de/

Cell size and cell count are adaptively regulated and intimately linked to growth and function. Yet, despite their widespread relevance, the relation between cell size and count has never been formally examined over the whole human body. Here, we compile a comprehensive dataset of cell size and count over all major cell types, with data drawn from >1,500 published sources. We consider the body of a representative male (70 kg), which allows further estimates of a female (60 kg) and 10-y-old child (32 kg). We build a hierarchical interface for the cellular organization of the body, giving easy access to data, methods, and sources (https://humancelltreemap.mis.mpg.de/). In total, we estimate total body counts of ≈36 trillion cells in the male, ≈28 trillion in the female, and ≈17 trillion in the child. These data reveal a surprising inverse relation between cell size and count, implying a trade-off between these variables, such that all cells within a given logarithmic size class contribute an equal fraction to the body's total cellular biomass. We also find that the coefficient of variation is approximately independent of mean cell size, implying the existence of cell-size regulation across cell types. Our data serve to establish a holistic quantitative framework for the cells of the human body, and highlight large-scale patterns in cell biology.

Tissue masses and other tissue level parameters derive from the International Commission on Radiological Protection (ICRP, listed below), for some 60 tissue types in the following three reference human anatomical models:

- **Male** (70 kg in mass, 176 cm in height and 20 to 50 years of age)
- **Female** (60 kg, 163 cm in height and 20 to 50 years of age)
- **Child** (32 kg, 138 cm in height and 10 years of age)

These reference models can be selected at top right. Cell masses for ~400 cell types were obtained direct from histology sources, estimated from various cell parameters such as shape, length and diameter, and/or from their similarity to other known cell types.

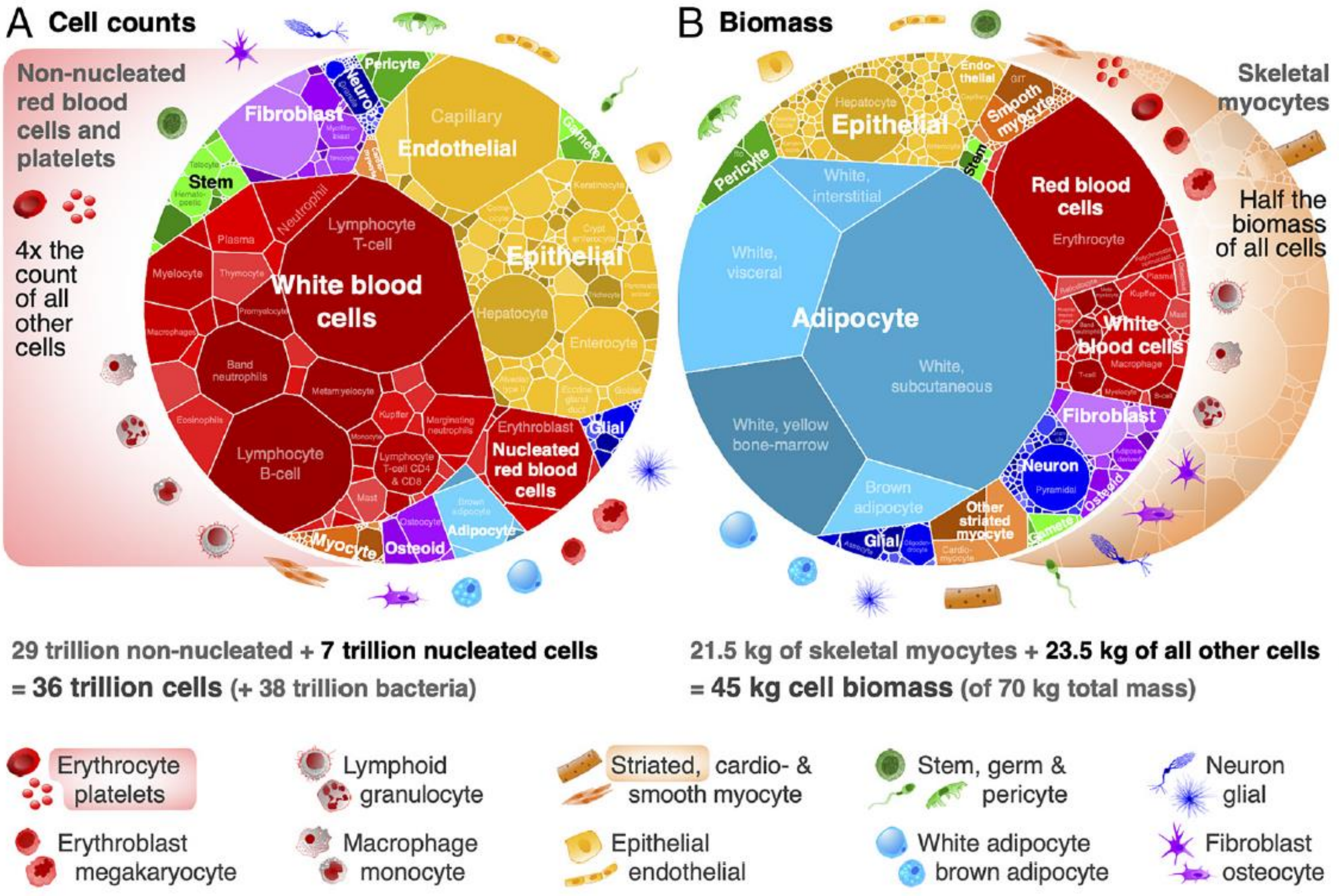
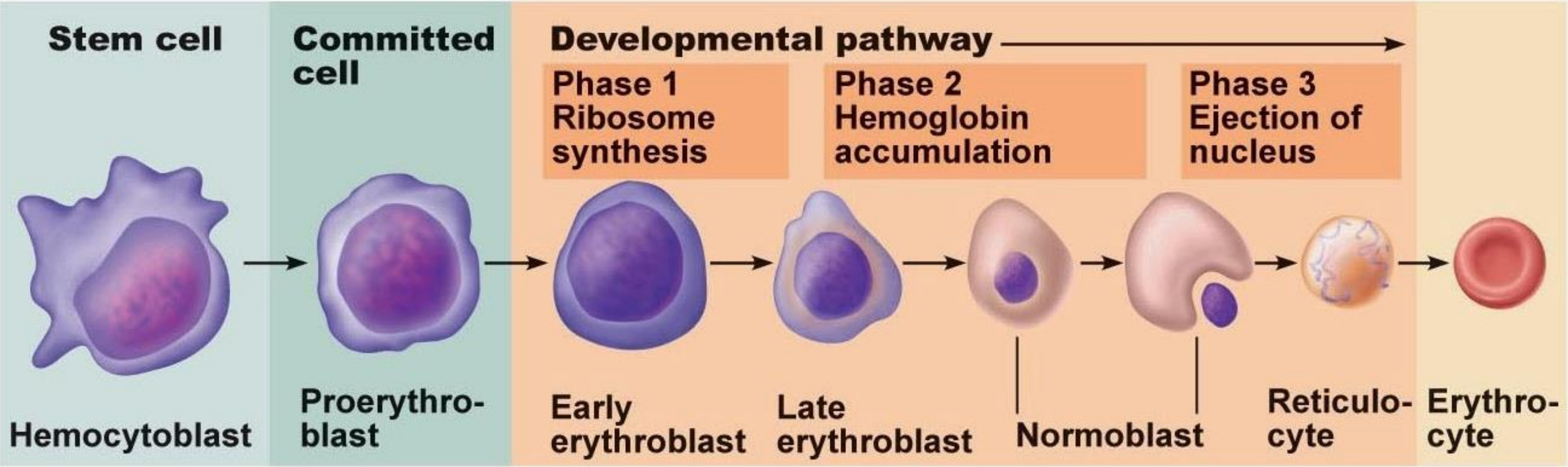


Fig. 1. Contrasting cell count and biomass distributions by cell type. Voronoi tree maps for all 400 investigated cell types of the reference male anatomical model (area represents relative cell number or biomass). (*A*) Cell counts are dominated by red blood cells and platelets, which are removed from the cell count tree map. Even after removing nonnucleated blood cells (≈29 trillion), white blood cells (≈3.4 trillion) still dominate the ≈7 trillion nucleated cell count, with 98% of white blood cells as tissue resident, 1% circulating and 1% intravascular marginating. (*B*) Cell biomass is dominated by skeletal myocytes, comprising about half of all 45 kg of cell biomass in the body, even though they make up <0.002% of the nucleated cell count, which are removed from the biomass tree map. Most of the remaining 23.5 kg of cell biomass are white adipocytes (≈12 kg; though body fat varies widely among subjects). Tree maps for a reference 60-kg female (≈28 trillion cells) and 32-kg child (≈17 trillion cells), and more detailed cell groups and organ systems can be explored at https://humancelltreemap.mis.mpg.de/ (*SI Appendix*, Figs. S7–S9).

