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Cell Specialization and Organ Systems

HASPI Medical Biology Lab 03

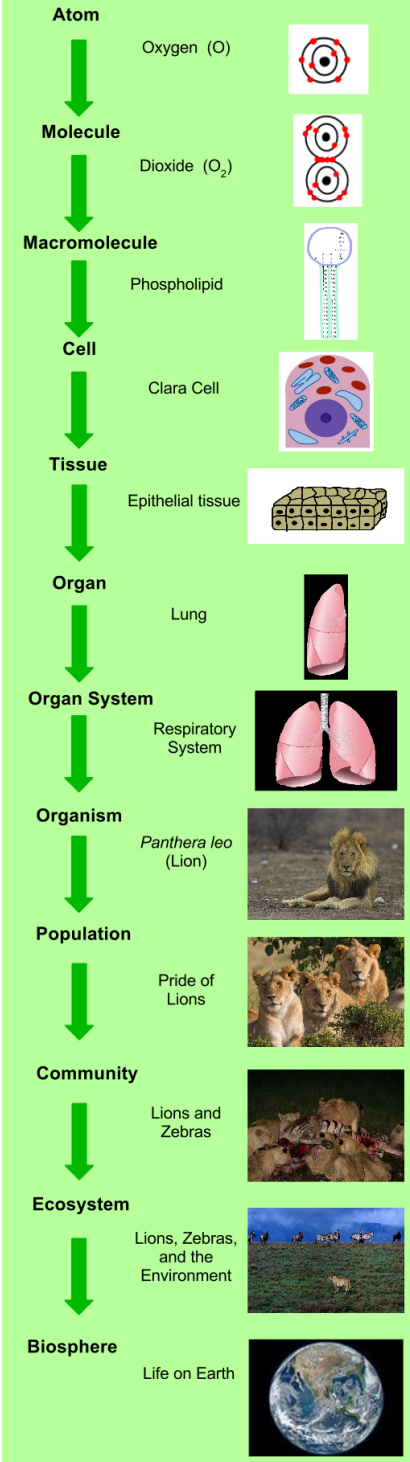
Background/Introduction

Organization of Life

Life on Earth is organized into a hierarchy based on complexity. Starting at the most basic level, the atom, each level becomes more complex than the last. Table 1 provides a definition and example(s) of life at each level.

Table 1. The Hierarchy of Life

Level	Definition	Example(s)
Atom	The most basic units of matter	Carbon (C), hydrogen (H), oxygen (O), sodium (Na)
Molecule	A collection of atoms that are bonded together	Water (H_20), carbon dioxide (CO_2), table salt (NaCl)
Macromolecule	Large molecules that perform a function in living organisms	Carbohydrates, proteins, DNA, lipids
Cell	A collection of macromolecules that combine to form a living organism that performs a specified function	Skin cell, muscle cell, bacteria, plant cell, protist
Tissue	A collection of cells that works together to perform a specified function	Muscle tissue is a collection of muscle cells that are capable of contracting
Organ	A specialized structure made of tissues that performs a specific function	A muscle, stomach, brain, lung, bone
Organ System	A specialized system within a living organism made up of organs that perform a unified function	Circulatory, respiratory, and digestive systems
Organism	A single living individual	The human body
Population	All individuals of a single species	A population of humans
Community	All of the species within an ecosystem	Only the living components including all bacteria, fungi, plants, and animals
Ecosystem	All living organisms and non-living matter within a specific area	Desert, pond, forest, the human mouth
Biosphere	All of the living organisms on Earth	All bacteria, fungi, plant, and animal life on the Earth



http://upload.wikimedia.org/wikipedia/commons/thumb/3/38/Levels_of_Organization.svg/512px-Levels_of_Organization.svg.png

A disturbance, or disease, in the lowest level of the hierarchy can greatly impact the more complex levels. For example, hemophilia is a genetic disease that prevents the blood from clotting. The mistake occurs at the macromolecule level in DNA. This leads to a mistake in cells involved in blood clotting. If an individual is cut, blood loss can impede the function of organs, and therefore organ systems, which can lead to the death of the human body, or organism.

