

Molecular and Cellular Physiology: Understanding the Basics and Beyond

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LM GENETICS AND MOLECULAR BIOLOGY

AA 2023/2024

Introduction

- **Practical Informations**
- **Course Overview**
- **Importance of Physiology in Genetics and Molecular Biology**
- **Learning Objectives**

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Room: Aula G CU014

MONDAY 4-6 pm - WEDNESDAY 4-6 pm

START ON TUESDAY OCTOBER 10TH 2023

eLearning:

<https://elearning.uniroma1.it/course/view.php?id=6161>

The learning objectives of the course on Molecular and Cellular Physiology for the Master Degree in Genetics and Molecular Biology are:

1. Understand the mechanisms underlying the communication of neuronal and glial cells in the homeostatic control and in the pathogenesis of brain diseases

2. Develop the ability to critically analyze and interpret primary literature in molecular and cellular physiology, and to effectively communicate scientific findings through written and oral presentations.

3. Apply molecular and cellular physiology concepts to design and execute a research project, and to develop independent research skills, such as experimental design, data analysis, and interpretation.

Course Evaluation:

- **Class participation and attendance (10%)**
- **Final exam (30%)**
- **Student project work and presentation (60%)**

Project Work Overview

•Goals of the Project Work

The goal of the project work for the students is to apply the knowledge and skills they have gained during the course to investigate and analyze a specific topic related to molecular and cellular physiology.

The project work is designed to enhance the students' critical thinking, problem-solving, and communication skills, as well as their ability to work independently and collaboratively.

The ultimate goal is to produce a high-quality research project that demonstrates a thorough understanding of the chosen topic and showcases the students' ability to apply their knowledge to real-world situations.

Project Work Overview

Guidelines and Deadlines #1

Group Work: The project work must be completed in small groups of 3-4 students.

Research Project: The project work consists of preparing a research project proposal in the field of molecular and cellular physiology, with a focus on neuroscience. The project proposal should include a clear hypothesis, detailed methodology, expected results, and potential implications of the research.

PPT Presentation: The research project proposal must be presented in a PPT format, with a minimum of 20 and a maximum of 30 slides. The presentation should be clear, concise, and well-organized.

Project Work Overview

Guidelines and Deadlines #2

Intermediate Deadlines: There will be intermediate deadlines every two weeks to ensure that the project is progressing as planned. These deadlines will include short presentations by each group, which will serve as an opportunity for feedback and discussion.

Literature Review: The project proposal should be based on a thorough literature review of the relevant scientific literature. Students are expected to use primary research articles, reviews, and other relevant sources to support their proposal.

Plagiarism: Plagiarism will not be tolerated. Students must properly cite all sources used in their proposal and presentation.

Project Work Overview

Guidelines and Deadlines #3

Grading: The project work will be graded based on the quality of the proposal, the clarity of the presentation, the level of engagement and participation in the intermediate deadlines, and the ability to answer questions and defend the proposal during the final presentation.

Deadline: The final deadline for the project work is May 20, 2023. No late submissions will be accepted without prior approval from the instructor. Submit the PowerPoint presentation as well as a written summary of the research proposal (maximum 2 pages, double-spaced) to the instructor by the assigned deadline.

Project Work Overview

Project Work Final Deadline

January 10th, 2024

Intermediate Deadlines

Every 2 weeks

Project Work Organization

Guidelines and Instructions #1

This project work will include the following sections:

Introduction:

In this section, you will introduce the topic of your project and provide some background information on why this topic is important. You should also clearly state the aims and objectives of your project, including the research questions that you will be addressing.

Background:

In this section, you will provide a detailed review of the relevant literature that is related to your project. You should summarize the key findings of previous studies that have investigated similar research questions and explain how your project will build upon this previous work.

Project Work Organization

Guidelines and Instructions #2

Aims:

In this section, you will clearly state the overall aims and objectives of your project. This should be a concise statement that outlines the main research questions that you will be addressing.

Methodology:

In this section, you will describe the methods and procedures that you will use to conduct your research. You should provide enough detail so that another researcher could replicate your study. This section should also include any ethical considerations or safety measures that you will need to take.

Expected Results:

In this section, you will describe what you expect to find as a result of your research. This should be based on your understanding of the literature and your hypothesis.

Project Work Organization

Guidelines and Instructions #3

Conclusions:

In this section, you will summarize the key findings of your research and draw conclusions based on your results. You should clearly state how your findings relate to your research aims and objectives. Additionally, you should suggest potential areas for future research.

Impact:

In this section, you will describe the potential impact of your research. This could include practical applications, contributions to the field, the broader scientific community, or society more generally.

Equality Plan:

In this section, you will describe any measures that you will take to ensure that your research is conducted in an inclusive and equitable manner. This might include considerations related to gender, ethnicity, or socioeconomic status.

Project Work Organization

Guidelines and Instructions #4

Timeline:

In this section, you will provide a detailed timeline for your project, including key milestones and deadlines. This will help you to stay on track and ensure that you are able to complete your project within the given timeframe.

The project work will be evaluated based on its quality, originality, and relevance to the course objectives. You are encouraged to be creative, innovative, and collaborative in your approach, and to seek feedback from your instructor or supervisor throughout the project work.

We look forward to seeing the results of your hard work, and to sharing your insights and discoveries with the rest of the class.

Project Work Guidelines

Tips and tricks #1

- Choose a research question related to the topics covered in the course and develop a research proposal to investigate it.
- Use scientific literature and other relevant sources to gather information about the chosen research question.
- Present the research question, background information, and research proposal in a PowerPoint presentation.
- The presentation should be approximately 20–30 minutes long.
- Include an introduction, literature review, methodology, and expected results in the presentation.

Project Work Guidelines

Tips and tricks #2

- Use clear and concise language to convey your ideas effectively.
- Use relevant diagrams, figures, and tables to enhance the clarity of the presentation.
- Provide citations for all sources used in the presentation.
- Be prepared to answer questions and engage in discussion with your peers and the instructor during and after the presentation.
- Submit the PowerPoint presentation as well as a written summary of the research proposal (maximum 2 pages, double-spaced) to the instructor by the assigned deadline.

Project Work Guidelines

Possible Topics #1

Investigating the pathophysiology of Alzheimer's disease: The students can investigate the molecular mechanisms underlying the development of Alzheimer's disease. They can explore the role of amyloid-beta and tau proteins, neuroinflammation, oxidative stress, and mitochondrial dysfunction in the pathophysiology of the disease.

Investigating the role of the microbiome-gut-brain axis in neurological disorders: The students can investigate the communication between the gut microbiome and the brain, and how this communication is disrupted in neurological disorders such as autism, depression, and anxiety. They can explore the mechanisms involved in this communication, including the production of neurotransmitters and inflammatory molecules.

Investigating the molecular mechanisms of pain: The students can investigate the molecular mechanisms underlying pain, including the roles of ion channels, receptors, and signaling pathways. They can explore the different types of pain, including acute and chronic pain, and how pain can be modulated by drugs and other interventions.

Project Work Guidelines

Possible Topics #2

Investigating the role of glia in neurological disorders: The students can investigate the role of glia cells in neurological disorders such as multiple sclerosis, Alzheimer's disease, and Parkinson's disease. They can explore the functions of different types of glia cells, and how these cells can contribute to disease pathology.

Investigating the molecular mechanisms of neurodegeneration: The students can investigate the molecular mechanisms underlying neurodegeneration, including the roles of protein misfolding, autophagy, and mitochondrial dysfunction. They can explore the different types of neurodegenerative diseases, including Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis.

Investigating the role of genetics in neurological disorders: The students can investigate the genetic basis of neurological disorders, including the roles of single gene mutations and genetic risk factors. They can explore how genetics interacts with environmental factors to contribute to disease pathology and how this knowledge can be used to develop personalized treatments.

Project Work Guidelines

Possible Topics #3

Investigating the effects of environmental toxins on brain function: The students can investigate the effects of environmental toxins, such as lead, mercury, and pesticides, on brain function. They can explore the mechanisms involved in toxin-induced neurotoxicity and how this knowledge can be used to develop strategies for preventing or treating toxin exposure.

Investigating the role of specific ion channels or receptors in synaptic plasticity: Students can choose a specific ion channel or receptor, such as NMDA or AMPA receptors, and investigate their role in short-term and long-term synaptic plasticity using electrophysiological techniques.

Exploring the role of astrocytes in neuronal function: Students can investigate the role of astrocytes in regulating neuronal activity, synaptic transmission, and plasticity using techniques such as calcium imaging and optogenetics.

Project Work Guidelines

Possible Topics #4

Investigating the effects of microbiota on brain function: Students can investigate the effects of gut microbiota on brain function, behavior, and cognition using techniques such as fecal transplants, microbiota depletion, and behavioral tests.

Investigating the role of glial cells in neurodegenerative diseases: Students can investigate the role of glial cells, such as microglia or astrocytes, in neurodegenerative diseases such as Alzheimer's disease, Parkinson's disease, or multiple sclerosis, using techniques such as histology and immunohistochemistry.

Investigating the role of neuropeptides in regulating behavior and physiology: Students can investigate the role of neuropeptides such as oxytocin, vasopressin, or corticotropin-releasing hormone in regulating behavior and physiology, using techniques such as receptor mapping and behavioral tests.

Project Work Guidelines

Possible Topics #5

Investigating the effects of environmental factors on neuronal function: Students can investigate the effects of environmental factors such as stress, exercise, or nutrition on neuronal function and plasticity, using techniques such as electrophysiology and molecular biology.

Investigating the molecular mechanisms of synaptic transmission: Students can investigate the molecular mechanisms of synaptic transmission, such as vesicle release and neurotransmitter uptake, using techniques such as electron microscopy and biochemical assays.

Investigating the role of microRNAs in regulating neuronal gene expression: Students can investigate the role of microRNAs in regulating gene expression in neurons and glial cells, using techniques such as RNA sequencing and bioinformatics analysis.

