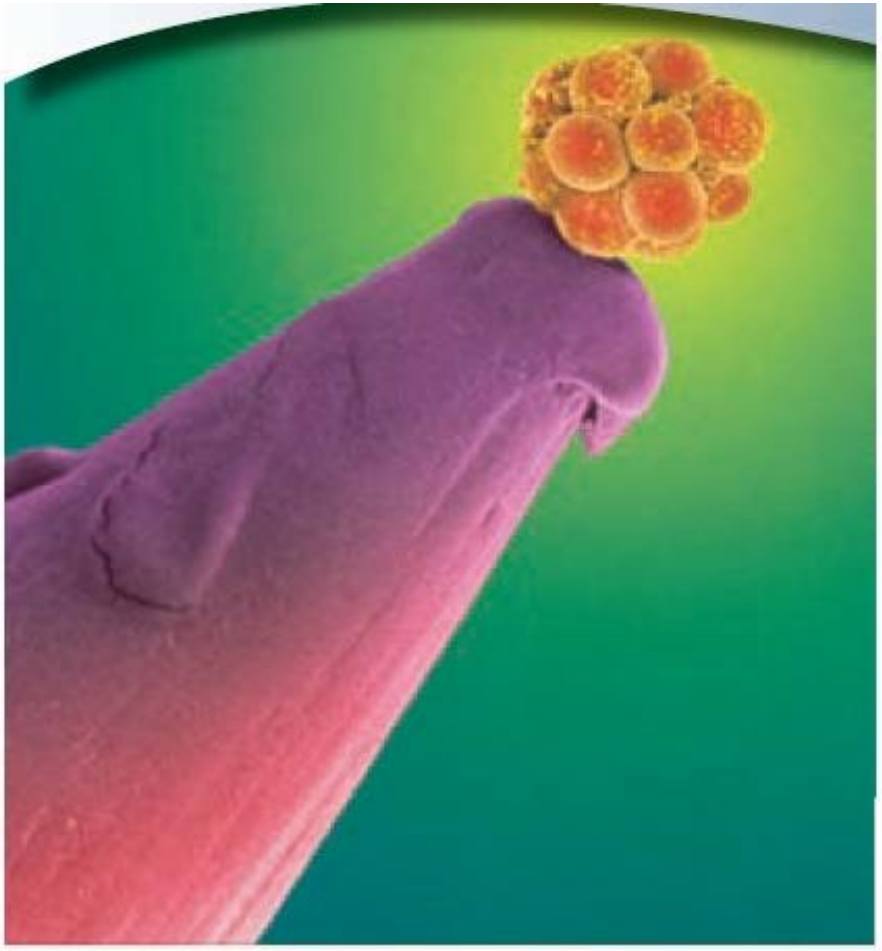
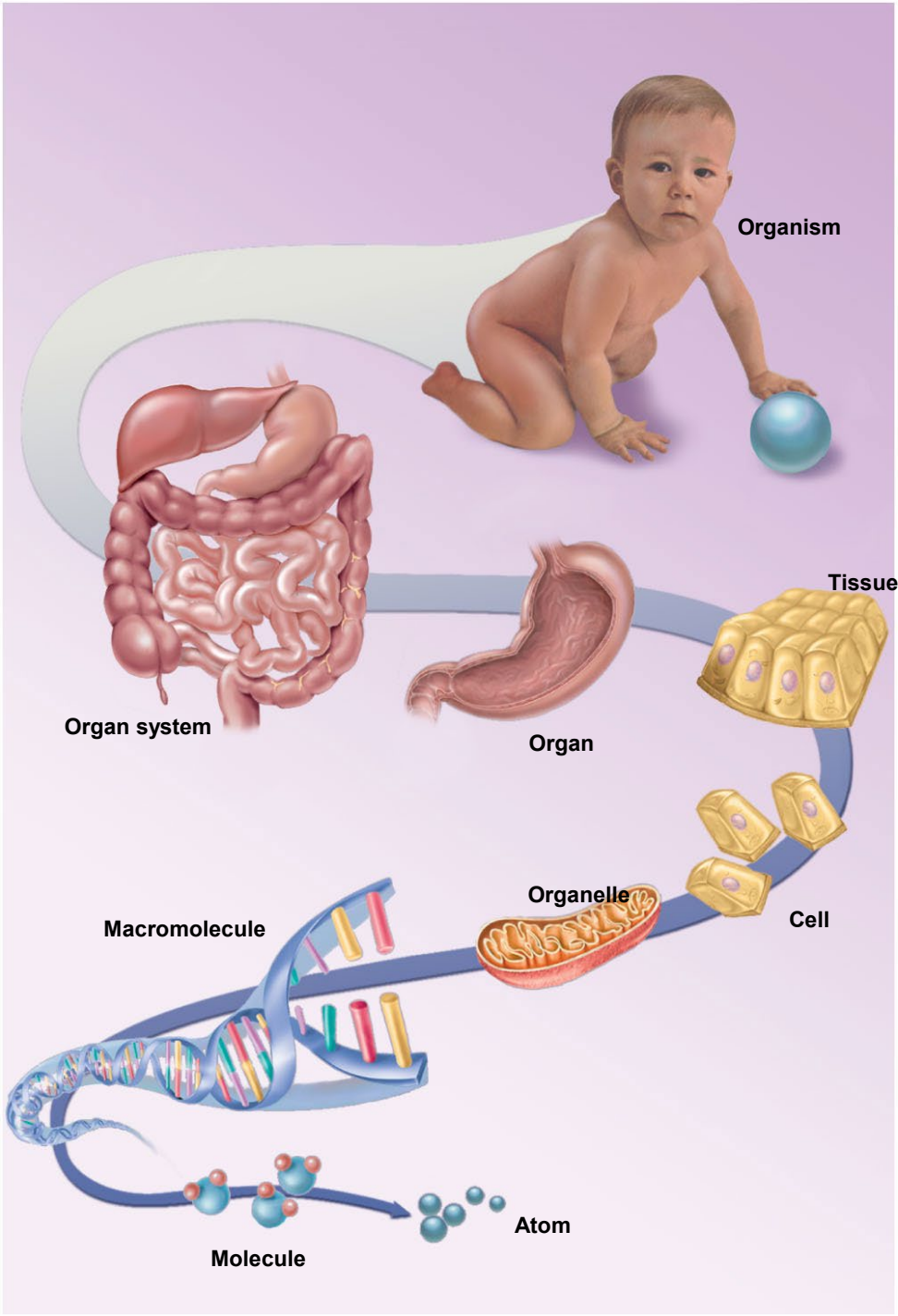
Chapter 1