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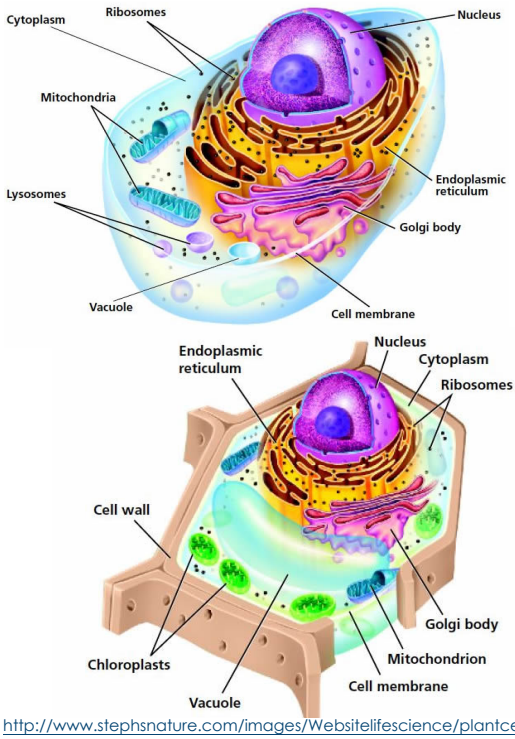
Cells

Cells are the smallest unit of life. All cells are capable of growth, use energy, reproduce, and respond to the environment. The simplest cells that were the first form of life on Earth are called **prokaryotes**. Prokaryotes are primarily bacteria and do not have a nucleus or membrane-bound organelles. More complex cells that contain a nucleus and membrane-bound organelles are called **eukaryotes**. Fungi, protists, plants, and animals are all eukaryotic organisms. Eukaryotic cells may have different organelles depending on their function and the type of organism in which they are found. For example, plant cells contain chloroplasts, while animal cells do not.

Some organisms, such as protists, are made up of only a single cell and are called **unicellular** organisms. Organisms that are made up of more than one type of cell working together, such as the human body, are **multicellular** organisms. In fact, a human adult body contains more than 100 trillion cells. Table 2 provides a description, image, and the types of cells in which some common organelles can be found.

Table 2. Common Organelles

Organelle	Function
Cell Membrane	Controls substances moving in/out of the cell
Cell Wall	Plants only; made of stiff cellulose that maintains cell shape
Chloroplast	Plants only; performs photosynthesis
Cytoplasm	Liquid substance that fills the cell; location where most chemical reactions occur
Cytoskeleton	Strengthens and supports cell shape
Endoplasmic Reticulum	Stores and carries materials throughout the cell; participates in protein synthesis
Golgi Apparatus	Modifies and transports proteins
Mitochondria	Perform cellular respiration
Nucleus	Contains and protects the DNA
Ribosomes	Location where protein synthesis occurs
Vacuole	Plants only; contains and stores water and other substances to maintain cell shape
Vesicles	Transport substances, such as proteins, through the cell



http://www.stephsnature.com/images/Websitelifescience/plantcell.jpg

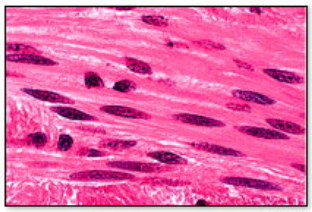
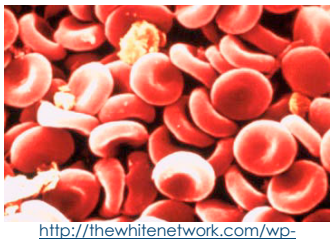
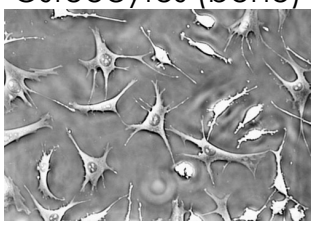
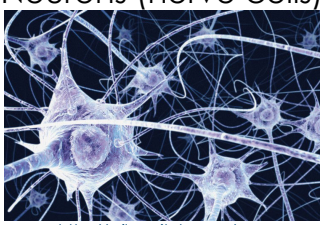
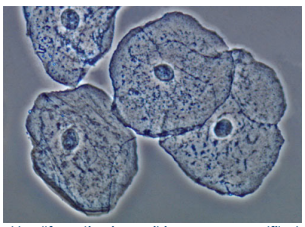
Cell Specialization or Differentiation

Why are not all cells within the human body exactly the same if they contain the same organelles and DNA? How and why is a muscle cell different from a brain cell when the instructions to create cells are the same? The answer is entirely about WHICH **genes**, or instructions, are used. If the DNA in all cells is thought of similar to a cookbook, different recipes within the book are used to create different cells. The recipe to make a chocolate cake contains different ingredients than a recipe for beef stew, even though both recipes are in the same cookbook. In the same way, the "recipe" to form a muscle cell is different than the "recipe" to form a brain cell. Cells can look and function differently, because only certain genes in a cell's DNA are used, or **expressed**, when those cells are formed.