Project Work Guidelines

Possible Topics #6

Investigating the molecular basis of sensory perception: Students can investigate the molecular mechanisms underlying sensory perception, such as photoreceptor signaling in vision or olfactory receptor signaling in smell, using techniques such as molecular biology and electrophysiology.

Investigating the effects of drugs of abuse on neuronal function: Students can investigate the effects of drugs of abuse such as cocaine, methamphetamine, or opioids on neuronal function and plasticity, using techniques such as electrophysiology and behavioral tests.

Introduction to Physiology

But first....



Introduction to Physiology

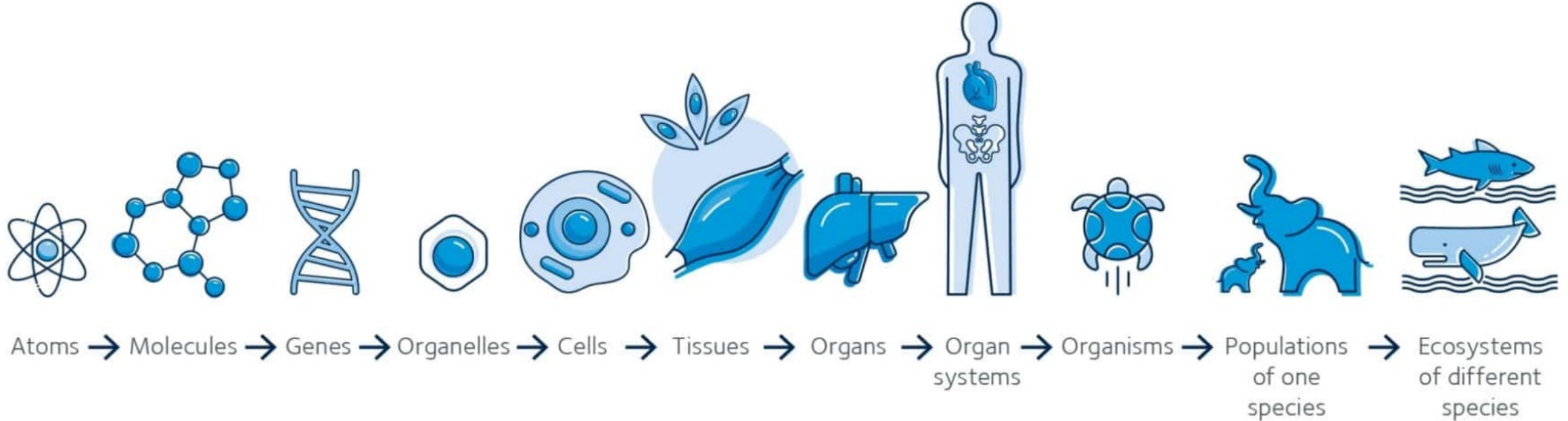
Why to study Anatomy & Physiology?

- To Understand structure - ANATOMY
- To Study the function of a structure - PHYSIOLOGY
- Structure is ALWAYS related to function



What is
Physiology?

What is Physiology?



Physiology is the science of life



What is Physiology?

- **Physiology:** biological sciences
 - dealing with the normal life phenomena exhibited by all living organisms.
- **Human physiology:** basic sciences
 - dealing with normal life phenomena of the human body.
- **Goal of physiology:**
 - explain the physical and chemical factors that are responsible for the origin, development and progression of **life**.

What is Physiology?

- Questions and observations that have led to knowledge.
- Knowledge about structure and function of the human body.

Human Physiology

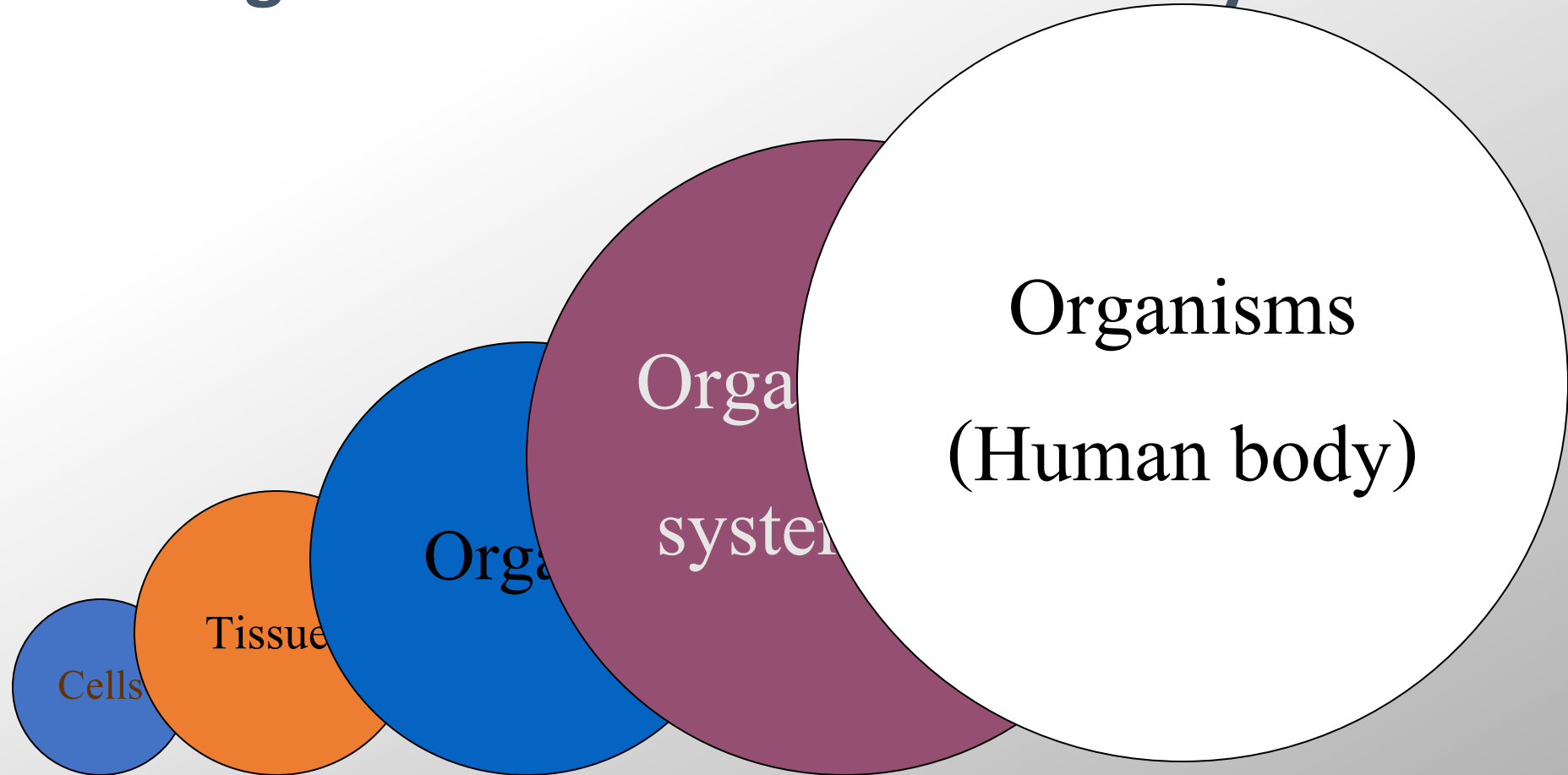
- **Physiology: (Greek) The study of nature, the involvement of Physics and Chemistry.**
- **The basis for**
 - **Pathophysiology**
 - **Pharmacology**
 - **Immunology**
 - **Biochemistry**
 - **Microbiology**

Why do we study Physiology?

- Understand the physical and chemical principle underlie normal function in order to cure the impairments.

Different Level of Physiological Research

Organization of the human body



HUMAN BODY

- The systematic study of human body –
performed in two ways

1. ANATOMY (STRUCTURE)

2. PHYSIOLOGY (FUNCTION)

Anatomy & Physiology

- **Anatomy** – the study of the structure of the human body

- **Physiology** – the study of the function of the human body

“The complementarity of structure and function.”

Why?

- Its base for understanding of physiology and pathophysiology
- Helps to study human evolution and development
- To understand pathology of disease and pathological changes
- For determining the techniques of surgeries

Physiology vs. Anatomy

While human anatomy is the study of the body's structures, physiology is the study of how those structures work.

An imaging scan like an X-ray or ultrasound can show your anatomy, but doctors use other tests -- like urine and blood tests or electrocardiograms (EKGs) -- to reveal details about your body's physiology.

Anatomy

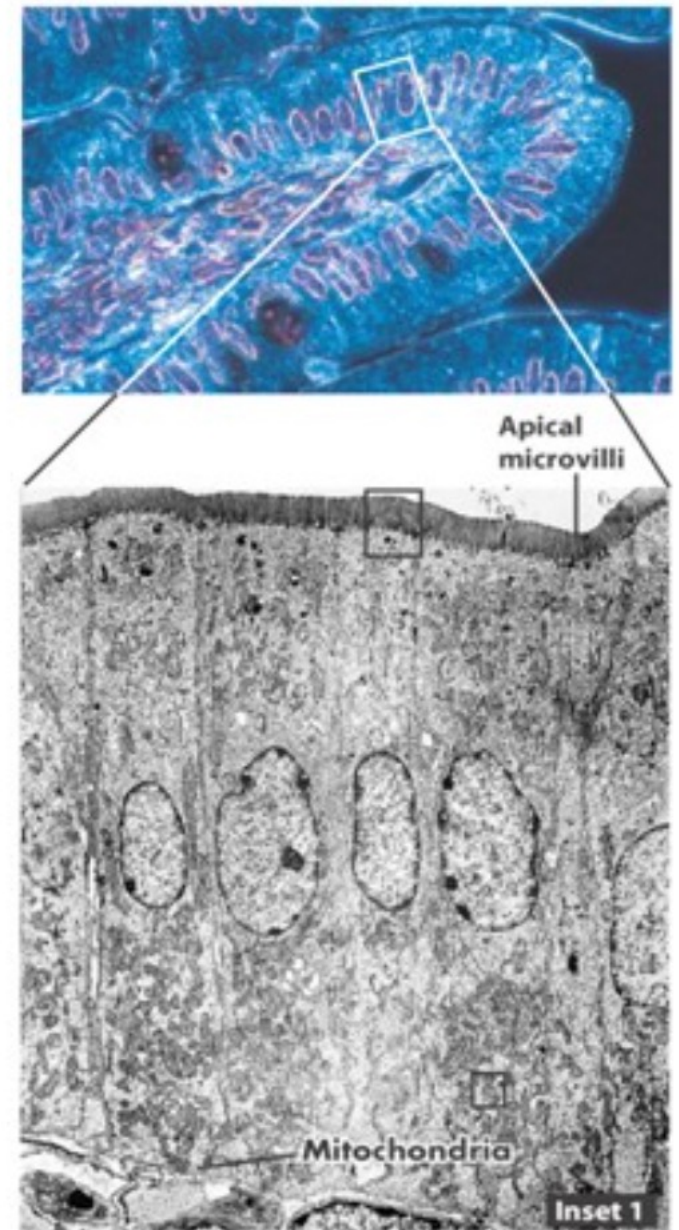
“It is the branch of medical science which involves the study of different structures of the human body and their relationship with each other”

- The term anatomy comes from the Greek word- meaning - **DISSECTION**.