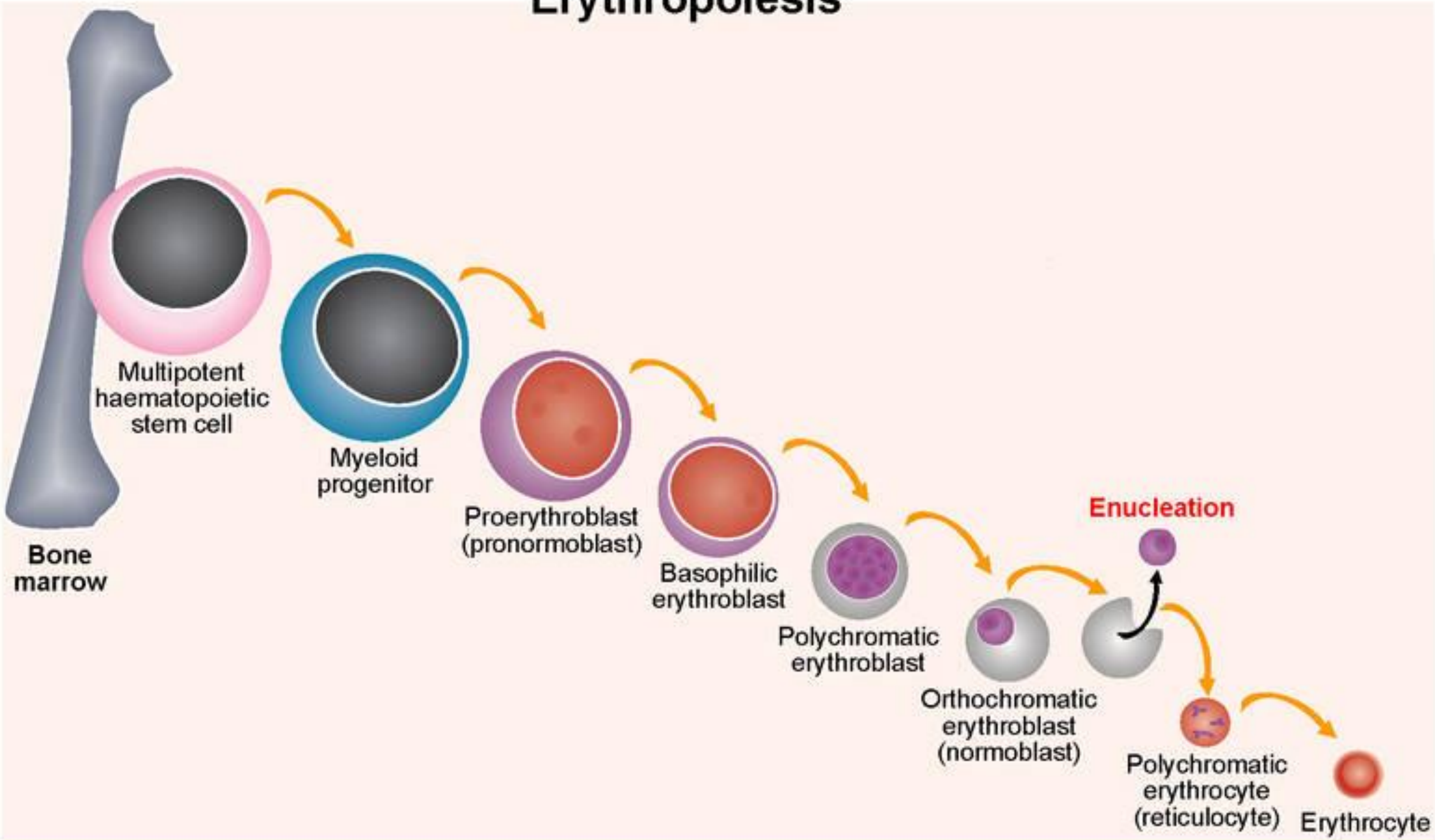
Red Blood Cells (RBCs)

- In humans, mature RBCs are flexible and oval biconcave disks.
- They lack a cell nucleus and most organelles, in order to accommodate maximum space for hemoglobin.
- They can be viewed as sacks of hemoglobin, with a plasma membrane as the sack.
- Approximately, 2.4 million new RBCs are produced per second in human adults.
- The cells develop in the bone marrow and circulate for about 100–120 days in the body before their components are recycled by macrophages.
- Approximately a quarter of the cells in the human body are RBCs.
- Nearly half of the blood's volume (40% to 45%) is RBCs.

- A RBC consists of 250-270 million hemoglobin (Hb) molecules, a complex metalloprotein containing heme groups. The color of RBCs is due to the heme group of hemoglobin.
- The iron atoms of heme temporarily bind to oxygen molecules (O_2) in the lungs and release them throughout the body.
- Oxygen can easily diffuse through the RBC's cell membrane.
- Hemoglobin in the RBCs also carries some of the waste product carbon dioxide back from the tissues; most waste carbon dioxide, however, is transported back to the pulmonary capillaries of the lungs as bicarbonate ($HCO3^-$) dissolved in the blood plasma.