Cell **specialization** or **differentiation** occurs when a less specialized cell, such as a stem cell, becomes a specialized cell, such as a red blood cell. Specialization occurs during the development of a multicellular organism and continues into adulthood. This is caused by a

highly complex system that controls when a gene should be expressed. The genes expressed will create different physical characteristics in the different cell types. Table 3 below summarizes a few examples of specialized cells within the human body and how structural features impact each cell type's function.

Table 3. Examples of Specialized Cells

Type of Cells	Function/Features	Type of Cells	Function/Features
Muscle cells  http://www.mhhe.com/biosci/esp/2001_saladin/folder_structure/su/m4/s13/assets/images/sum4s13_1.jpg	***Function to contract and move the body;*** Long and narrow, contain myosin and actin which are able to make the muscle cell shorten (contraction)	Red blood cells  http://thewhitenetwork.com/wp-content/uploads/2013/03/red-blood-cells.jpg	***Function to carry oxygen;*** Hemoglobin on the surface to bind oxygen and large surface area
Sperm cells  http://cdn-imgs-mag.aeon.co/images/2013/07/sperm.jpg	***Function to travel to and fertilize an egg;*** Head with enzymes to break into egg and long tail for travel	Osteocytes (bone)  https://vault.swri.org/cms/upload/cells_500pixels.jpg	***Function to build and shape bone;*** Contain proteins capable of building and breaking down minerals surrounding them
Neurons (nerve cells)  http://wileywitch.com/wp-content/uploads/2013/02/173_neurons.jpg	***Function to relay messages through the body;*** Long and narrow with strands to form connections with other neurons	Skin cells  http://cellfunctioning.wikispaces.com/file/view/cheekcells.jpg/210933652/cheekcells.jpg	***Function to form a protective layer;*** Flat shape and containing massive amounts of keratin that form a protective outer layer as the skin cell dies

Tissues & Organs

A tissue is made up of a group of cells that work together to perform a specific function. The study of tissues is called histology. The tissues of the human body are grouped into four types based on function:

- ***Connective tissue*** – provides shape and support
- ***Muscle tissue*** – capable of contraction and producing movement
- ***Nervous tissue*** – capable of passing impulses, or messages
- ***Epithelial tissue*** – provides covering and protection

An organ is made up of a group of tissues that work together to perform a specific function. There are approximately 78 organs in the human body. A few examples of organs found in the human body, along with their functions, include:

- ***Kidneys*** – regulate water levels and remove waste products from the blood
- ***Heart*** – pumps blood throughout the body
- ***Stomach*** – digestion
- ***Skin*** – protection