Subdivisions of Anatomy

- **Gross Anatomy** is the study of structures with the naked eye.
- **Histology** is the study of **tissues**.
- **Cytology**, like histology, uses a microscope, but restricts the study to individual **cellular structures**.

This micrograph is typical of an histological and cytological examination under light microscopy



Physiology

“Study of functioning of human body and its parts”

SUBTYPES:

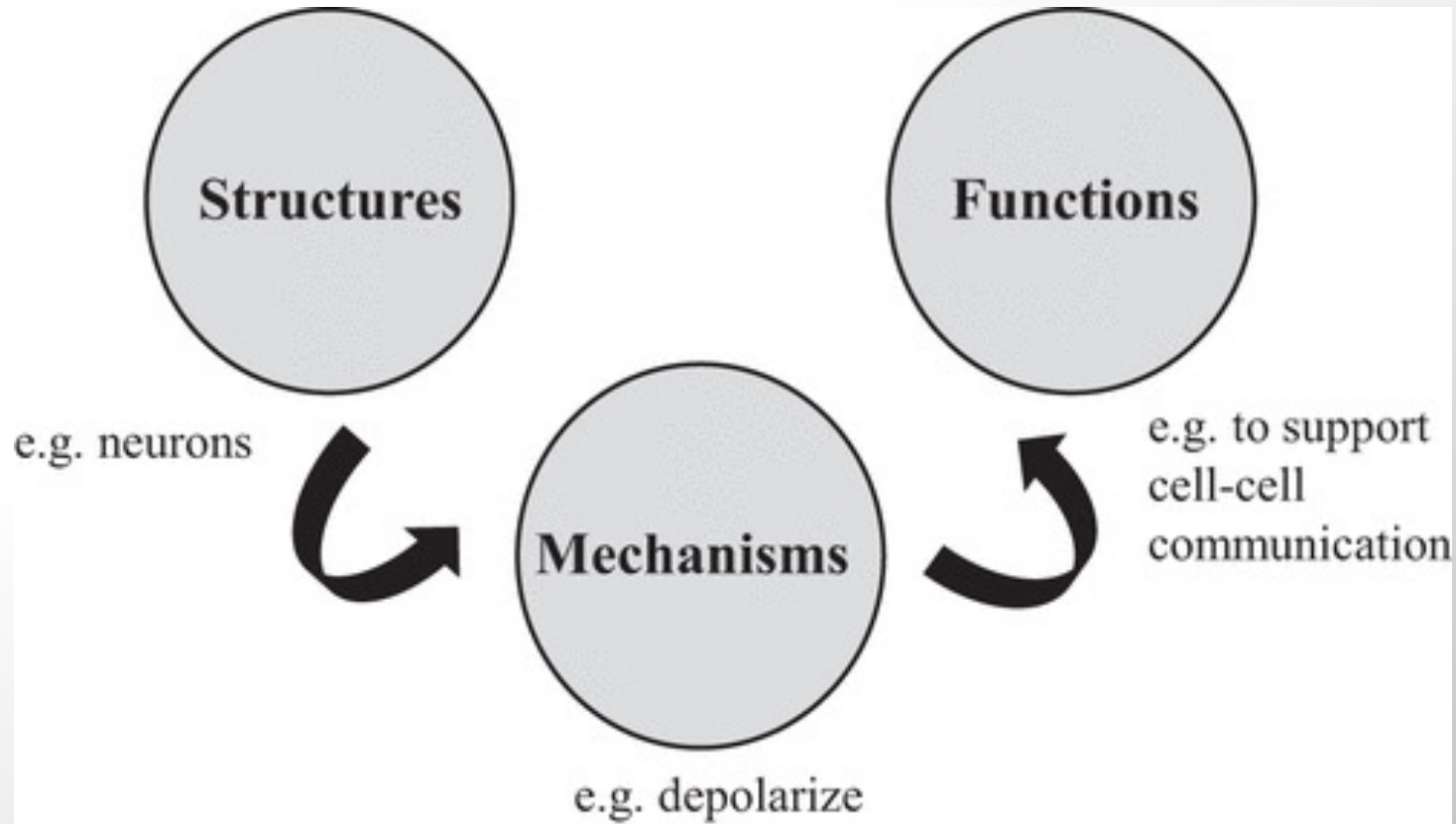
neurophysiology

explains the working of the nervous system,

Cardiac physiology

studies the function of the heart.

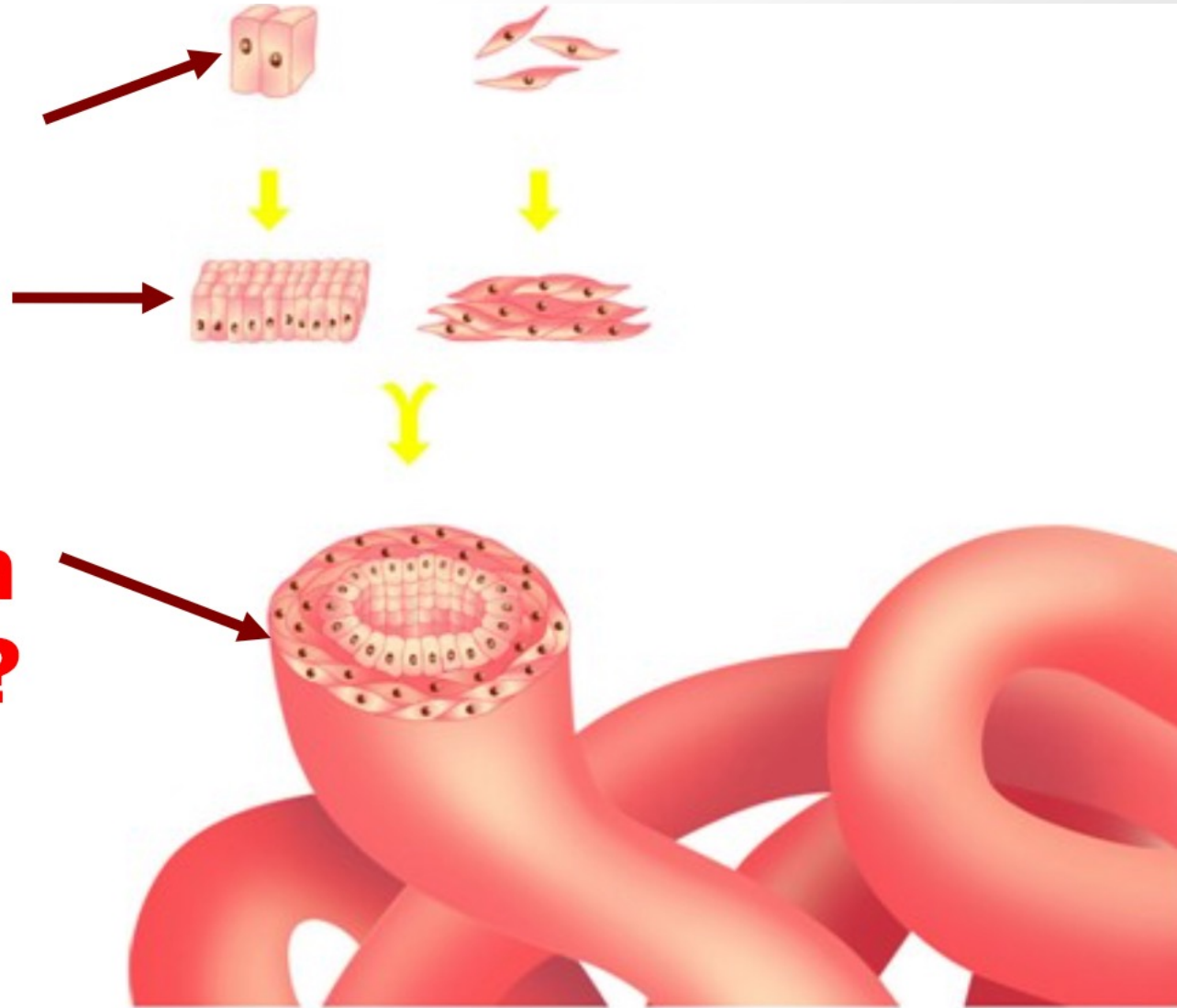
Anatomy & Physiology



“The complementarity of structure and function.”






Believe it or not ... you are organized

**Can you
identify
the 3 levels
of
organization
shown here?**



Levels of Organization

The Human Body has several “layers” of organization beginning with the simplest and becoming more complex.