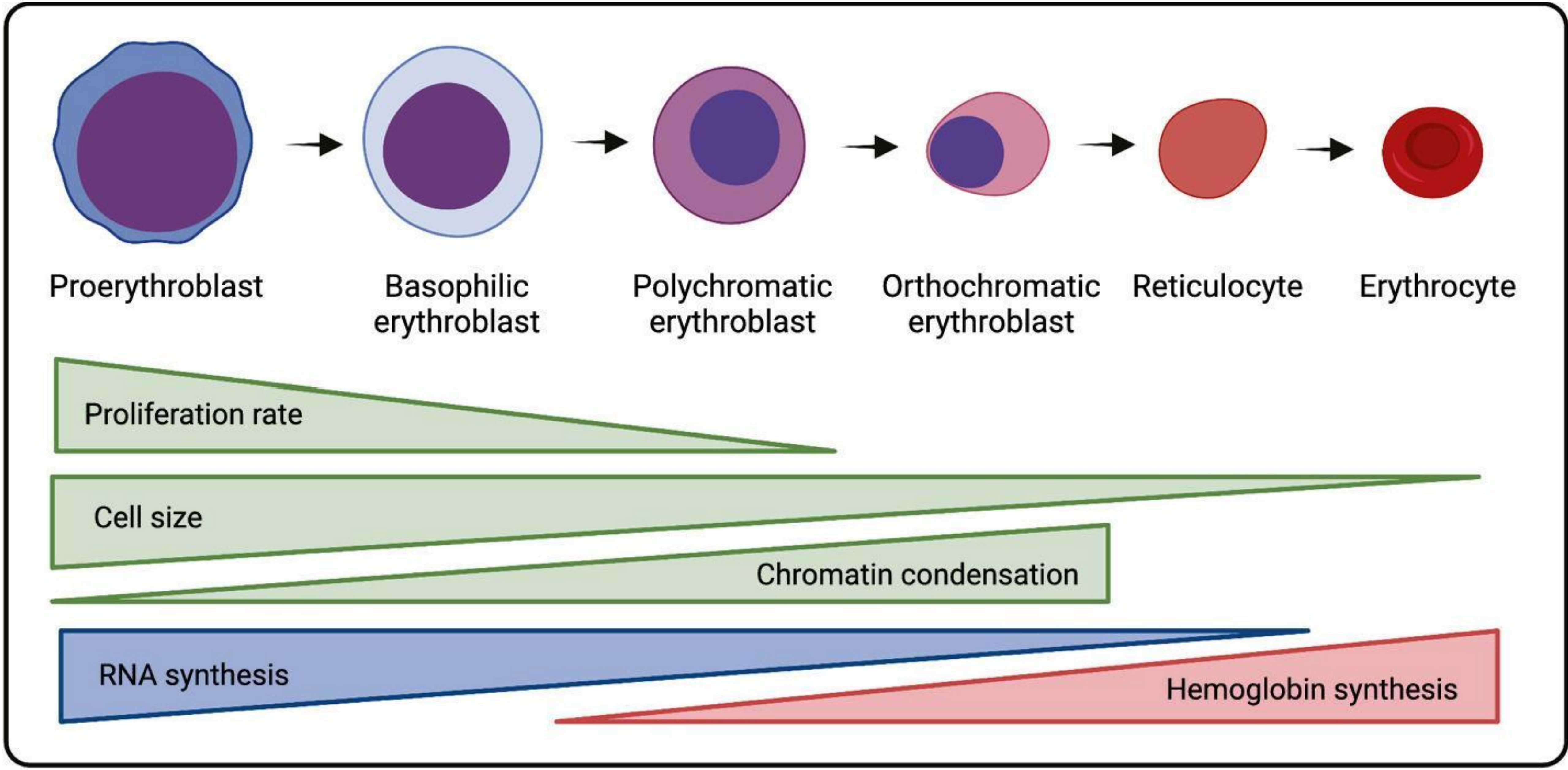

Stem cell
Committed cell
Developmental pathway
Phase 1 Ribosome synthesis
Phase 2 Hemoglobin accumulation
Phase 3 Ejection of nucleus
Hemocytoblast
Proerythro-blast
Early erythroblast
Late erythroblast
Normoblast
Reticulo-cyte
Erythro-cyte

Erythropoiesis



The development of erythrocytes in bone marrow is regulated by the hormone erythropoietin that stimulates the differentiation of progenitor cells into erythroid precursor cells. A number of intermediate cell stages can be identified beginning with the proerythroblast (pronormoblast). The cell nucleus is extruded at the orthochromatic erythroblast (normoblast) stage before formation of an enucleated polychromatic erythrocyte (reticulocyte). These cells are released into the circulation where they mature into functional erythrocytes.

immunopaedia.org



Hematol Transfus Cell Ther. 2022;44:574-81

Proc Natl Acad Sci U S A. 2023 Oct 31;120(44):e2308511120. doi: 10.1073/pnas.2308511120. Epub 2023 Oct 23.

The total mass, number, and distribution of immune cells in the human body

Ron Sender [1], Yarden Weiss [2], Yoav Navon [1], Idan Milo [3], Nofar Azulay [3], Leeat Keren [3], Shai Fuchs [4], Danny Ben-Zvi [5], Elad Noor [1], Ron Milo [1]

Affiliations + expand

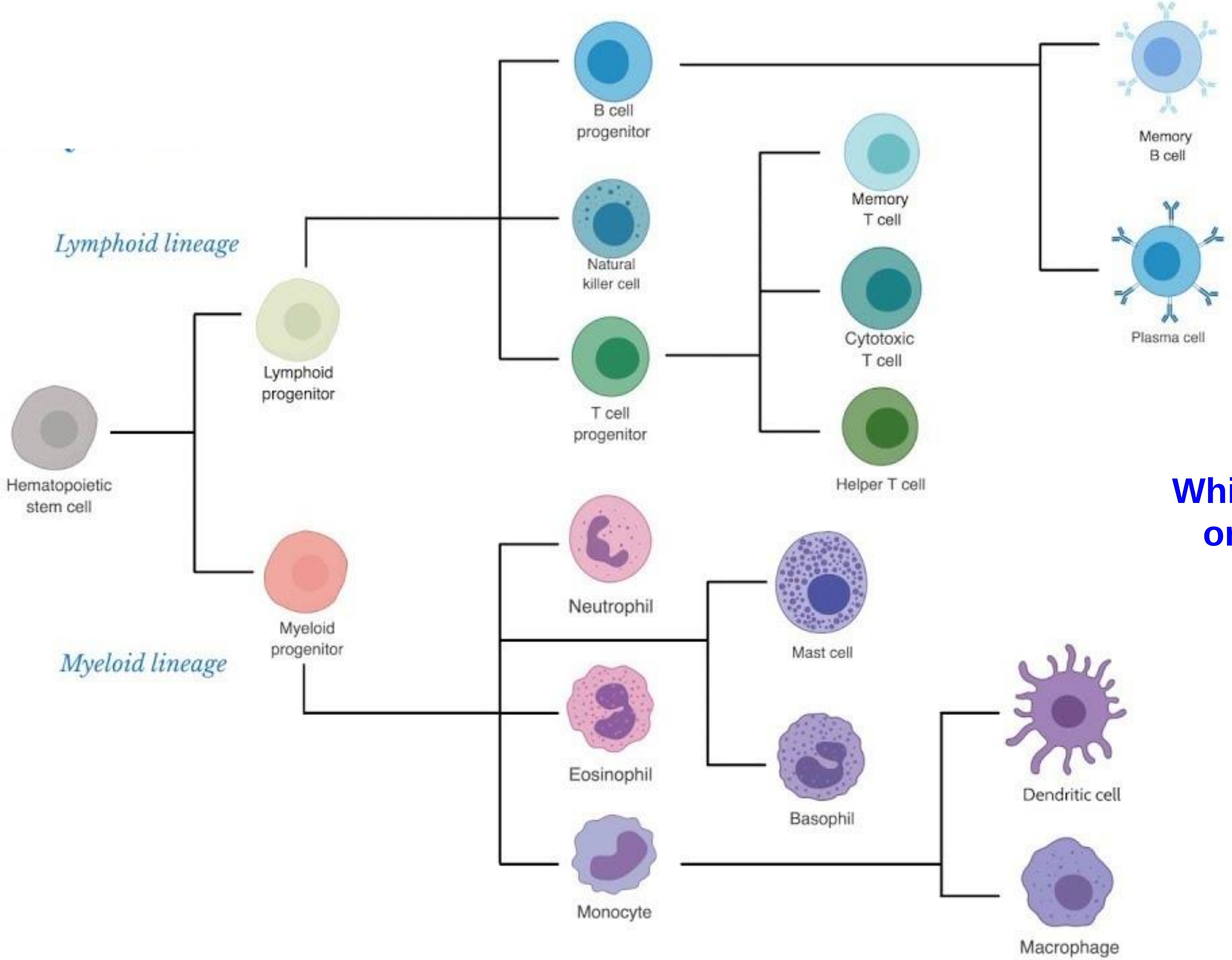
PMID: 37871201 PMCID: PMC10623016 DOI: 10.1073/pnas.2308511120

Abstract

The immune system is a complex network of cells with critical functions in health and disease. However, a comprehensive census of the cells comprising the immune system is lacking. Here, we estimated the abundance of the primary immune cell types throughout all tissues in the human body. We conducted a literature survey and integrated data from multiplexed imaging and methylome-based deconvolution. We also considered cellular mass to determine the distribution of immune cells in terms of both number and total mass. Our results indicate that the immune system of a reference 73 kg man consists of 1.8×10^{12} cells (95% CI $1.5\text{-}2.3 \times 10^{12}$), weighing 1.2 kg (95% CI 0.8-1.9). Lymphocytes constitute 40% of the total number of immune cells and 15% of the mass and are mainly located in the lymph nodes and spleen. Neutrophils account for similar proportions of both the number and total mass of immune cells, with most neutrophils residing in the bone marrow. Macrophages, present in most tissues, account for 10% of immune cells but contribute nearly 50% of the total cellular mass due to their large size. The quantification of immune cells within the human body presented here can serve to understand the immune function better and facilitate quantitative modeling of this vital system.