Major Themes in A/P



Major Themes of Anatomy and Physiology

- Form and Function
- The Scientific Method
- Hierarchy of Complexity
- Homeostasis
- Regulation of Homeostasis
- Components of a Feedback Loop



Anatomy - The Study of Form (Structure)

Examining structure of the Human Body

–inspection

–palpation

–auscultation

–percussion

Cadaver dissection

–cutting and separation of tissues to reveal their relationships

Comparative anatomy

–study of more than one species in order to examine structural similarities and differences

–analyze evolutionary trends

Anatomy - The Study of Form

Gross Anatomy

–study of structures that can be seen with the naked eye

Cytology

–study of structure and function of cells

Histology (microscopic anatomy)

–examination of tissue with microscope

Ultrastructure

–the molecular detail seen in electron microscope

Histopathology

–microscopic examination of tissues for signs of disease

Physiology - The Study of Function

Subdisciplines

–neurophysiology (physiology of nervous system)
–endocrinology (physiology of hormones)
–pathophysiology (mechanisms of disease)

Comparative Physiology

–limitations on human experimentation
–study of different species to learn about bodily function
- animal surgery
- animal drug tests

–basis for the development of new drugs and medical procedures

Scientific Method

Francis Bacon, in England, and **Rene Descartes,** in France

These philosophers invented new habits of scientific thought in 1600s

Looked for a systematic way of seeking similarities, differences, and trends in nature

Wanted to drawing useful generalizations from observable facts

This is how we solve problems.

This is how we find the truth.

What is the purpose of science? Find truth!

The Scientific Method

A Proof in Science Requires

– reliable observations
– tested and confirmation // repeated by peers
– not falsified by any credible observation

In science, all truth is tentative // "proof beyond a reasonable doubt" // as new evidence is verified, the truth may change!

Falsifiability // if we claim something is scientifically true, then we must be able to specify what evidence it would take to prove it wrong

Scientific Method's Goal is to set standards for truth

Two Different Approaches to the Scientific Method (See Next Slide)

Inductive Method VS Hypothetico-Deductive Method

Inductive Method by making numerous observations until one becomes confident in drawing generalizations and predictions from them // knowledge of anatomy obtained by this method

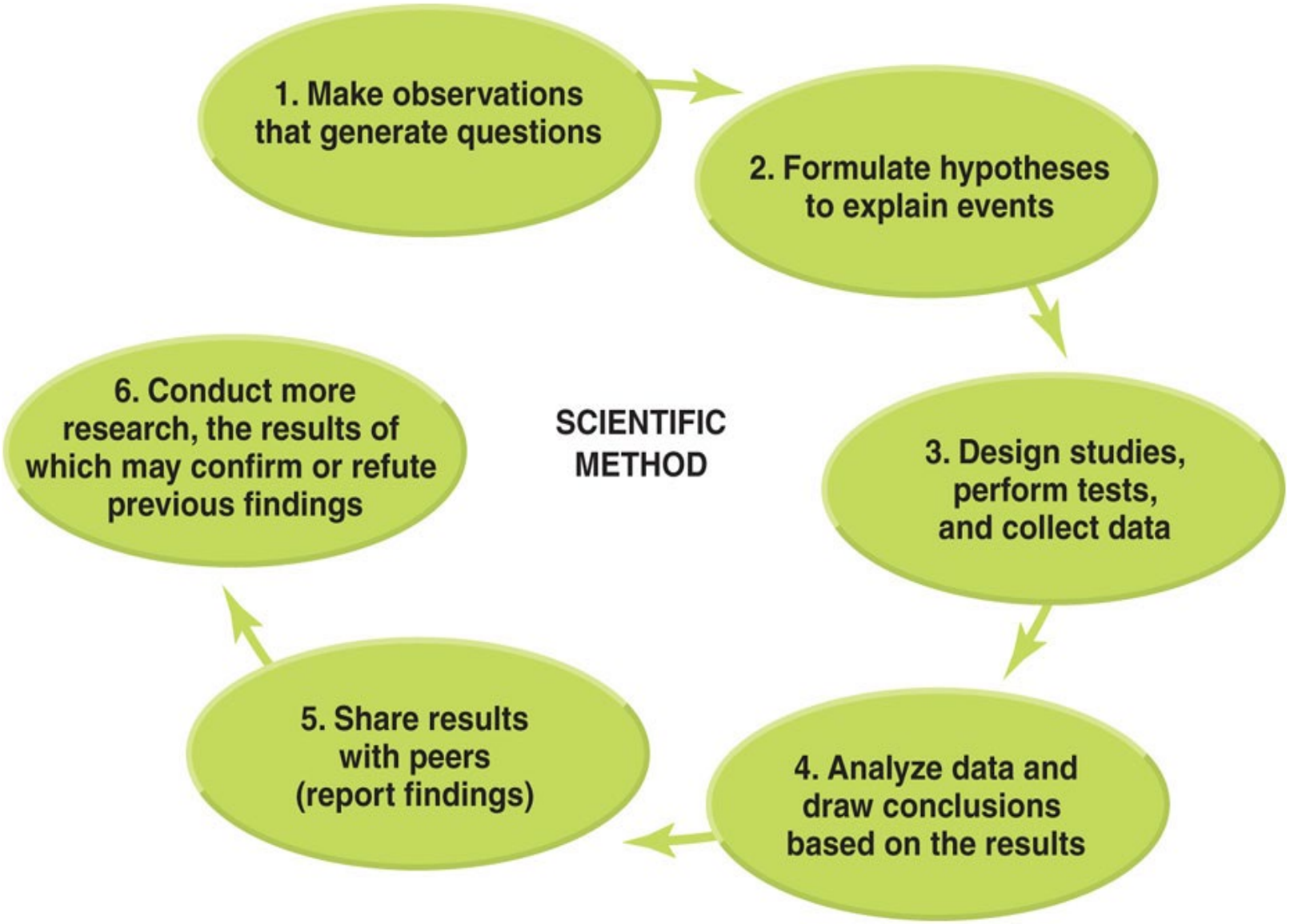
Deductive Method (Hypothetico-Deductive Method) finds truth by investigator's observation which leads to a question, speculation, or possible answer to the question, this results in a hypothesis.