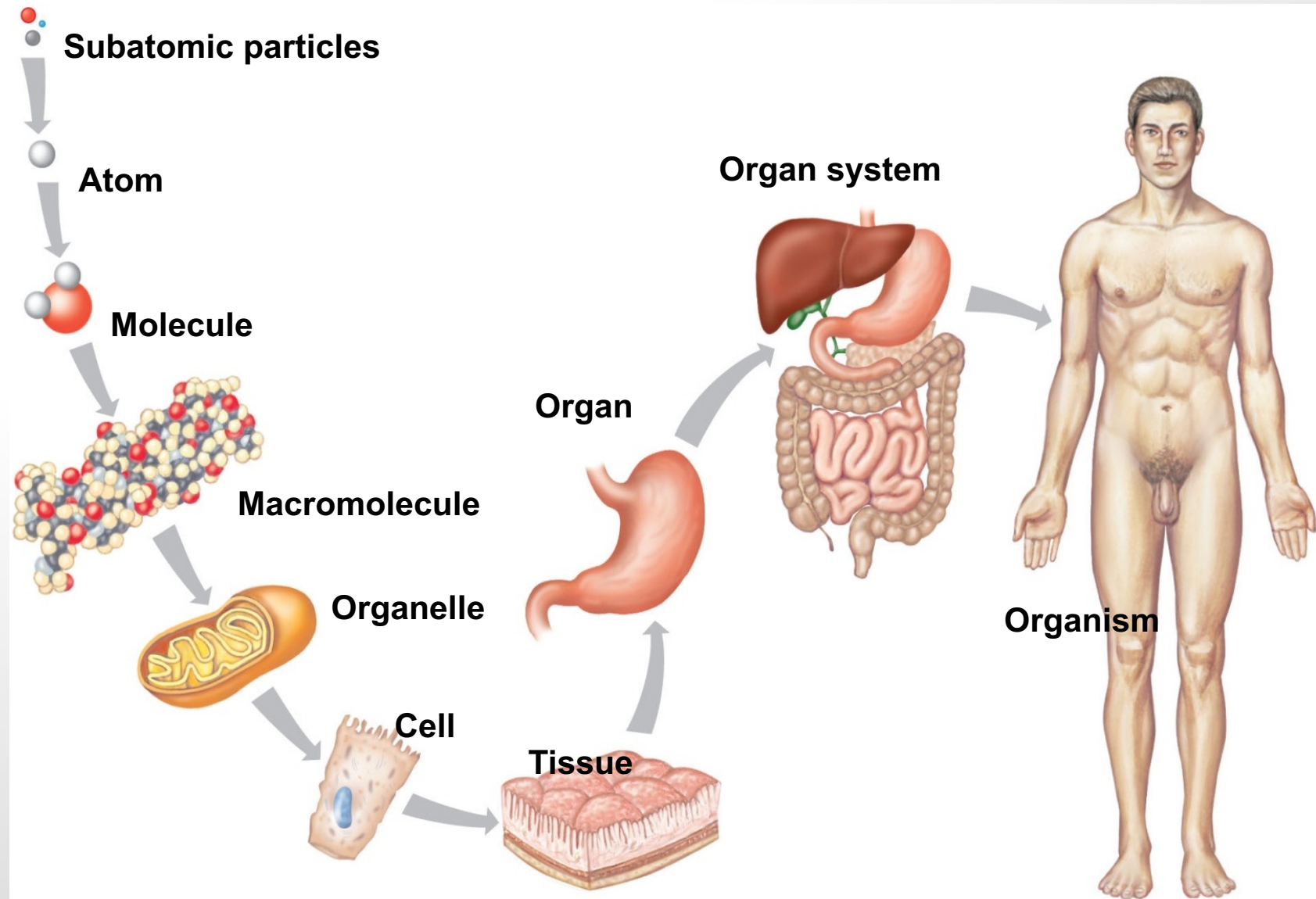
Level of Organization				
				
Atom and Molecule	Cell	Tissue	Organ	Organ System
Definition				
<p>Atom: Smallest unit of an element of matter.</p> <p>Molecule: More than one atom in a stable association.</p>	Smallest unit of life.	An association of cells with the same general structure and function.	An association of several tissue types that carry out a specific function.	Two or more organs that work together to carry out a general function, such as digestion or movement.
Current Issues and Controversies				
<ul style="list-style-type: none"> • How to dispose of radioactive wastes. • Role of free radicals in cancer and aging. 	Cloning adult animals, plants and humans from a single cell.	The use of human fetal tissues in research.	<ul style="list-style-type: none"> • How to increase the supply of human organs for transplantation. • Transplanting animal organs into humans. 	<ul style="list-style-type: none"> • Enhancing human performance with drugs or by genetic engineering.

Answers to previous slide: cell, tissue, organ (small intestine).

Levels of Organization

- **Subatomic Particles** – electrons, protons, and neutrons
- **Atom** – hydrogen atom, lithium atom, etc.
- **Molecule** – water molecule, glucose molecule, etc.
- **Macromolecule** – protein molecule, DNA molecule, etc.
- **Organelle** – mitochondrion, Golgi apparatus, nucleus, etc.
- **Cell** – muscle cell, nerve cell, etc.
- **Tissue** – epithelia, connective, muscle and nerve
- **Organ** – skin, femur, heart, kidney, etc.
- **Organ System** – skeletal system, digestive system, etc.
- **Organism** – the human

Levels of Organization



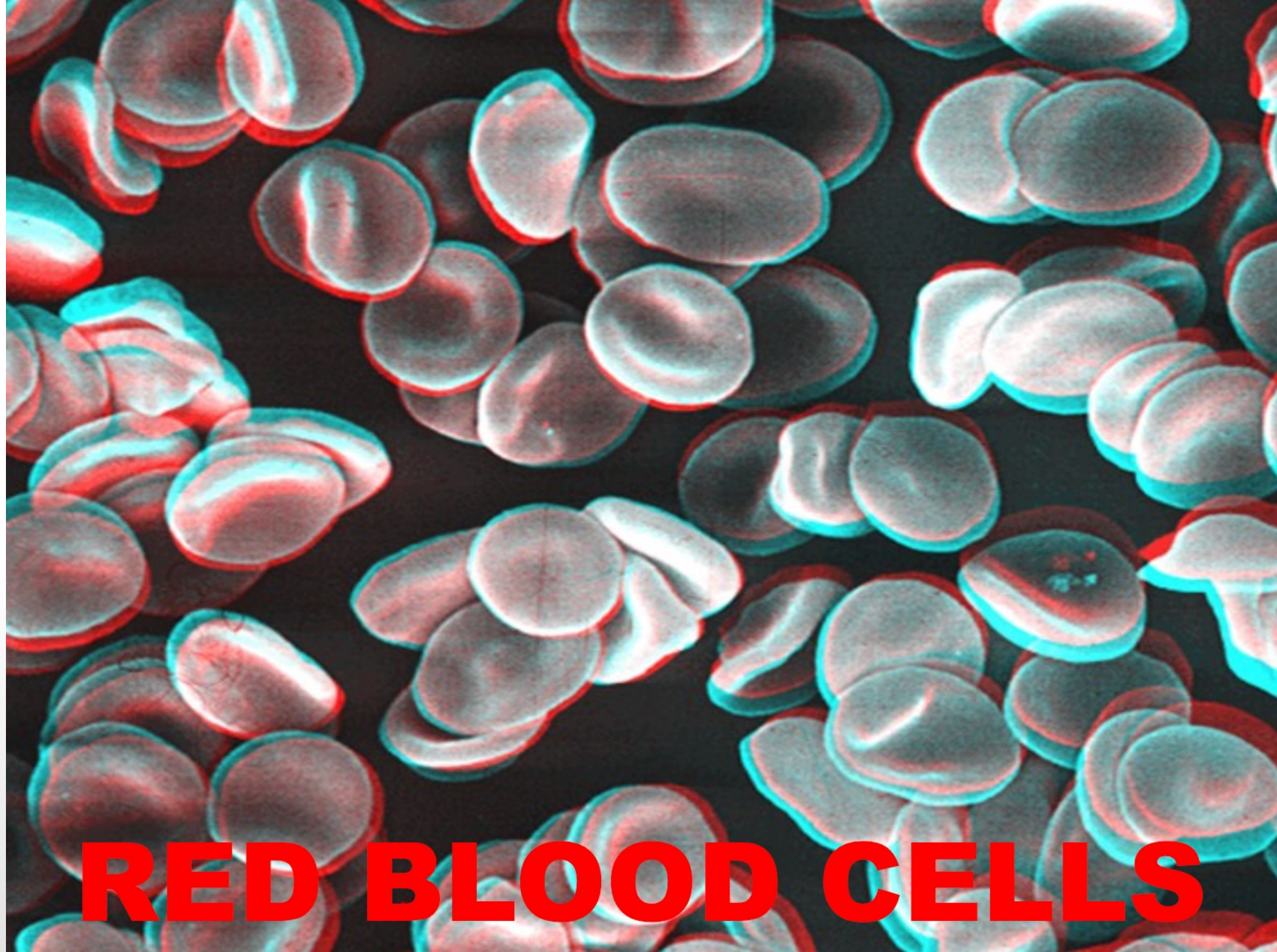
The work of cells



On a baseball team,
every player has his job.

Cells have their own
positions (or jobs) in
the body!





RED BLOOD CELLS

Tissues

Groups of cells working together form a *TISSUE*

There are 4 types of tissues:

- Epithelial Tissue
- Nervous Tissue
- Muscle Tissue
- Connective Tissue

Tissues

EPITHELIAL TISSUE

Covers and protects underlying tissue.
When you look at the surface of your skin, you see epithelial tissue

CONNECTIVE TISSUE

Joins, supports, protects, insulates, nourishes, and cushions organs. It also keeps organs from falling apart.