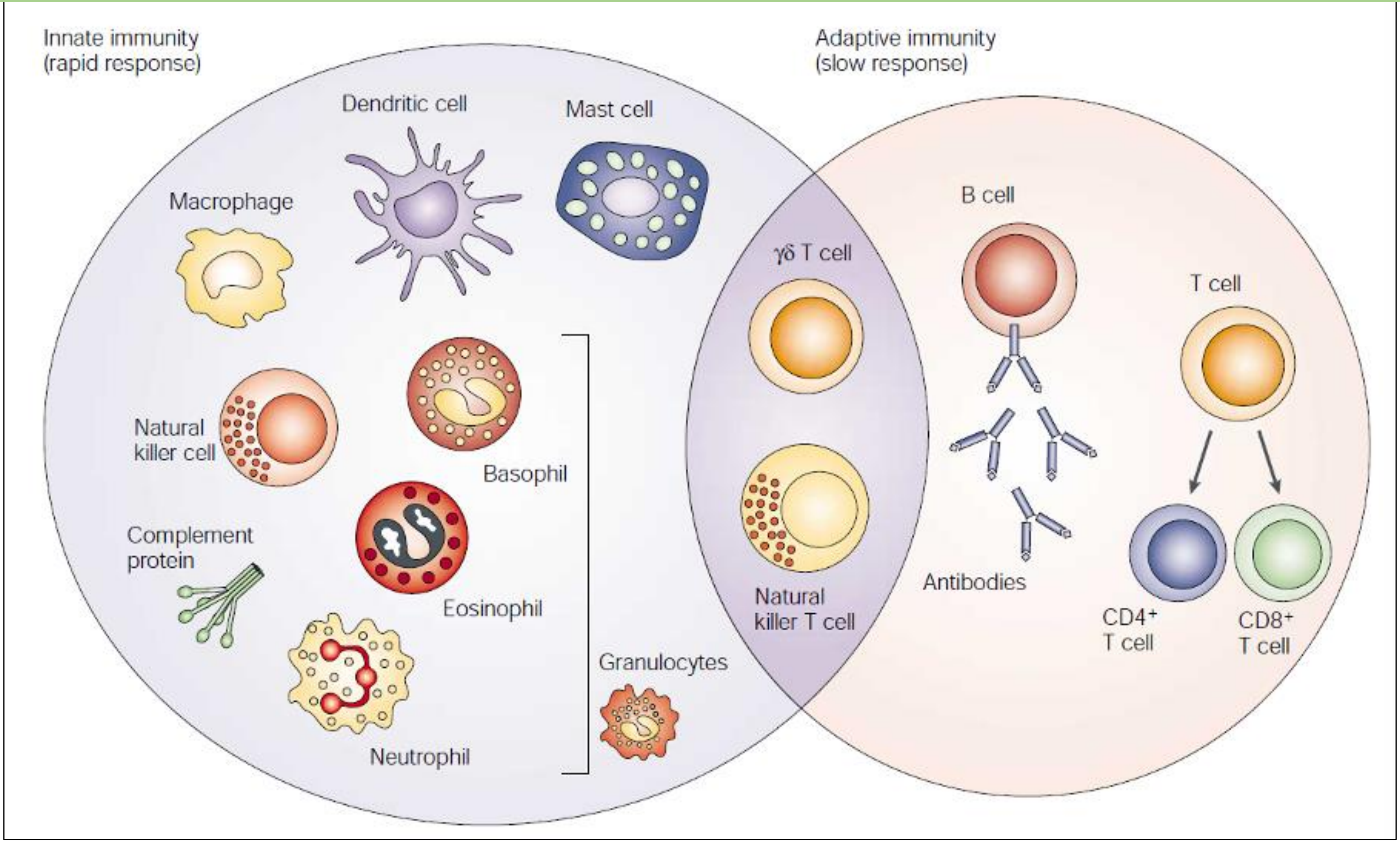
Keywords: distribution; immune cells; lymphocyte; macrophage; total mass.

Cells of the Immune System

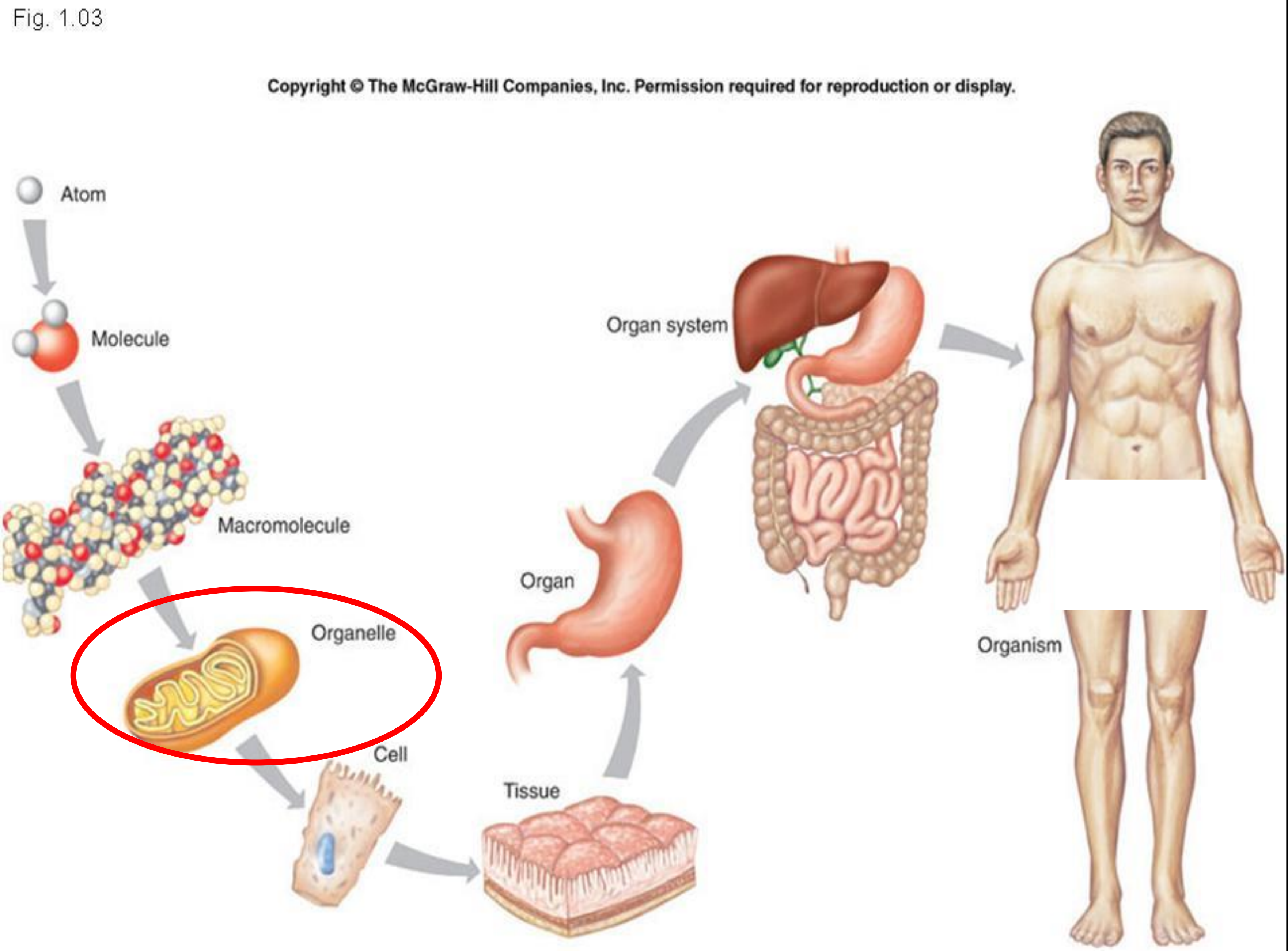


White Blood Cells or Leuckocyte

Cells of the Immune System



Eukaryote – Homo sapiens (Human)



- The human body is the structure of a human being.
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Various organelles in a human cell and its major function(s)

1. **Cell membrane** – (is a membrane that separates the interior of all cells from the outside environment (the extracellular space) and protects the cell from its environment; acts as a barrier for cell contents. It consists of double phospholipid layer and monolayer of protein scattered around phospholipid layer. The other components in plasma membrane are cholesterol and glycoproteins).
2. **Cytosol** – (fluid that contains organelles; represents the material outside the nucleus and inside the cell membrane)
3. **Cytoskeleton** – (a network of protein structures that extend throughout the cytoplasm; provides the cell with an internal framework (e.g. microfilaments and microtubules))
4. **Nucleus** – (control center of the cell; contains genetic material; It is the center of the cell because it contains genetic material (DNA). It consists of three main regions: the nuclear membrane, the nucleolus and chromatin.

    ***Nuclear membrane*:** Nuclear membrane serves as a barrier of nucleus. It consists of a double phospholipid membrane and contains nuclear pores that allow for the exchange of material with the rest of the cell.