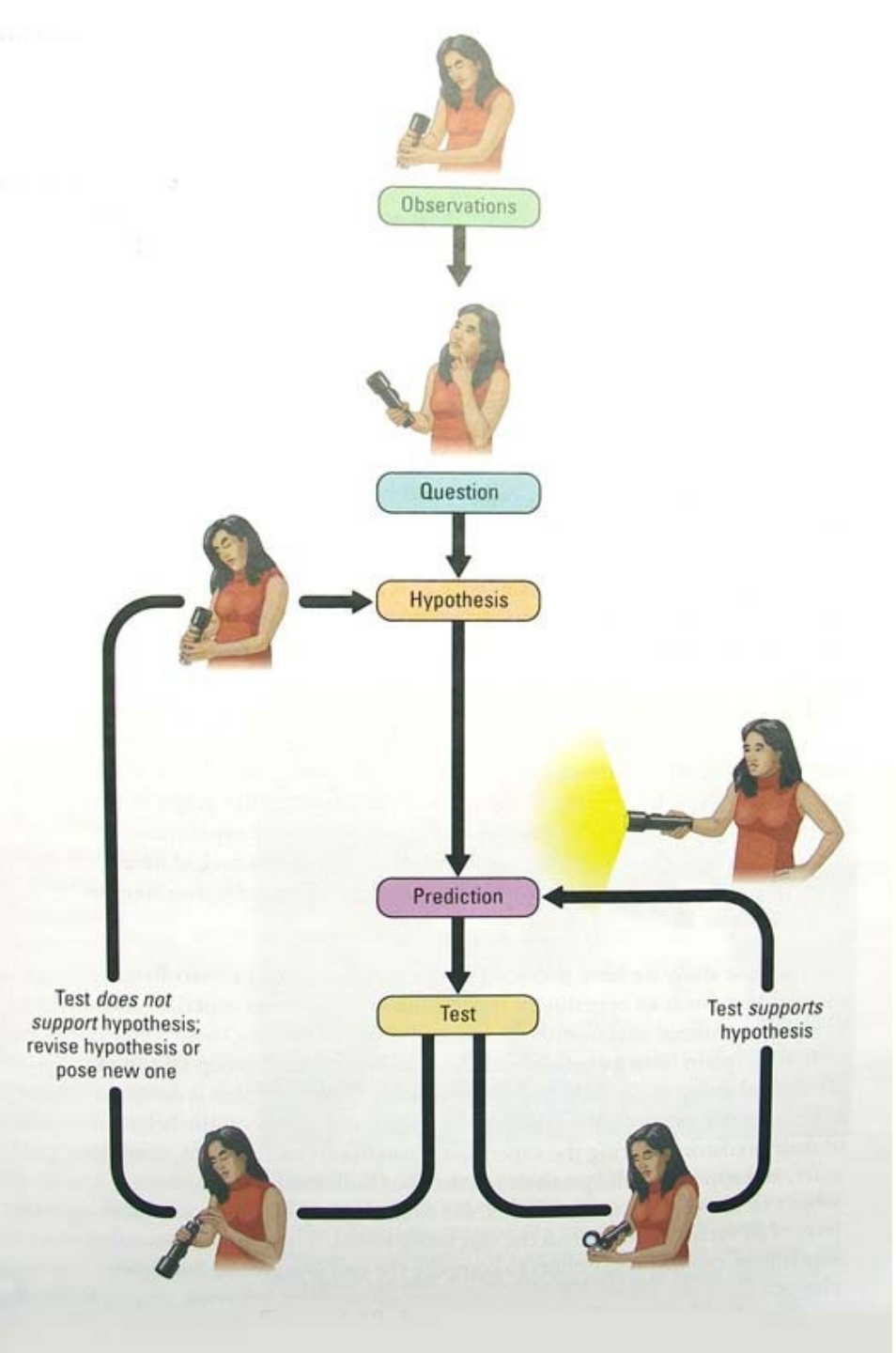
The hypothesis is written as an "If-Then Statement"

The hypothesis is nicknamed an educated guess

Physiological knowledge is discovered by using the deductive - hypothetico method.

Scientific Method / Deductive Method





Observation: My flashlight doesn't work.

Question: What's wrong with my flashlight?

Hypothesis: The flashlight's batteries are dead.

Prediction: If I replace the batteries, the flashlight will work

Experiment: I replace the batteries with new ones.

Predicted Effect: The flashlight should work.

But it did not! So, did the experiment proved something? Yes. The experiment had value. What is the next step? Make another hypothesis then test the hypothesis!

Different Perspectives on How to Investigate Science

Reductionism

- complex system can be understood by studying its simpler components
- first espoused by Aristotle
- highly productive approach
- essential to scientific thinking

Holism

- there are ‘emergent properties’ of the whole organism
- cannot be predicted from the properties of the separate parts
- humans are more than the sum of their parts
- complementary theory to reductionism

Facts, Laws, Hypothesis, and Theories

Scientific facts // observations about the world around us // information that can be independently verified // eg. It is bright outside during the day - fact

Law of nature // statement based on repeated experimental observations that describes some phenomenon of nature (gravity) // describe the events using mathematics // results from inductive reasoning and repeated observation // law **tells us how** but not why something happens

Hypothesis // a possible explanation for a phenomenon made as a starting point for further investigation // an educated guess to be tested // consistent with what is already known // testable and must be falsifiable with evidence