MUSCLE TISSUE

Made up of cells that can contract and relax to produce movement

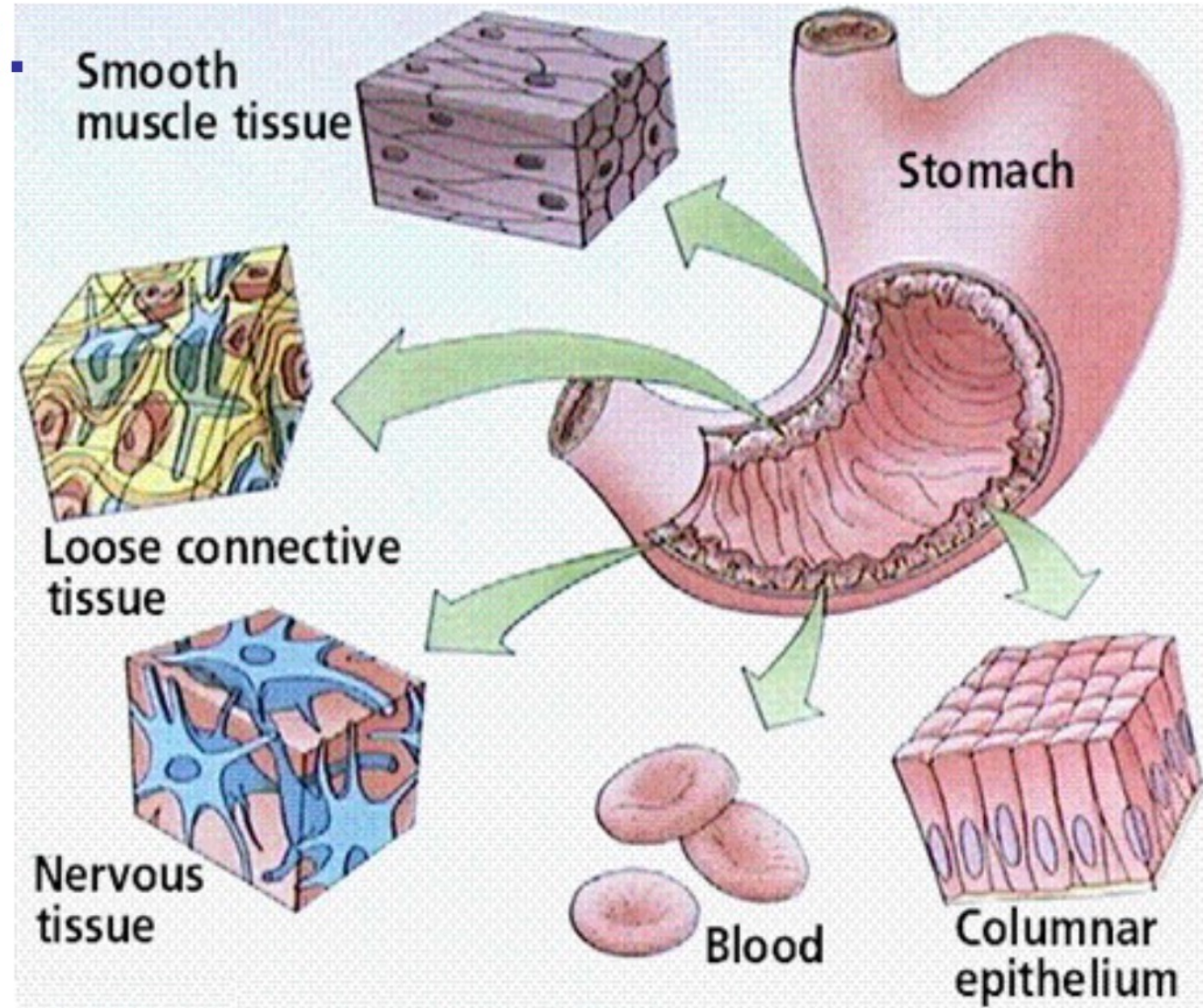
NERVOUS TISSUE

Sends electrical signals through the body. It is found in the brain, nerves and sense organs.

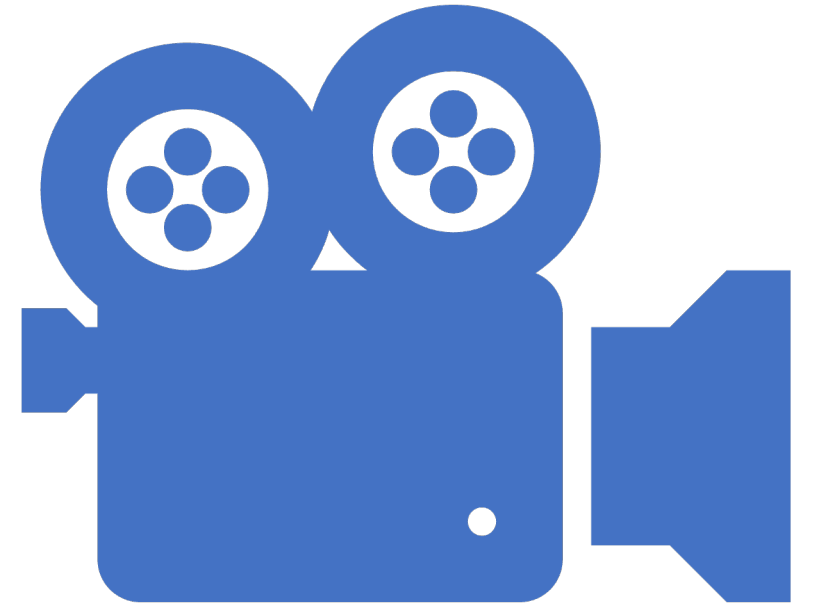
Organ

Two or more tissues working together, form an **organ**.

One type of tissue alone cannot do all of the things that several types working together can do.



Video



Practice:

What are the levels of organisation in organisms, from least complex to most complex?

Organelles → _____ → tissues → _____ → organ systems

Answer:

What are the levels of organisation in organisms, from least complex to most complex?

Organelles → cells → tissues → organs → organ systems

Practice:

What is a tissue?

A group of organelles with similar structures working together

A group of similar cells working together to perform a common function

A collection of similar organs

Answer:

What is a tissue?

A group of organelles with similar structures working together

A group of similar cells working together to perform a common function

A collection of similar organs

<https://cognitoedu.org>

Organs + Organ +.. =Organ System

CAUTION

The failure of any
part can affect
the entire system



Organ Systems



Integumentary system

ORGANS

- Skin

FUNCTIONS

- Waterproofs, cushions, protects deeper tissue
- Excretes salts & urea; pain, pressure
- Regulates body temp; synthesize vitamin D

Organ Systems

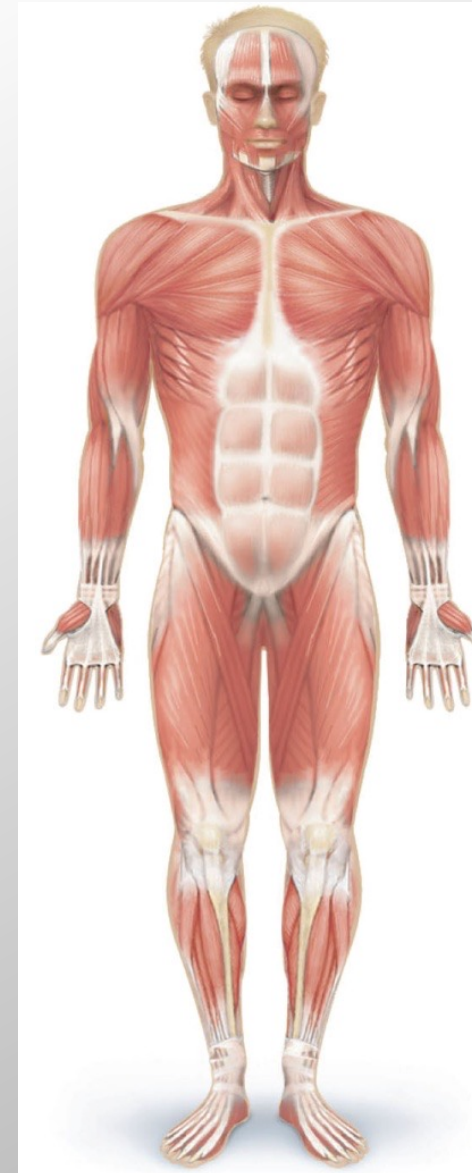
Muscular system

ORGANS

- Skeletal muscle attached to bone)
- Smooth muscle
- Cardiac muscle

FUNCTIONS

- Contraction & mobility
(locomotion)
- Facial expression, posture
- Produce body heat



Organ Systems

Skeletal system



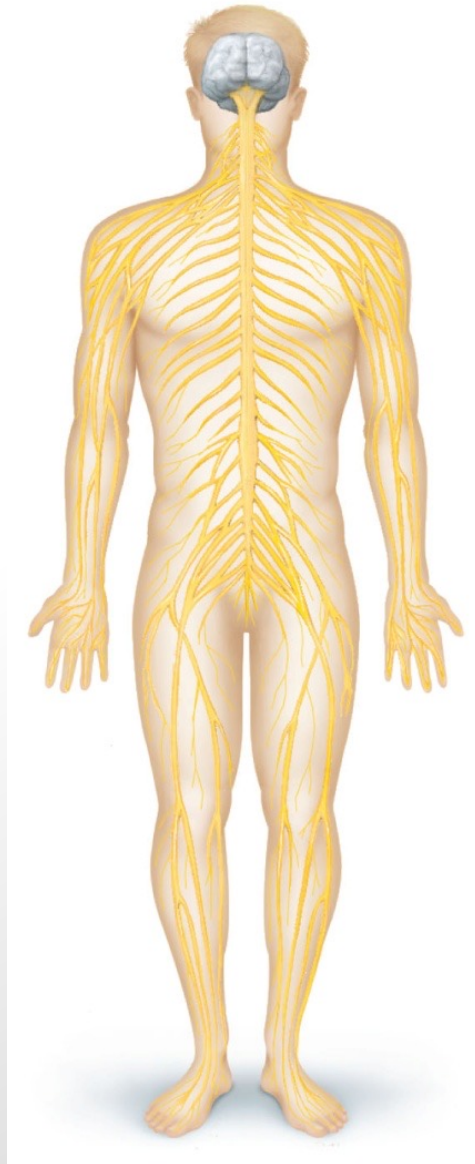
ORGANS

- Bones, cartilages, ligaments, joints

FUNCTIONS

- Protects & supports body organs
- Framework for muscles & movement
- Hematopoiesis, store minerals

Organ Systems



Nervous system

ORGANS

- Brain, spinal cord, nerves, & sensory receptors

FUNCTIONS

- Fast-acting central control system
- Responds to external/internal stimuli via nerve impulses (electrical messages)