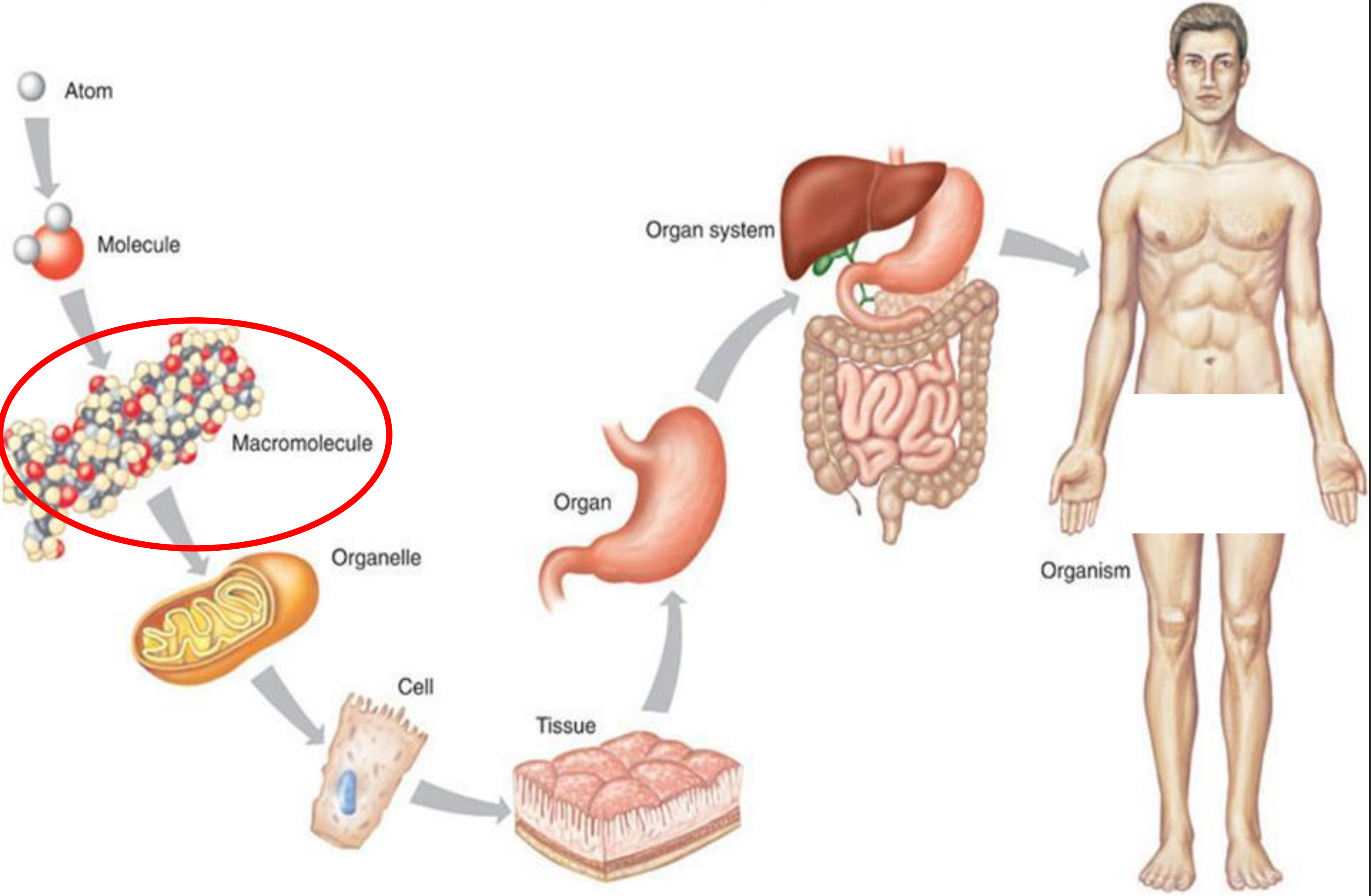
    Chromatin: It is composed of DNA and protein scattered throughout the nucleus. Chromatin condenses to form chromosomes when the cell divides)
5. **Nucleolus** – (functions as site of ribosome production; ribosomes then migrate to the cytoplasm through nuclear pores)
6. **Ribosome** (little dots) – sites of protein synthesis in the cell.

Various organelles in a human cell and its major function(s)

7. **Rough endoplasmic reticulum** – (carry ribosomes that represent sites of protein synthesis)
8. **Smooth endoplasmic reticulum** – (function in cholesterol synthesis and breakdown, fat metabolism, and detoxification of drugs)
9. **Smooth endoplasmic reticulum** – (function in cholesterol synthesis and breakdown, fat metabolism, and detoxification of drugs)
10. **Golgi apparatus** (or "Golgi body") – (modifies and packages proteins, secrete vesicles, plasma membrane components and lysosomes)
11. **Mitochondrion** – (powerhouse of the cell; generate ATP for cellular activities)
12. **Lysosomes** – (suicidal bag of the cell; contain enzymes that digest non-usable materials within the cell)
13. **Peroxisomes** – (detoxify harmful substances and break down free radicals; involved in catabolism of very long chain fatty acids,)
14. **Centrioles** – (involved in the organization of mitotic spindle fibers during cell division and in the completion of cytokinesis)
15. **Centrosomes** – (serves as the main microtubule organizing center (MTOC) of the animal cell, as well as a regulator of cell-cycle progression; are composed of two centrioles arranged at right-angles to each other)
16. **Vesicles** – (involved in metabolism, transport, buoyancy control, and temporary storage of food and enzymes)

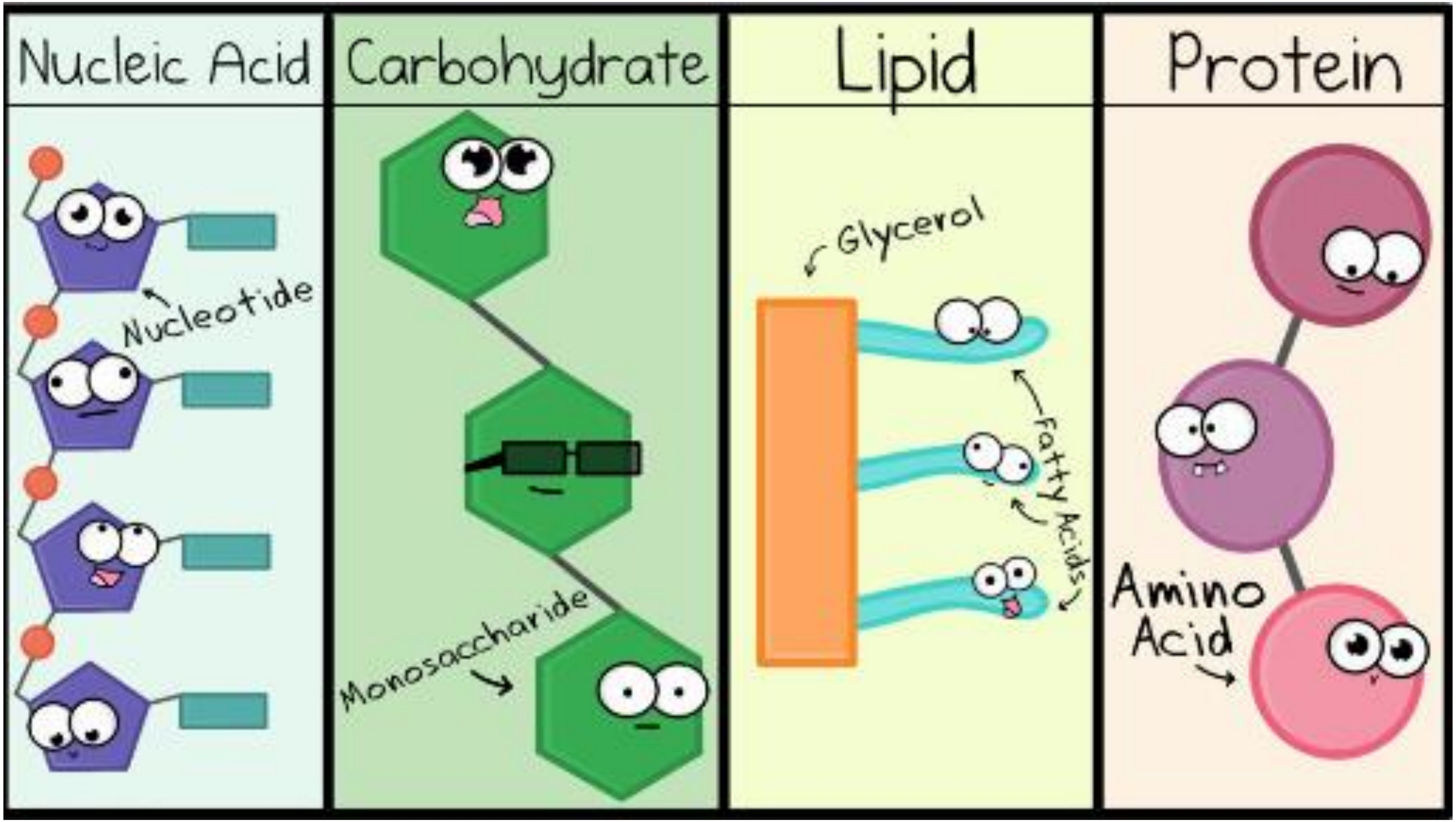
Eukaryote – Homo sapiens (Human)