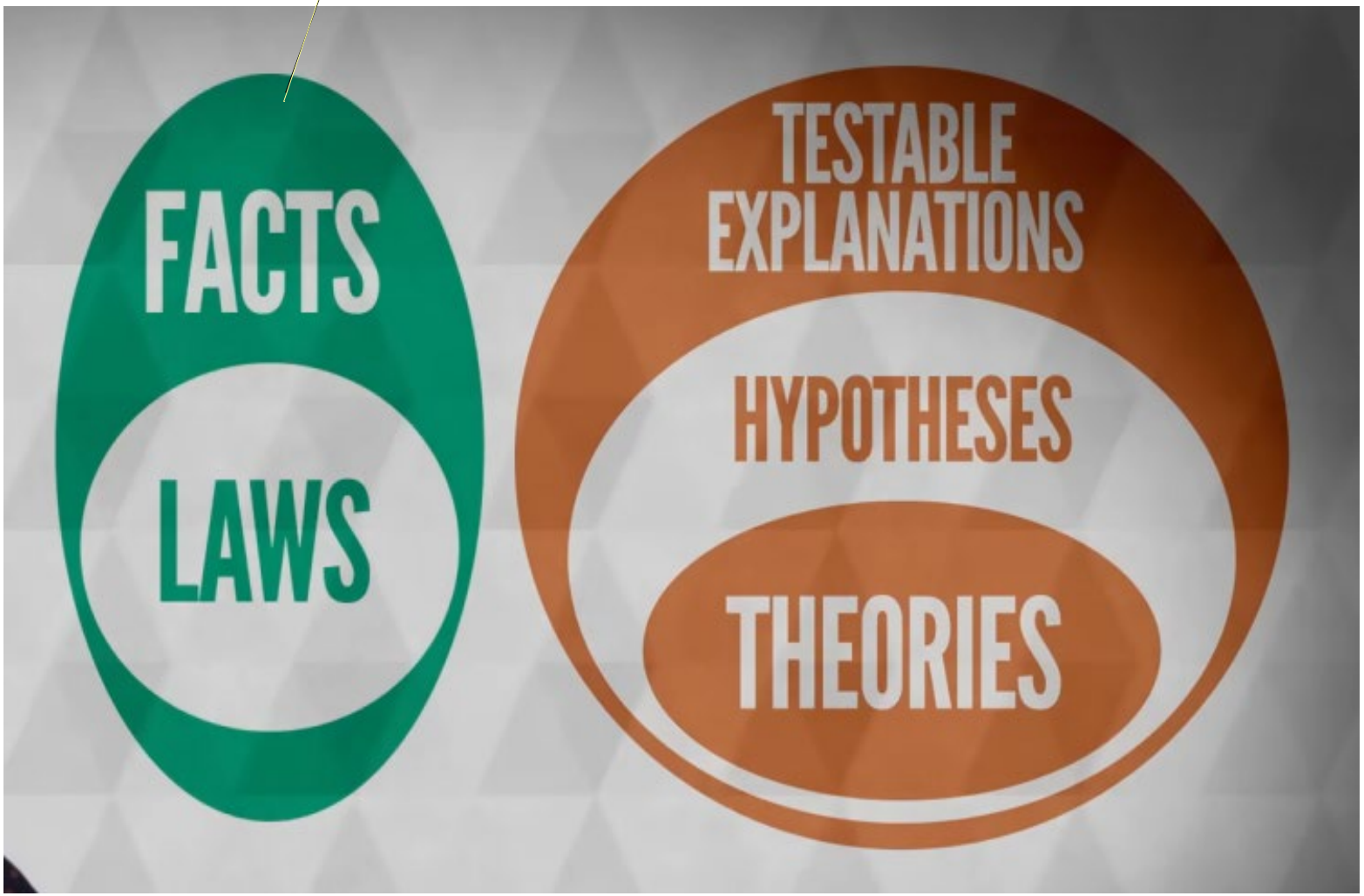
Facts, Laws, Hypothesis, and Theories

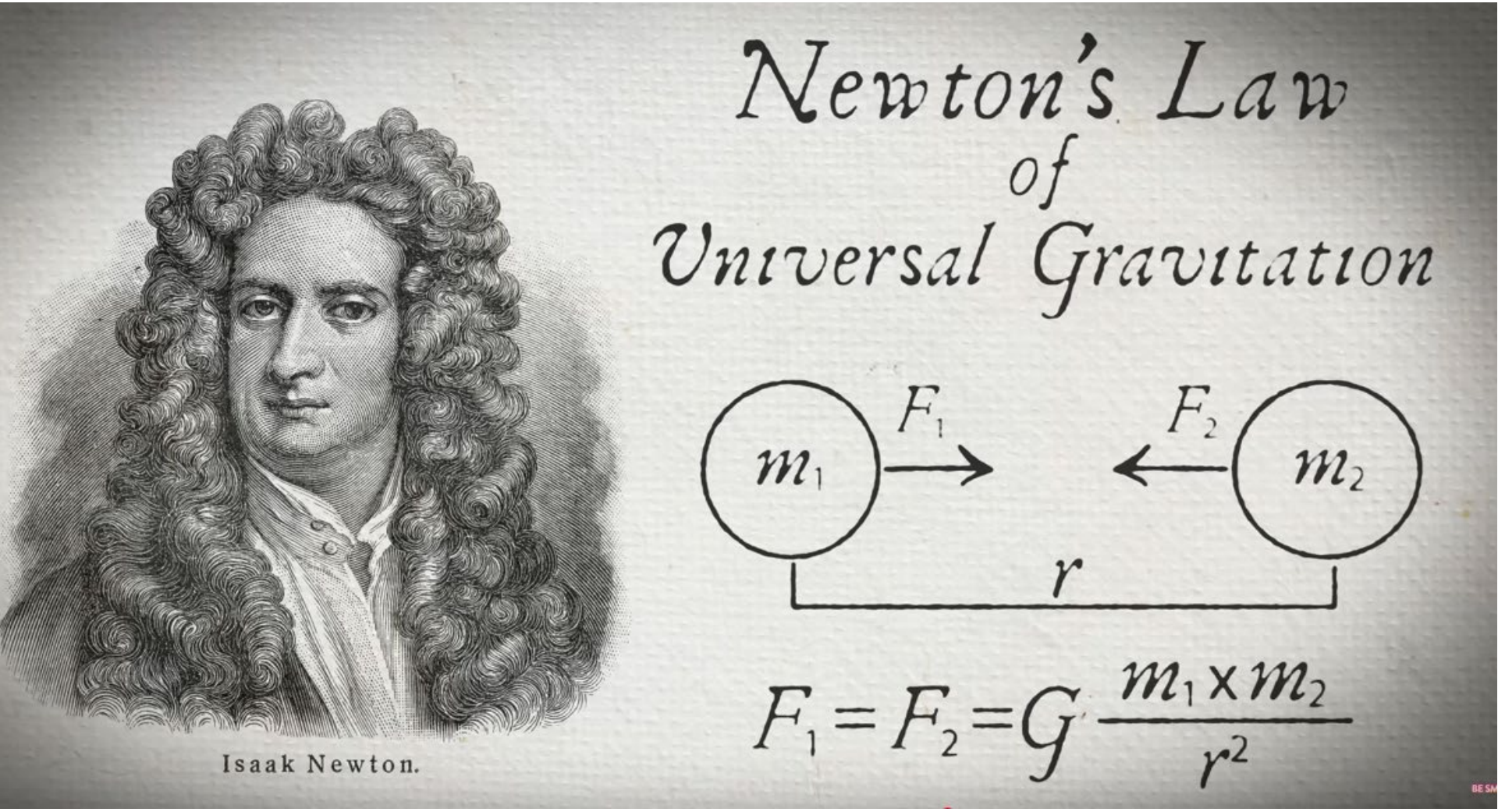
Theory // a well-substantiated explanation acquired through the scientific method /// repeatedly tested and confirmed through observations and experimentation /// an explanatory statement or set of statements *derived from facts, laws, and confirmed hypotheses*