Organ Systems

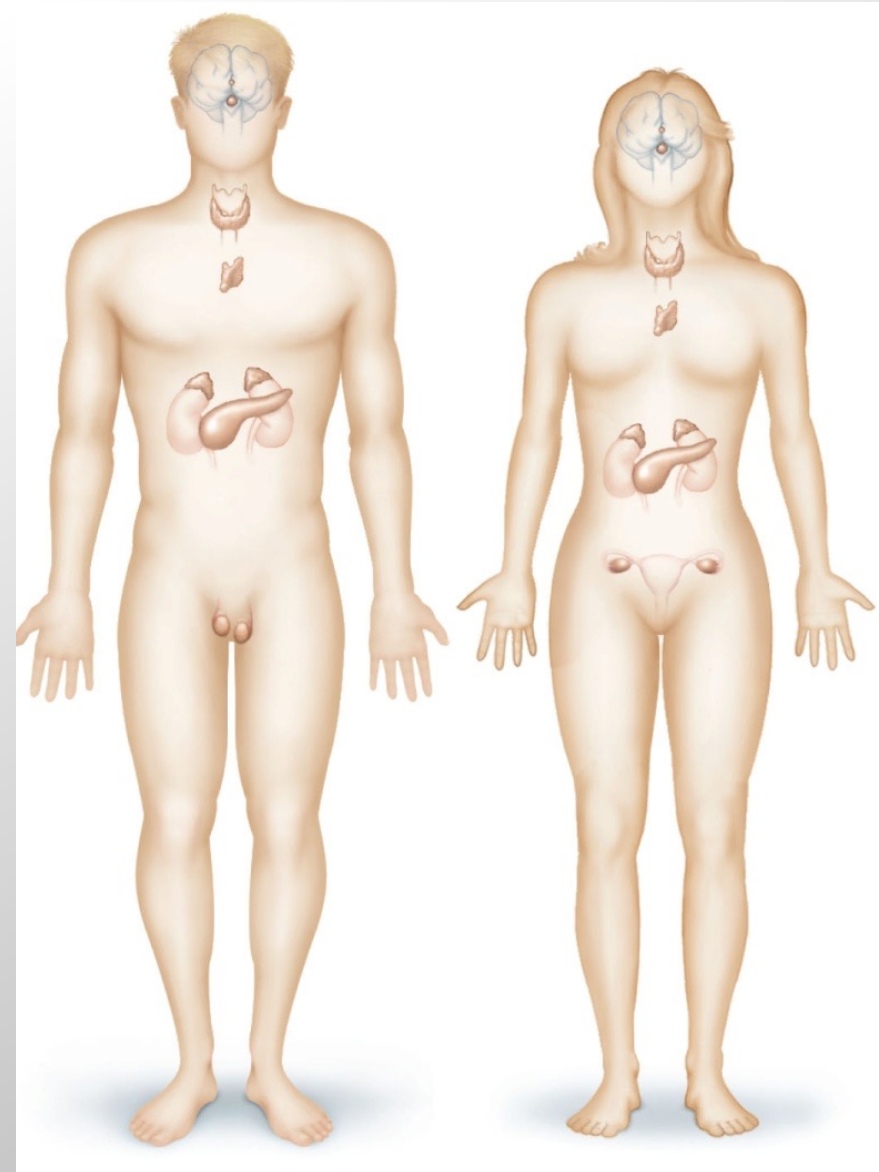
ORGANS

- Pituitary, thyroid, parathyroids, adrenals, thymus, pancreas, pineal, ovaries, testes.....etc.

FUNCTIONS

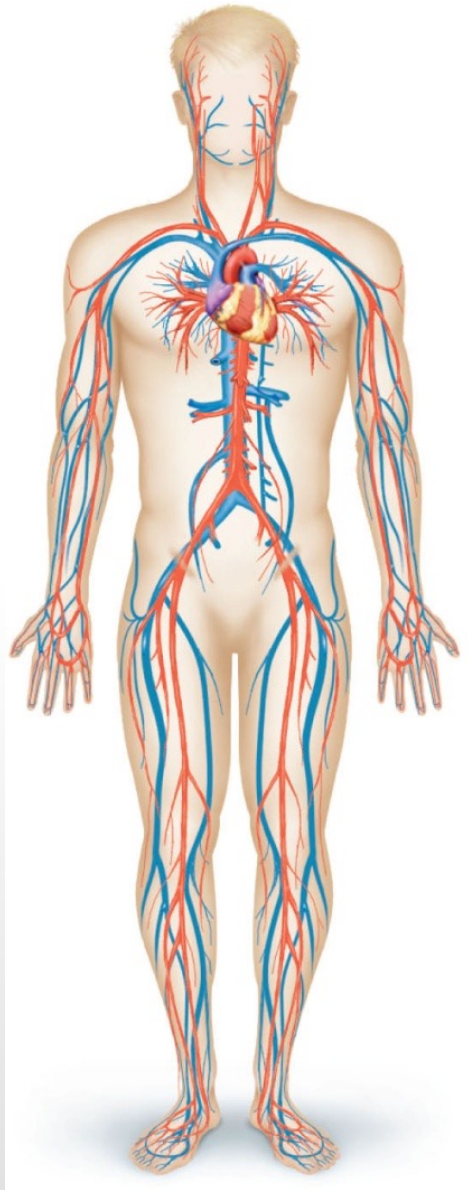
- Slow -acting control system
- Glands produce hormones that regulate growth, reproduction, metabolism,.... etc.

Endocrine system



Organ Systems

Cardiovascular system



ORGANS

- Heart, blood vessels, capillaries & blood

FUNCTIONS

- Carries O₂ nutrients, hormones, & other substances
- White blood cells protect against bacteria, toxins, tumors

Organ Systems

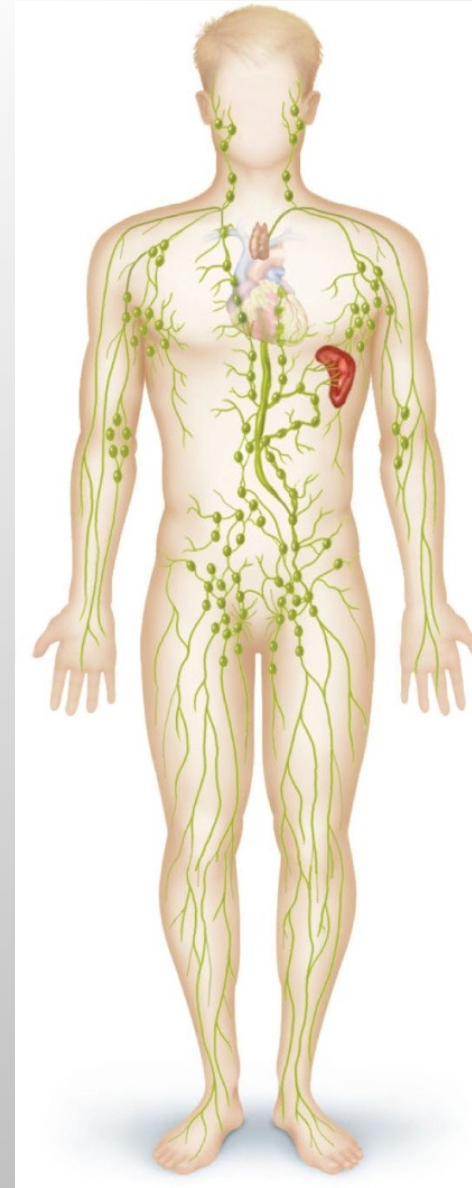
ORGANS

- Lymphatic vessels, lymph nodes, spleen, tonsils

FUNCTIONS

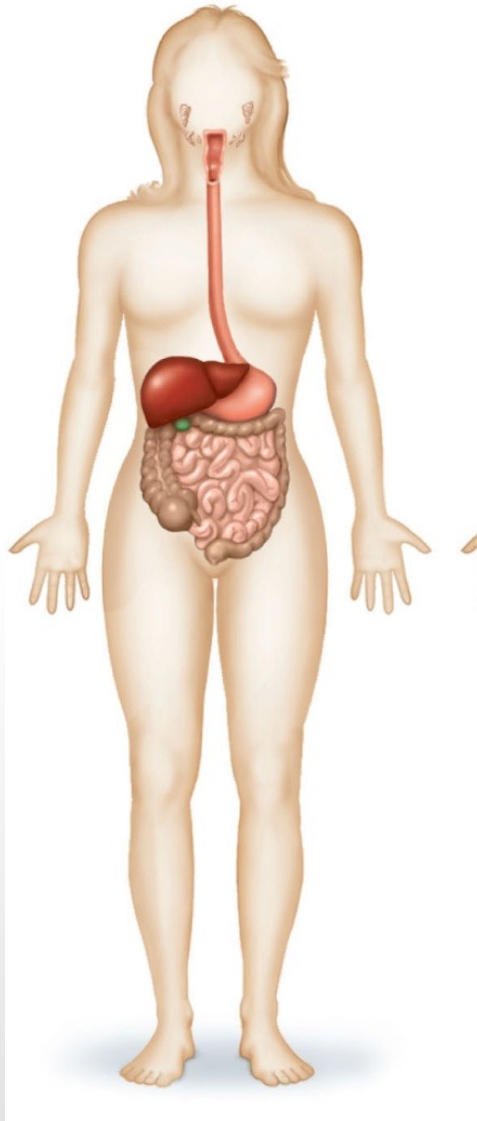
- Provides immunity against disease and infections

Lymphatic system



Organ Systems

Digestive system



ORGANS

- Oral cavity, esophagus, stomach, small intestine, large intestine, rectum, anus (liver & pancreas)

FUNCTIONS

- Breaks food down into absorbable units that enter the blood; indigestible food eliminated as feces