Fig. 1.03



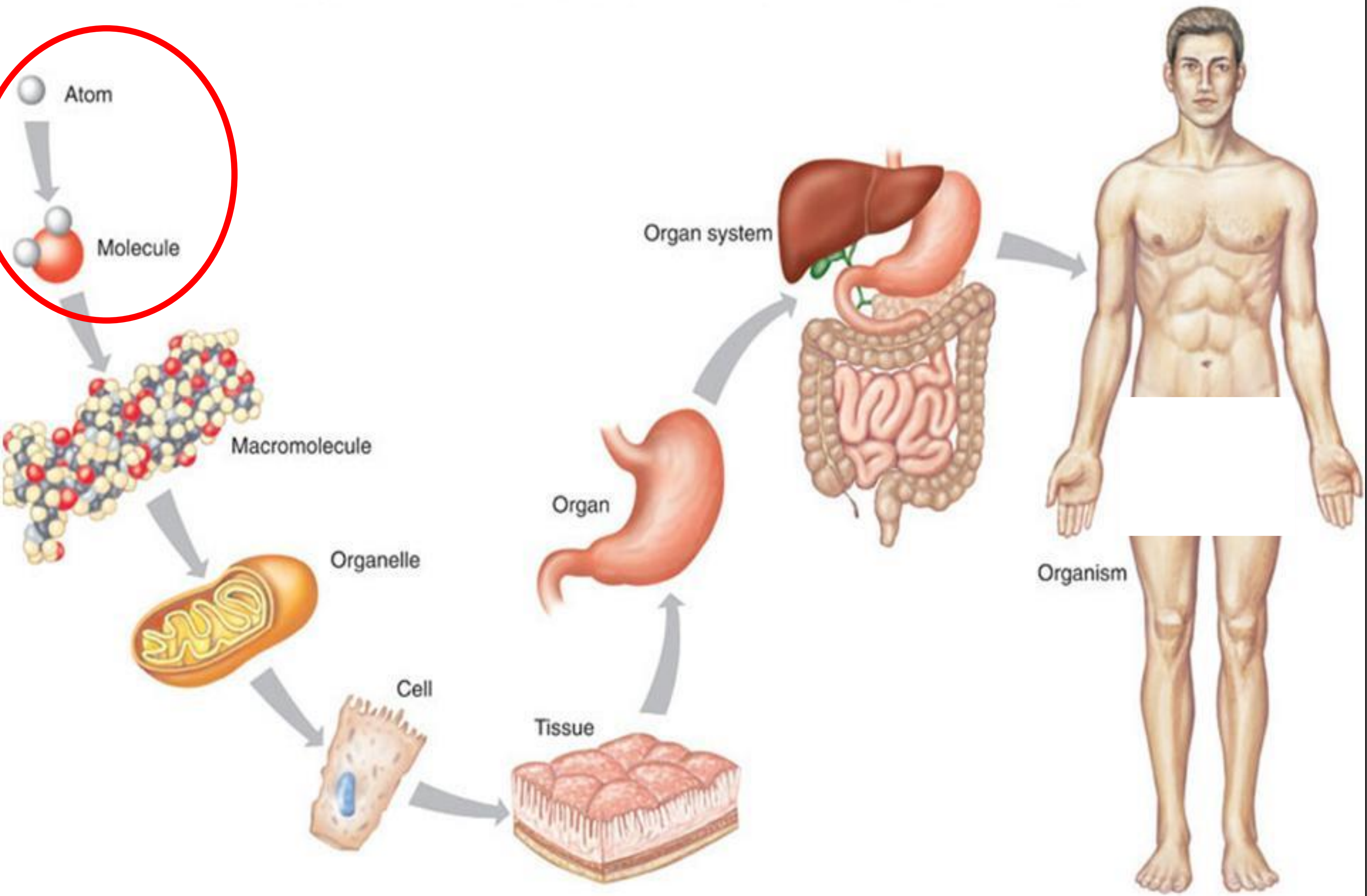
- The human body is the structure of a human being.
- It is composed of many different types organ systems.
- They ensure homeostasis and the viability of the human body.

Macromolecules



Eukaryote – Homo sapiens (Human)

Fig. 1.03



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Number of molecules and atoms in human body

❑ How many molecules are there in the human body?

❑ https://socratic.org/questions/how-many-molecules-are-in-the-human-body

➢ The human body consists of about **2×10^{25} molecules**, and more than 99% of is water.

❑ How many atoms are there in the human body?

❑ https://www.thoughtco.com/how-many-atoms-are-in-human-body-603872

❑ https://education.jlab.org/qa/mathatom_04.html

➢ There are approximately **$7\text{x}10^{27}$ atoms** in the average human body. This is the estimate for a 70 kg adult human male. Generally, a smaller person would contain fewer atoms; a larger person would contain more atoms.

➢ According to an estimate made by engineers at Washington University, there are around **10^{14} atoms in a typical human cell**.

➢ Carbon, hydrogen, nitrogen, oxygen, calcium and phosphorus together account for 99 percent of the atoms in a person.

Different Levels of organization

Atom:

An atom is the smallest particle of an element or a molecule.
[carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), etc.]

Molecule:

A molecule is a particle composed of two or more joined atoms by chemical bonds.
(carbon dioxide (CO_2), water (H_2O))

Macromolecule:

A macromolecule is a very large molecule.
(carbohydrates, lipids, proteins, and nucleic acids)

Organelle:

An organelle is a specialized subunit within in a cell which performs a particular function.
(cell membrane, cytoplasm, nucleus, mitochrondria, etc.)

Cell:

The cell is a structural and functional unit of a living organism.
(neuron, cardiomyocyte, beta-cell, hepatocyte, fibroblast, keratinocyte, etc.)

Different Levels of organization

Tissue:

A tissue is a group of similar cells that perform a specialized function
(epithelial, connective, muscle and nervous).

Organ:

An organ is a structure consisting of a group of tissues that perform a specialized function (skin, heart, brain, etc.).

Body System:

A body system is a group of organs that act together to perform a specialized function.
In total, there are 10 body systems.

Human body:

A living organism is the most complex level of organization. It consists of all the systems arranged in a discrete manner so as to facilitate functioning of the various organ systems in a synchronous manner.

Regarding developmental biology, the succession of only 45 mitotic cycles is sufficient to produce the estimated total amount of human cells starting from the first cell, the zygote.

5 essential processes:

- An animal or plant starts its life as a single cell—a fertilized egg. During development, this cell divides repeatedly to produce many different cells in a final pattern of spectacular complexity and precision. Ultimately, the genome determines the pattern, and the puzzle of developmental biology is to understand how it does so.

- The genome is normally identical in every cell; the cells differ not because they contain different genetic information, but because they express different sets of genes. This selective gene expression controls the four essential processes by which the embryo is constructed.

5 essential processes:

- **Cell proliferation (or division or growth):** producing many cells from one
- **Cell specialization (or differentiation):** creating cells with different characteristics at different positions
- **Cell-cell interactions (or communication):** coordinating the behavior of one cell with that of its neighbors
- **Cell migration (or movement):** rearranging the cells to form structured tissues and organs
- **Cell polarity:** intrinsic asymmetry observed in cells, either in their shape, structure, or organization of cellular components and is a key step in the migration, development, and organization of eukaryotic cells, both at the single cell and multicellular level.
- **Genetically programmed cell death (or apoptosis):** coordinating the behavior of one cell with that of its neighbors

The Role of Stem Cells in Cell Count Dynamics

- Stem cells are unique because they have the potential to develop into various cell types throughout life. They play a crucial role in **growth, repair, and regeneration** processes within our bodies.

- In adults, stem cells are primarily found in bone marrow and certain tissues like skin or intestines where they help replace damaged or dying cells.
- For instance, hematopoietic stem cells give rise to all types of blood cells—including red blood cells—ensuring a continual supply throughout life.