- tells us how and why something happened
- most comprehensive understanding on specific topic
- used to suggests direction for further study
- may use theory to make "predictions"
- gravity is both a law and a theory!

*E*volution is a law, but natural selection is a theory because it explains how evolution occurred.

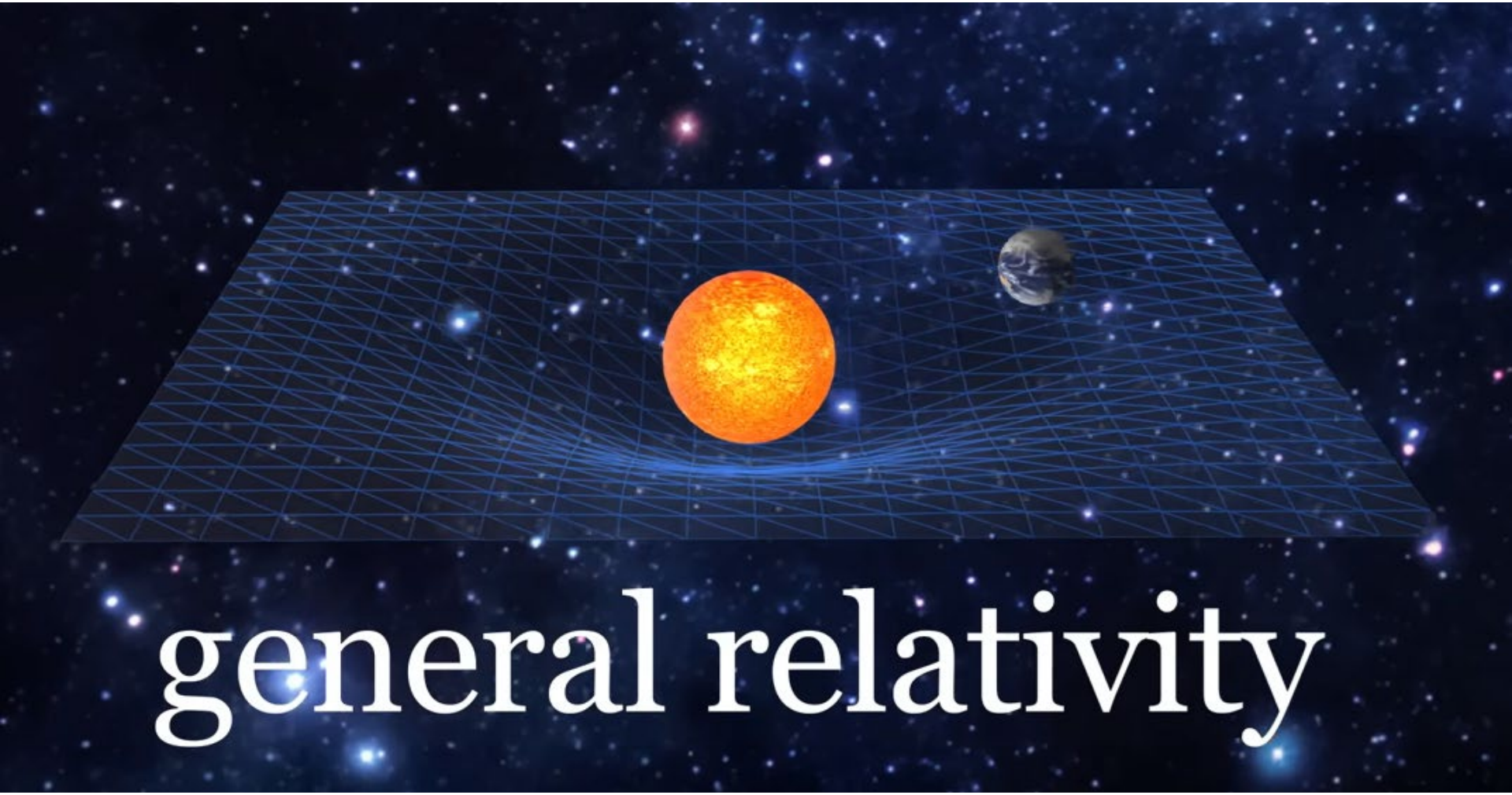
Start With An Observation





Gravity is a law.

General Relativity Is Einstein's Theory of Gravity



Einstein tells us how gravity works. Gravity is both a law and a theory!

A theory may change if new scientific hypothesis are proven!

People who do not study science often misuse common scientific terms. This includes our policy-makers. This ignorance often makes communication between scientist and policy makers confusing which then results in bad public policy.