Organ Systems

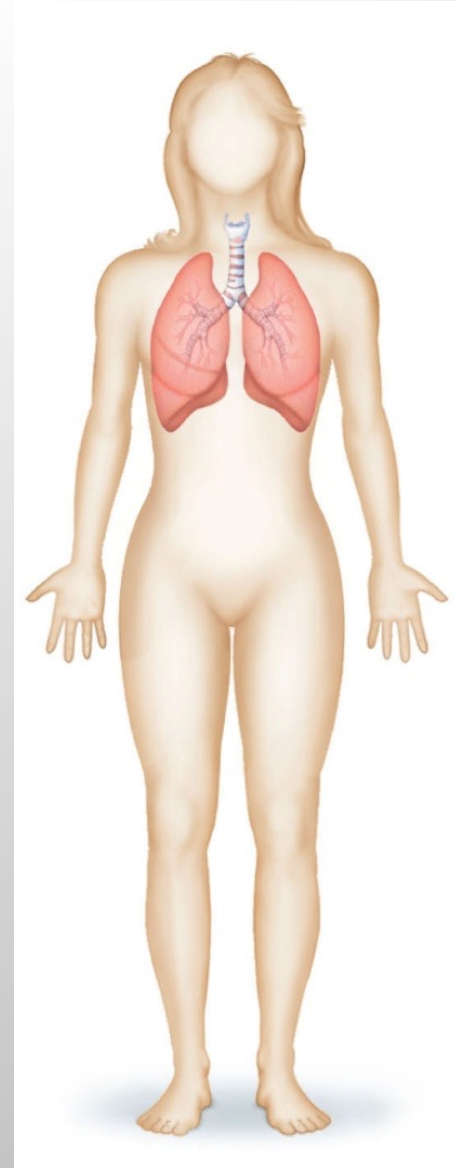
Respiratory system

ORGANS

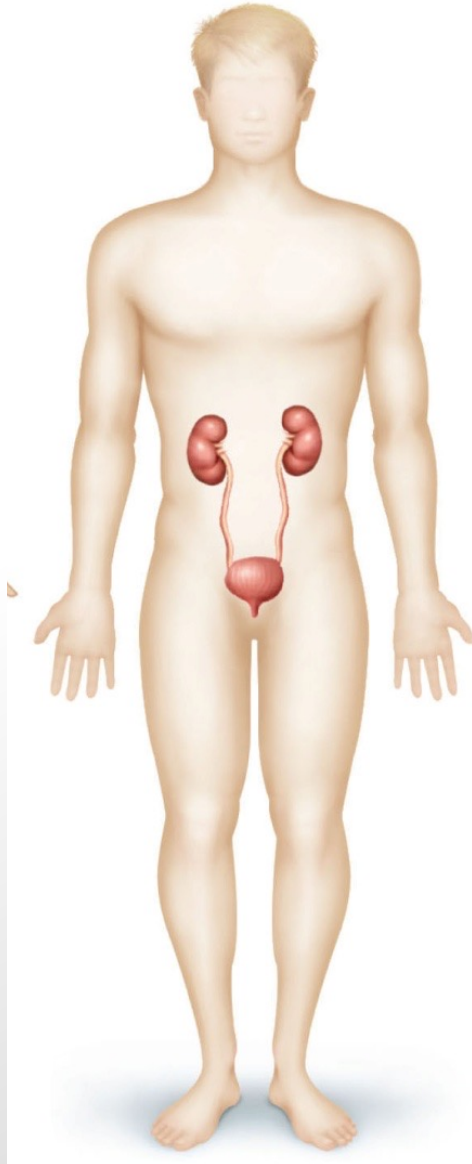
- Nasal cavity, pharynx, larynx, trachea, bronchi, & lungs

FUNCTIONS

- Keeps blood supplied with O_2 & removes CO_2
- Carries gas exchanges



Organ Systems



Urinary system

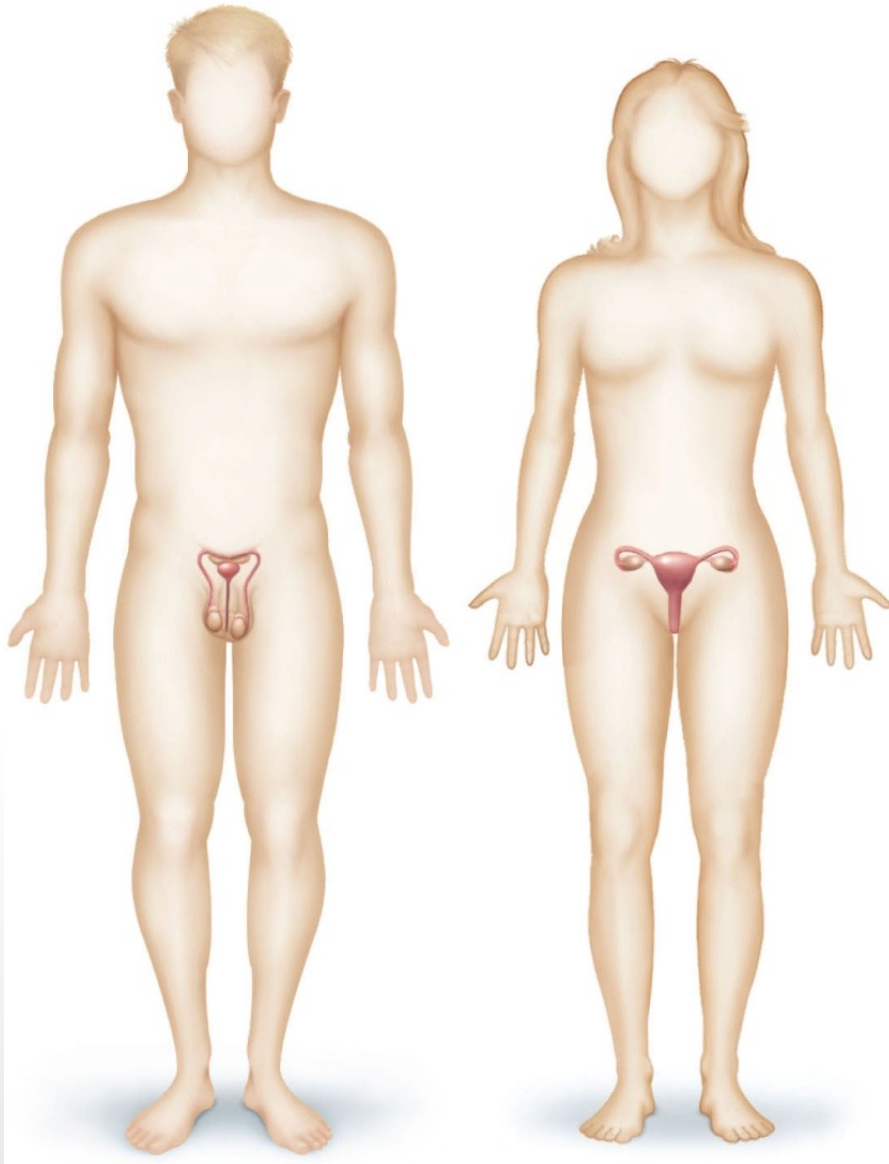
ORGANS

- Kidney, ureter, urinary bladder, urethra

FUNCTIONS

- Eliminates waste products from the body (urea & uric acid)
- Regulates water, electrolytes, & acid-base balance of the blood

Organ Systems



Reproductive system

ORGANS

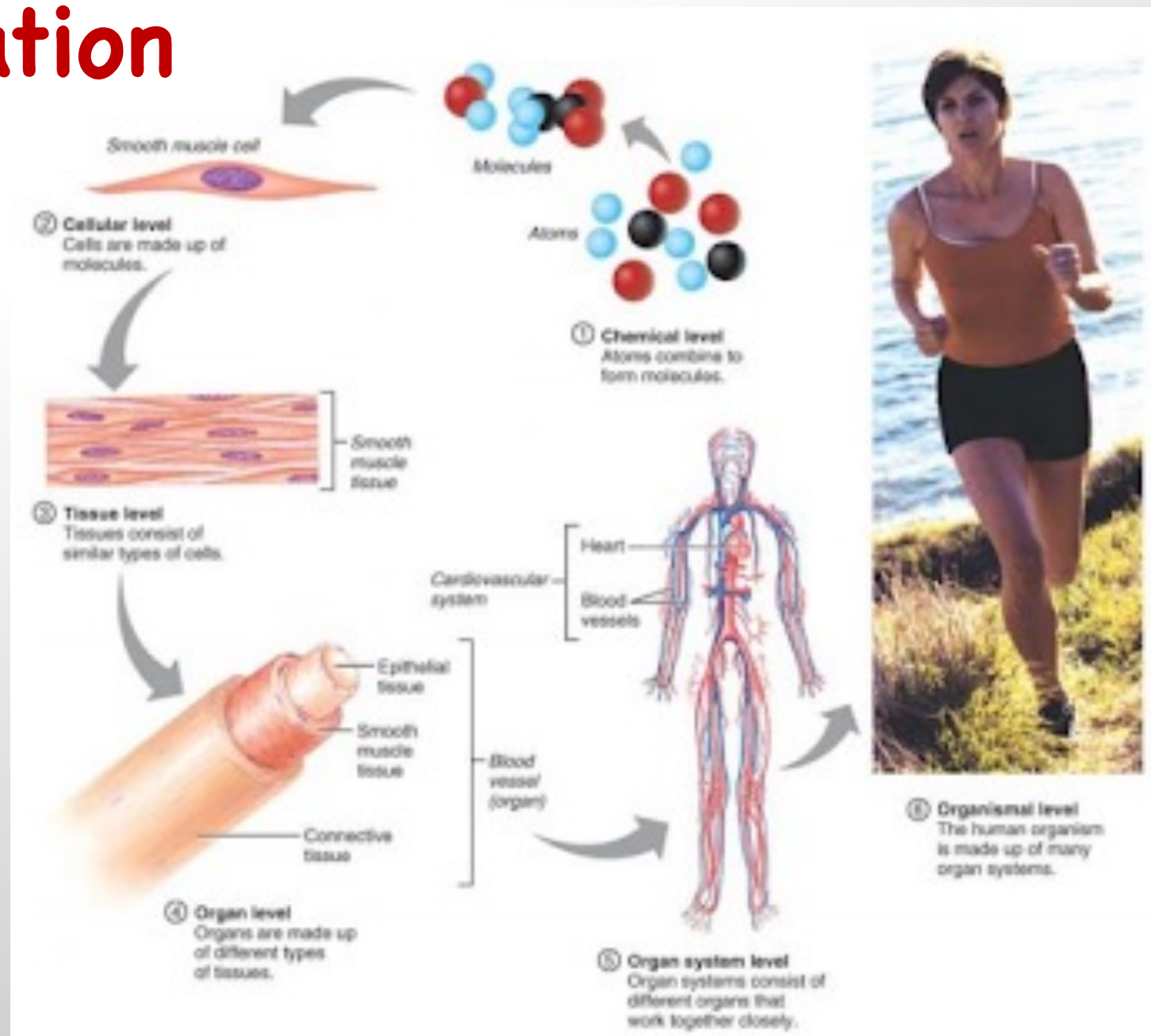
- Male
 - Seminal vesicles, prostate, penis, vas deferens, testis, scrotum
- Female
 - Ovaries, mammary glands, uterus, vagina, uterine tube