- This regenerative capacity allows organisms to adapt to injury or disease by replacing lost or damaged tissue efficiently. The study of stem cells has opened up exciting possibilities for medical treatments aimed at regenerating tissues or organs affected by disease or injury.

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Human organoids: model systems for human biology and medicine

Jihoon Kim, Bon-Kyoung Koo & Juergen A. Knoblich

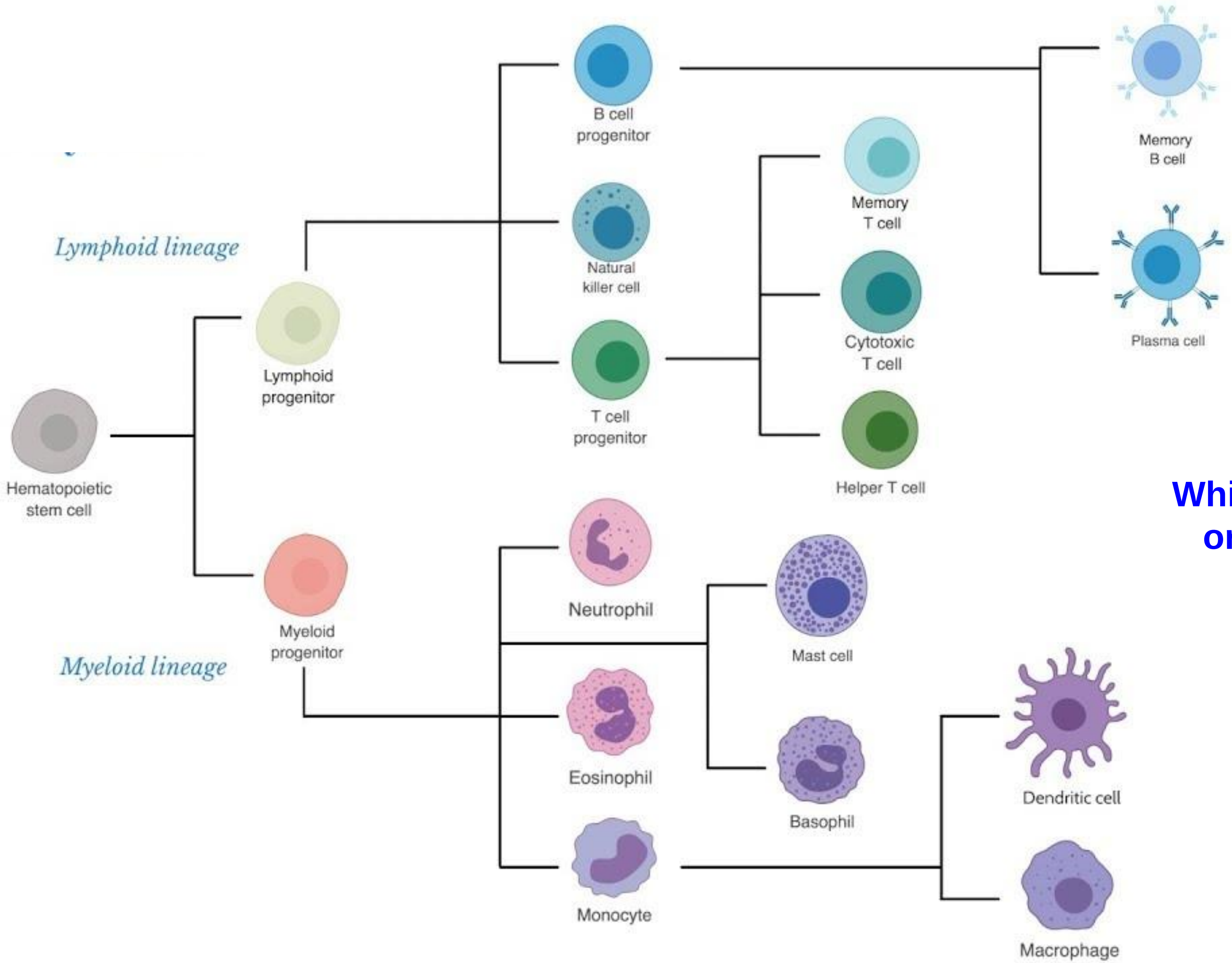
Nature Reviews Molecular Cell Biology **21**, 571–584 (2020) | Cite this article

Abstract

The historical reliance of biological research on the use of animal models has sometimes made it challenging to address questions that are specific to the understanding of human biology and disease. But with the advent of human organoids – which are stem cell-derived 3D culture systems – it is now possible to re-create the architecture and physiology of human organs in remarkable detail. Human organoids provide unique opportunities for the study of human disease and complement animal models. Human organoids have been used to study infectious diseases, genetic disorders and cancers through the genetic engineering of human stem cells, as well as directly when organoids are generated from patient biopsy samples. This Review discusses the applications, advantages and disadvantages of human organoids as models of development and disease and outlines the challenges that have to be overcome for organoids to be able to substantially reduce the need for animal experiments.

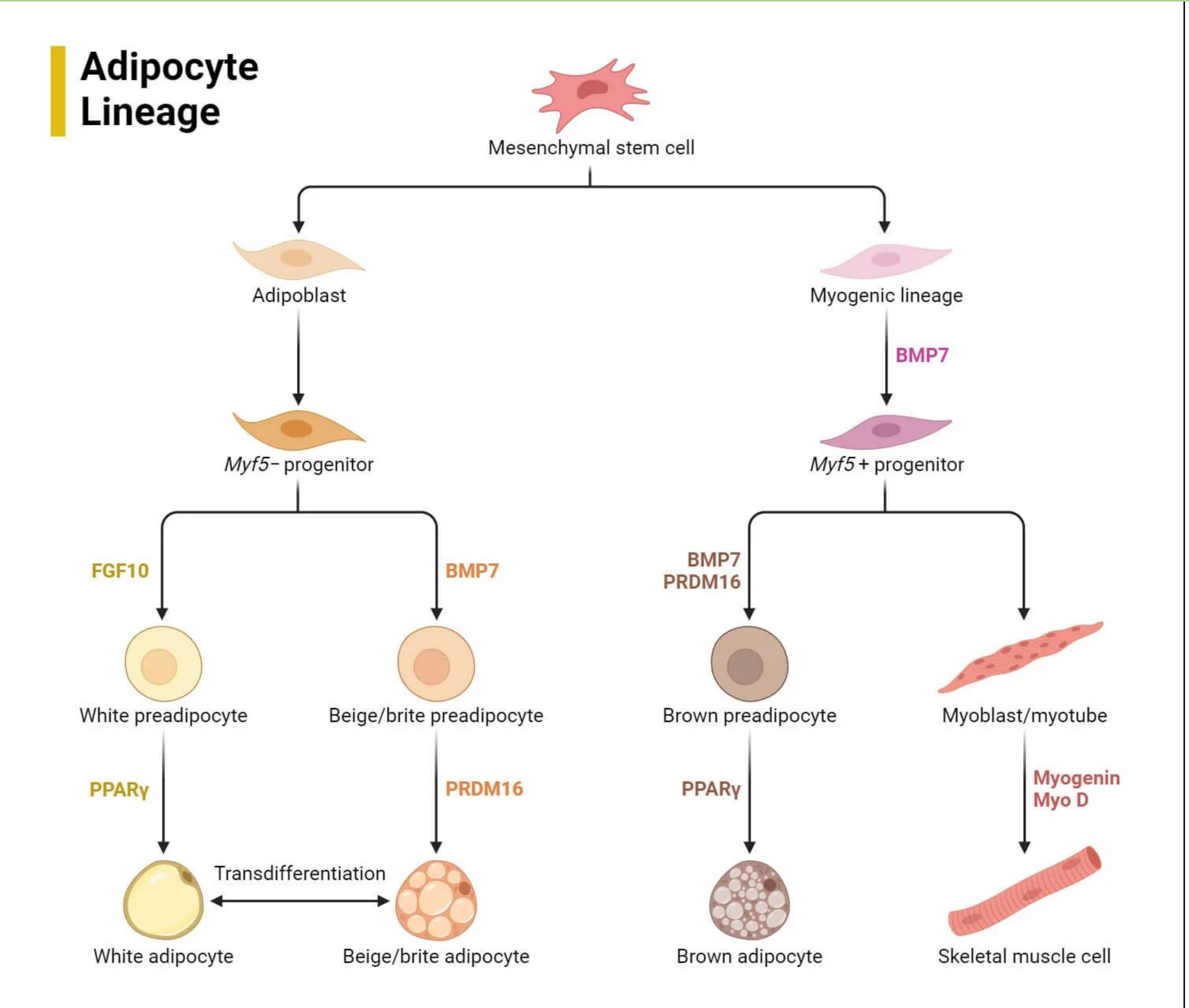
https://www.nature.com/articles/s41580-020-0259-3