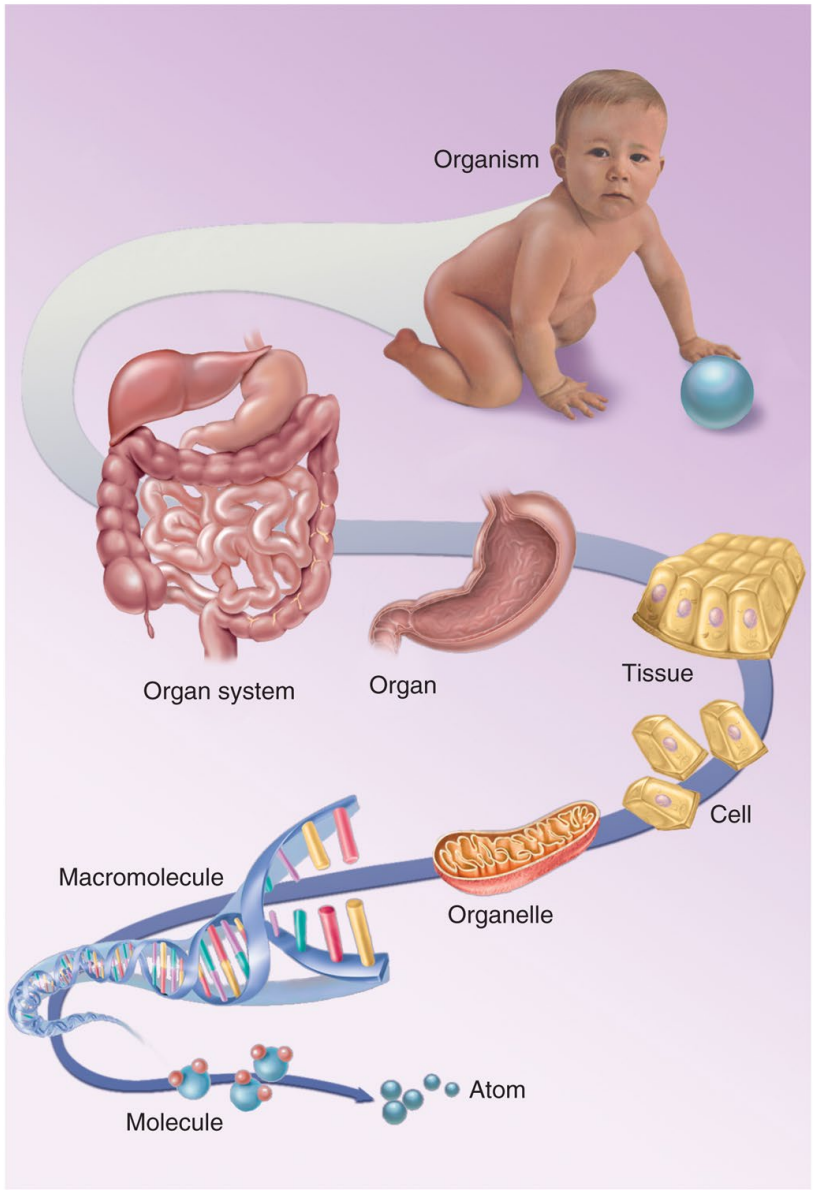
Case Study

What is Evolution?

Is it a hypothesis or a theory?

What is Creationism? (science or belief system)

Hierarchy of Complexity



Hierarchy of Complexity

Organism – a single, complete individual

Organ System – human body made of 11 organ systems

Organ – structure composed of two or more tissue types that work together to carry out a particular function

Tissue – a mass of similar cells and cell products that form discrete region of an organ and performs a specific function // connective tissue, nervous tissue, muscle tissue, and epithelial tissue

Cells – the smallest units of an organism that carry out all the basic functions of life // Four cell types (connective cells, nervous cells, muscle cells, and epithelial cells.

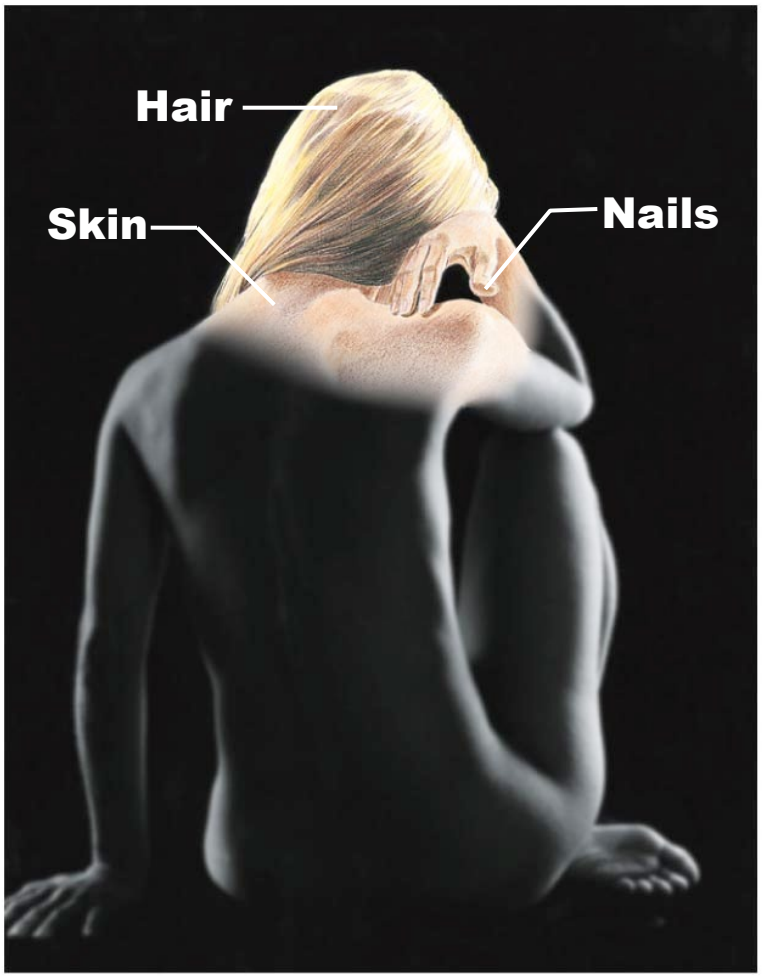
Organelles – microscopic structures in a cell that carry out its individual functions