FUNCTIONS

- Primary function for both sexes is to produce offspring
- Male – testes produce sperm & male sex hormones
- Female – ovaries produce eggs & female sex hormones;

Levels of Organization

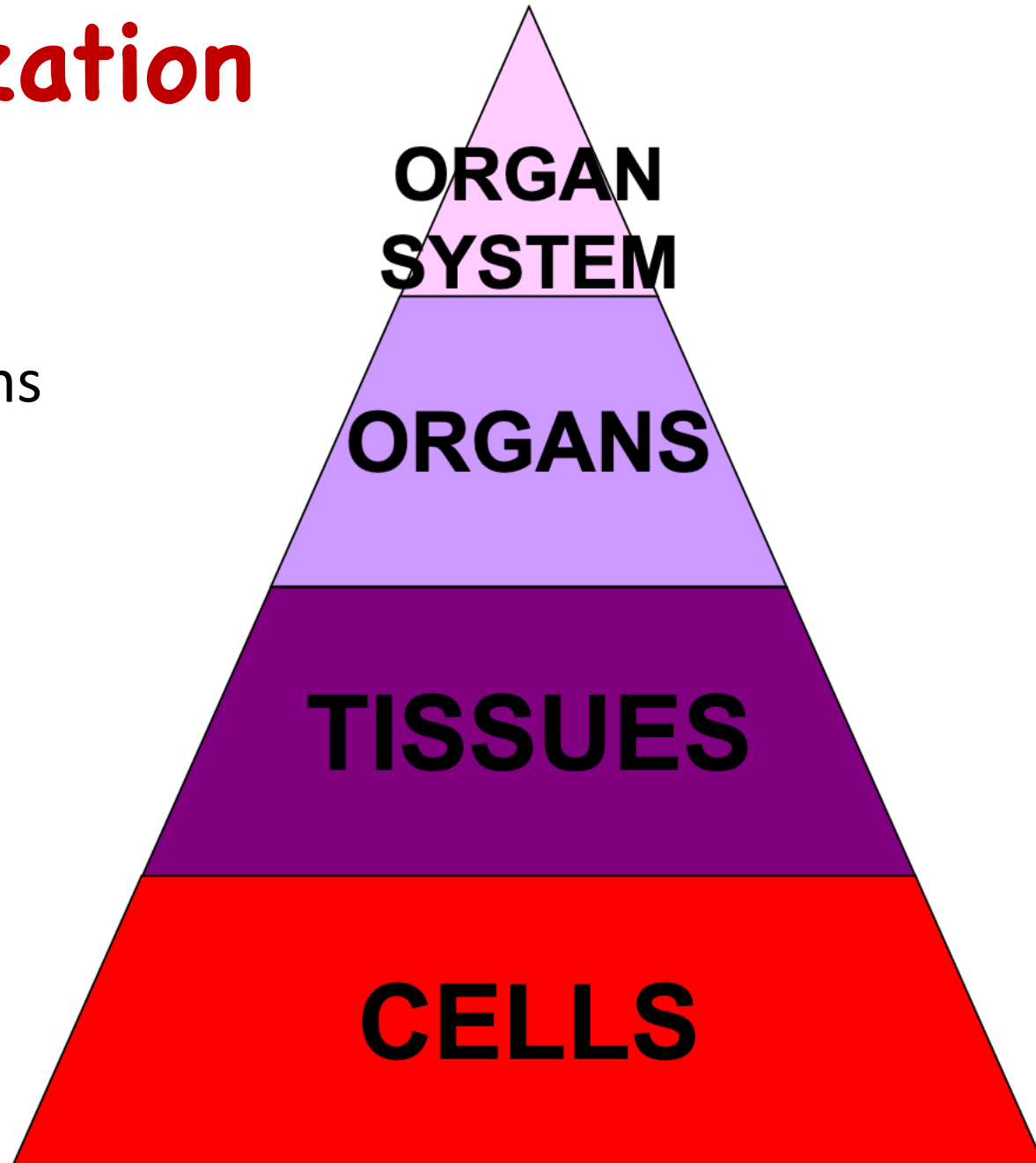
•An **organism** is a system possessing the characteristics of living things—the ability to obtain and process energy, the ability to respond to environmental changes, and the ability to reproduce.



Levels of Organization

- atoms/ molecules < cells < tissues < organs < organ systems < organisms

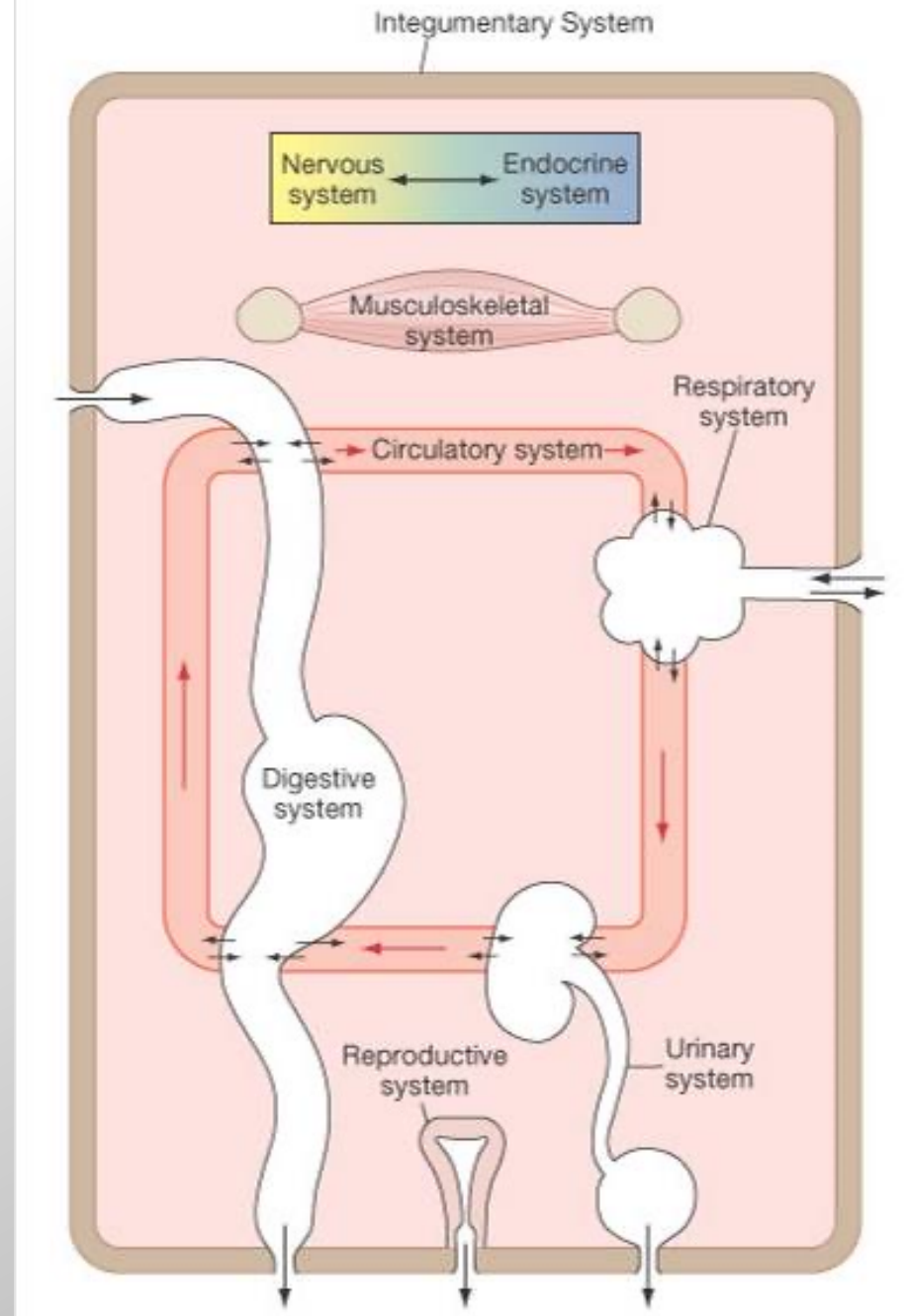
- Each level is more complex than the previous.



Recap: Cellular structures and functions

The integration between systems of the body

- Many systems combines to form ORGANISM
- An individual can survive only if all the systems of the body works harmony



What is Physiology?

Physiology is the science of life.

It is the branch of biology that aims to understand the mechanisms of living things, from the basis of cell function at the ionic and molecular level to the integrated behaviour of the whole body and the influence of the external environment.

Research in physiology helps us to understand how the body works in health and how it responds and adapts to the challenges of everyday life; it also helps us to determine what goes wrong in disease, facilitating the development of new treatments and guidelines for maintaining human and animal health.

The emphasis on integrating molecular, cellular, systems and whole body function is what distinguishes physiology from the other life sciences.

Discussion questions:

1. Explain the relationship between cells, tissues, organs and organ systems.
2. Compare the four kinds of tissues found in the human body.