Hematopoietic Stem Cells (HSCs) Differentiation

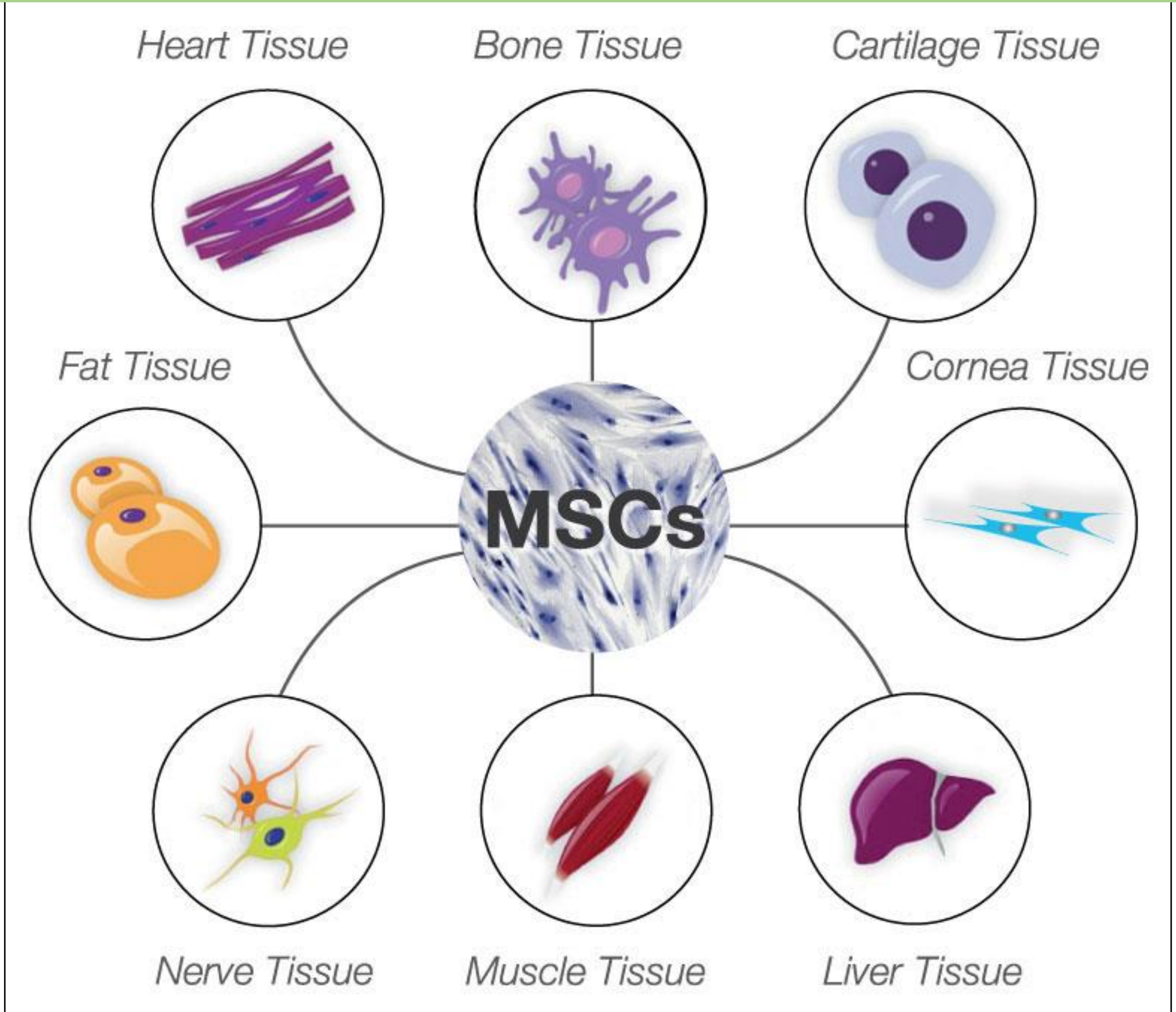


White Blood Cells or Leuckocyte

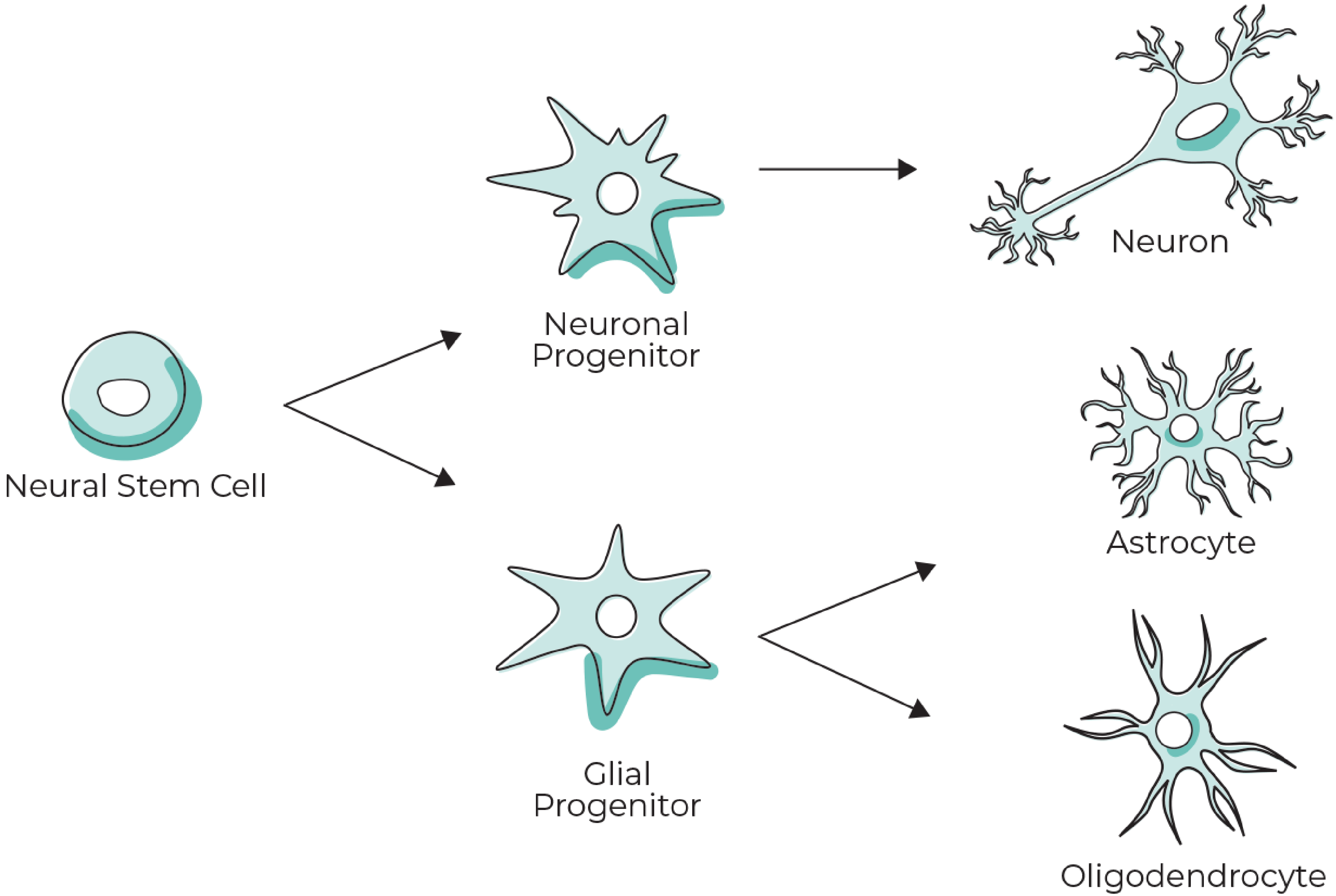
Mesenchymal Stem Cells (MSCs) Differentiation



Mesenchymal Stem Cells (MSCs) Differentiation



Neural Stem Cells (NSCs) Differentiation



https://captivatebio.com/what-are-neural-stem-cells/

Thank you for your attention