Macromolecules – proteins, carbohydrates, fats, DNA

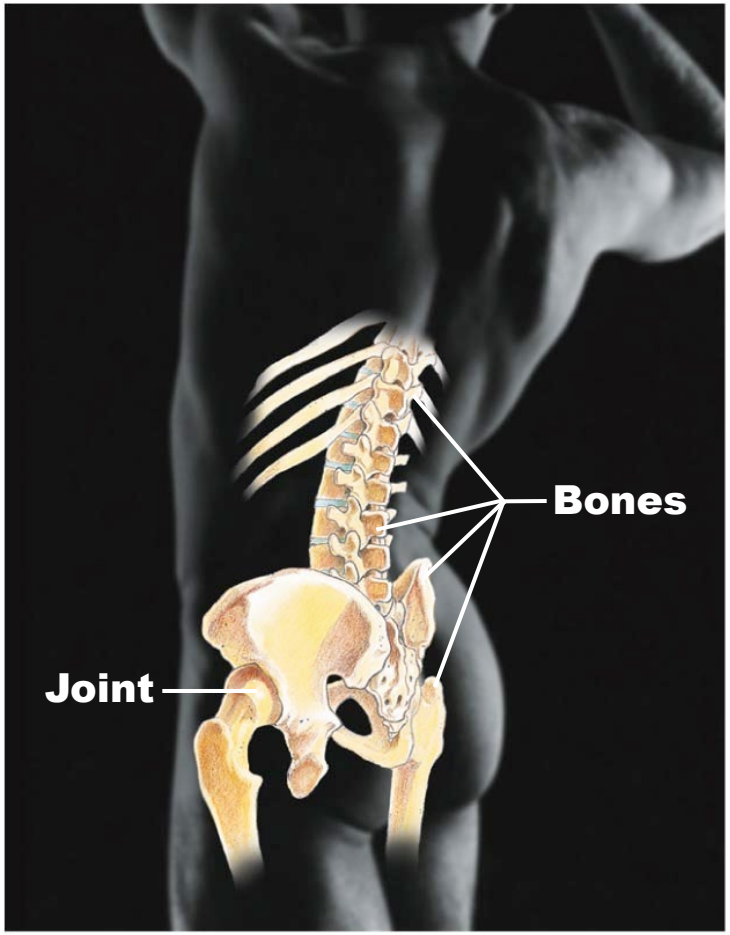
Molecules – make up organelles and other cellular components

Atoms – the smallest particles of matter with unique chemical identities

Here are the eleven systems of the human body and their functions.

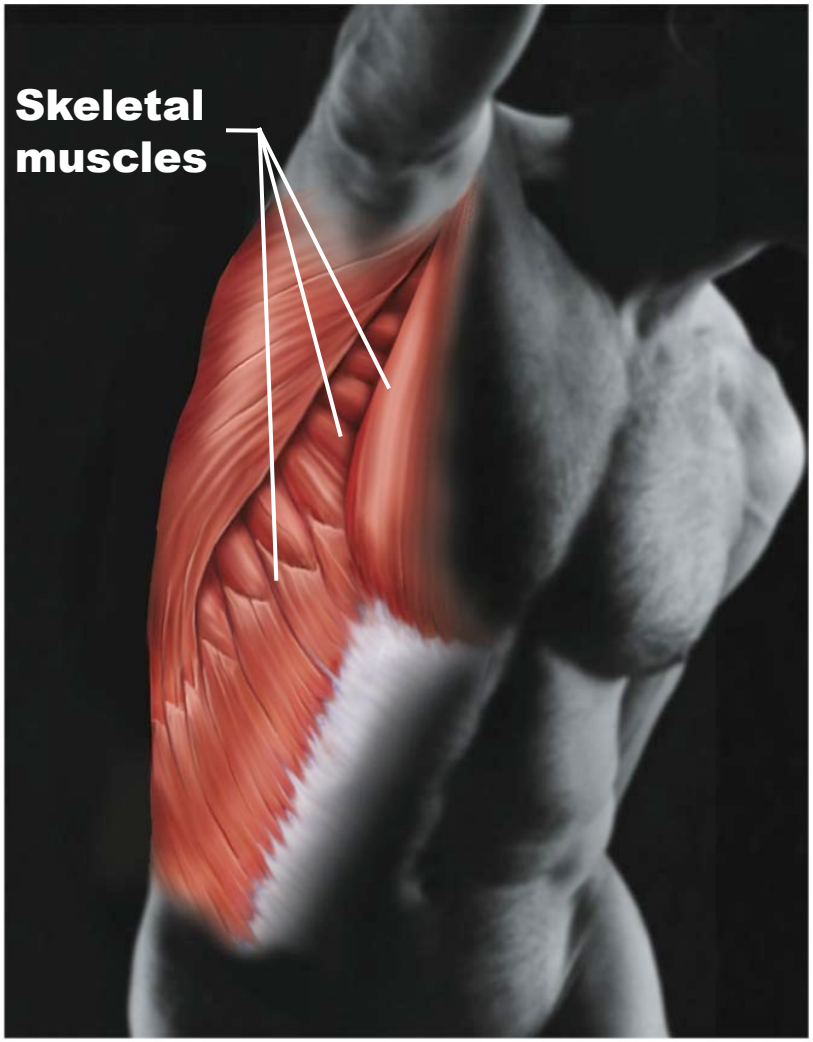


(a) Integumentary System
Forms the external body covering, and protects deeper tissues from injury. Synthesizes vitamin D, and houses cutaneous (pain, pressure, etc.) receptors and sweat and oil glands.