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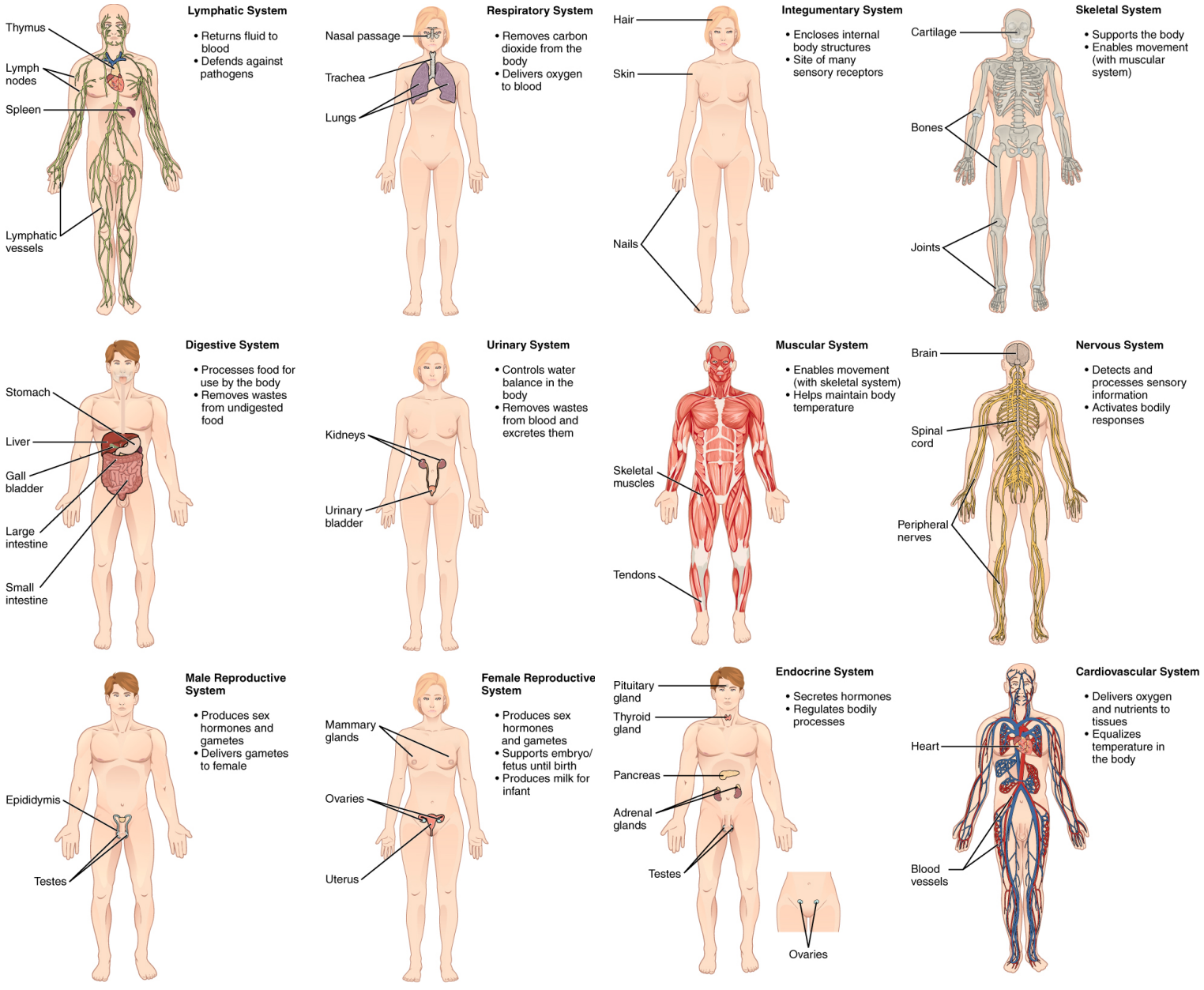
Human Organ Systems

Organ systems are made up of a group of organs that work together to perform a specific function. Most of these organ systems overlap, and the health of one system can greatly impact the health of the other organ systems in the human body. The diagrams below show the organ systems found in the human body.

Organ Systems of the Human Body



http://upload.wikimedia.org/wikipedia/commons/d/d8/Organ_Systems_I.jpg

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Disease: Imbalance in the System

Diseases are abnormal conditions that affect an organism. In terms of the organ systems, disease creates an imbalance in cells, tissues, or organs that can result in an inability of an organ system to function properly, or not at all. When this happens, it more often than not creates a domino effect that results in imbalances in multiple organ systems throughout the body. This is the reason that signs and symptoms of diseases are often found system-wide. Treating and correcting the imbalance in the original system affected will often correct the imbalances, and cure the symptoms, in the other organ systems.

For example, the Human Immunodeficiency Virus (HIV) is a virus that only infects white blood cells in the immune system. White blood cells are responsible for protecting and providing immunity to the human body from outside sources. Once HIV has destroyed a large number of white blood cells, creating an imbalance in the immune system, symptoms begin to appear in other organ systems that eventually lead to death. For example, these symptoms can appear in the following organ systems in cases of advanced HIV infection:

- **Digestive system** – painful swallowing, weight loss, fatigue, severe and persistent diarrhea, nausea, vomiting
- **Respiratory system** – persistent cough, shortness of breath, respiratory infections
- **Integumentary system** – skin rashes, flaky skin, persistent cold sores
- **Nervous system** – short-term memory loss, confusion, seizures, lack of coordination, vision loss, severe headaches

Review Questions *– answer questions on a separate sheet of paper*

1. Why do you think it is important for scientists to organize life into a hierarchy for study?
2. What is the difference between an atom, molecule, and macromolecule? Give an example of each.
3. How are cells, tissues, and organs related to one another? Give an example of each.
4. How are populations, communities, and ecosystems related to one another? Give an example of each.
5. Explain how a disturbance in a lower level of the life hierarchy organization, a cell for example, can impact the higher levels, a population for example.
6. Compare and contrast prokaryotes and eukaryotes. Give an example of each.
7. Why are there many different cell types in the human body if they all contain identical DNA?
8. Describe cell specialization. Why is it important that cells are able to specialize?
9. Compare and contrast the structure and function of a neuron and a red blood cell. How do their structures allow them to perform their functions?
10. What are the four types of tissues found in the human body? How are they classified?
11. Give an example of three organs that can be found in the human body and their functions.
12. What is an organ system? Choose one of the organ systems and list the organs that belong to that system, as well as the system's function.
13. What are diseases? How can a disease create symptoms in multiple organ systems? Give an example.

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Scenario

Diseases that affect specific cells or tissues often create symptoms that impact many other body systems. For this reason, it is important to look at symptoms, cell and tissue samples (pathology), and to perform additional tests to determine the specific cause of a disease.

You and your partner are members of the HASPI Hope Hospital team. You have five patients today that have not yet been diagnosed, and must be before they can be treated. Spend time looking through each patient's symptoms, pathology images, and test results to determine what disease may be causing each patient's illness.

Materials

Patient 1001
Normal stomach image
Patient 1001 stomach image
Patient stool sample
Fecal occult test sheet
Q-tip
Paper towels

Patient 2002
Normal lung image
Patient 2002 lung image
Patient 2002 fluid sample
Infectious disease test
Test tube
Paper towels

Patient 3003
Normal bone marrow image
Patient 3003 bone marrow image
Patient CBC image

Patient 4004
Normal brain image
Patient 4004 brain image
Patient CSF sample
Bacteria load test
Test tube
Paper towels

Patient 5005
Normal blood image
Patient 5005 blood image
Patient oxygen saturation test results

Procedure/Directions

	Task	Response
1	Find a partner.	a. Who is your partner?
2	This is a station lab. There are 5 patients placed throughout the room.	b. Why is it important to have a correct diagnosis?
3	Choose a patient and follow the instructions at each station to diagnose the patient. Each station should take approximately 10-15 minutes to complete.	
4	Answer the questions for each station using the lab answer sheet.	c. Hypothesize why a disease that affects one system can cause symptoms in other body systems.

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Connections & Applications

Your instructor may assign or allow you to choose any of the following activities. As per NGSS/CCSS, these extensions allow students to explore outside activities recommended by the standards.

1. **RESEARCH DISEASE SYMPTOMS:** Choose one of the following diseases and use the Internet to research and answer the questions. Create an informational newsletter OR brochure on your disease, including the answers. Use a minimum of 2-3 images or graphs associated with your disease. Cite all of your sources.

Disease Choices	Questions
Cerebral palsy Diabetes Diverticulitis Endometriosis Lymphatic filariasis Meningitis MRSA Tetanus Tuberculosis Rabies	a. What is/are the cause(s) of this disease? b. What are the signs and symptoms? c. Specifically which cells AND tissues does this disease affect and HOW does it affect them? *Be prepared to do some serious research for this question!* d. What organ systems can this disease affect and HOW does it affect them? e. How is it diagnosed and what are the treatment options?

2. **CREATE A MODEL OF AN ORGAN SYSTEM:** Develop a model to illustrate the hierarchical organization and interaction of the cells, tissues, and organs in a human organ system of your choice. Provide a title and a description of the organ system's function somewhere on your model. Your model must include:
    a. At least THREE cells that can be found in the organ system
    b. At least THREE tissues that can be found in the organ system
    c. ALL of the organs that can be found in the organ system

   Suggestions for media to create your model include freehand drawing, Play-doh, modeling clay, food/candy, or basic craft supplies. Before you construct your model, check with your teacher to ensure that your media choice is appropriate and realistic.

3. **BECOME AN ORGAN SYSTEM EXPERT:** Choose and research a body system. Create a website with textual, graphical, audio, visual, and interactive elements. There are many sites, such as www.webs.com that host free websites. The website can be set-up however you would like, but must include the following information:
    a. An image, description, and the function of a minimum of 5 cell types that can be found within the organ system
    b. An image, description, and the function of all of the tissues that can be found within the organ system
    c. An image, description, and the function of all of the organs that can be found within the organ system
    d. A description, causes, and symptoms of a minimum of 3 diseases that can affect the organ system
    e. Embed at least one video or animation pertaining to the organ system

Resources & References

- *NIH. 2013. How Genes Work. NIH, National Institute of Health, National Institute of General Medical Sciences – Basic Discoveries for Better Health; http://www.nigms.nih.gov/.*

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