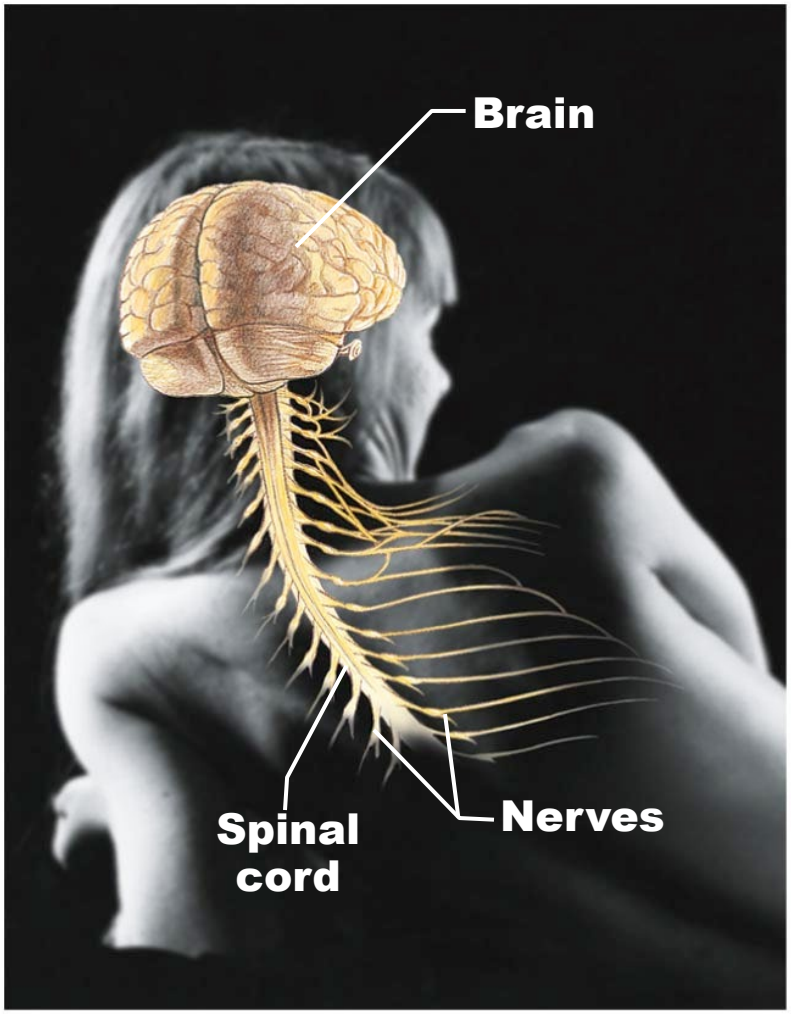
(b) Skeletal System

Protects and supports body organs, and provides a framework the muscles use to cause movement. Blood cells are formed within bones. Bones store minerals.



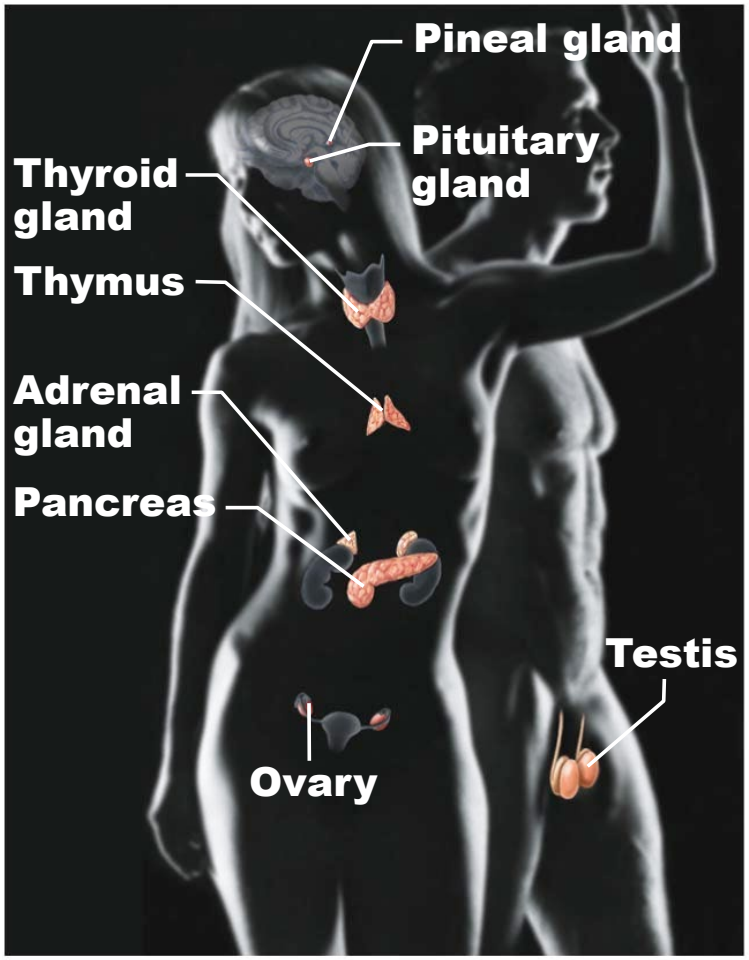
(c) Muscular System

Allows manipulation of the environment, locomotion, and facial expression.
Maintains posture, and produces heat.

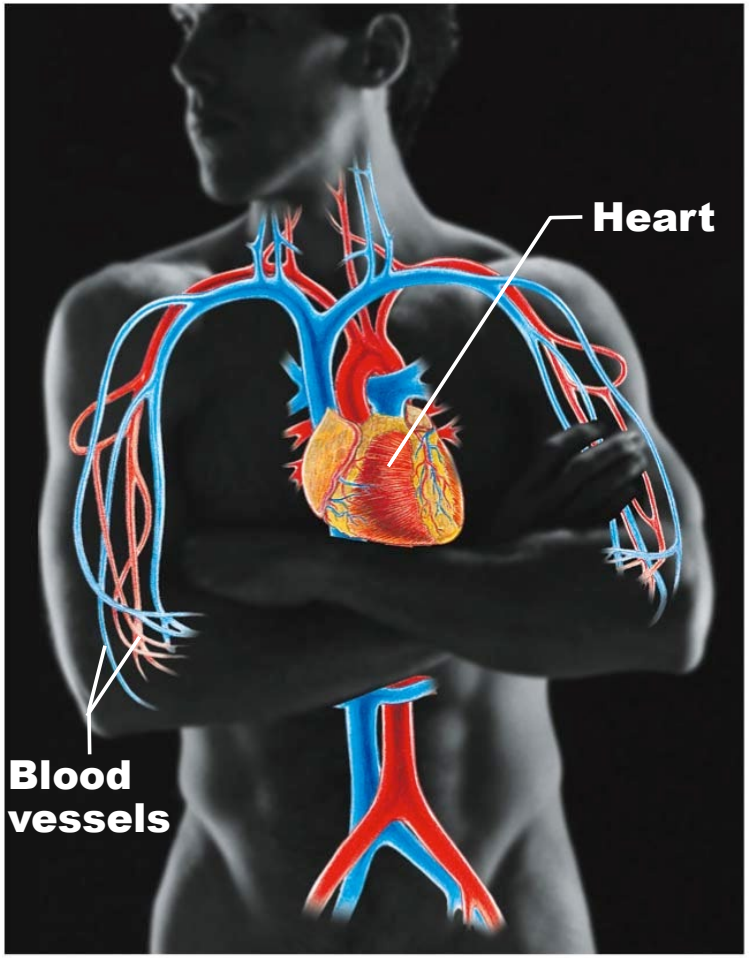


(d) Nervous System

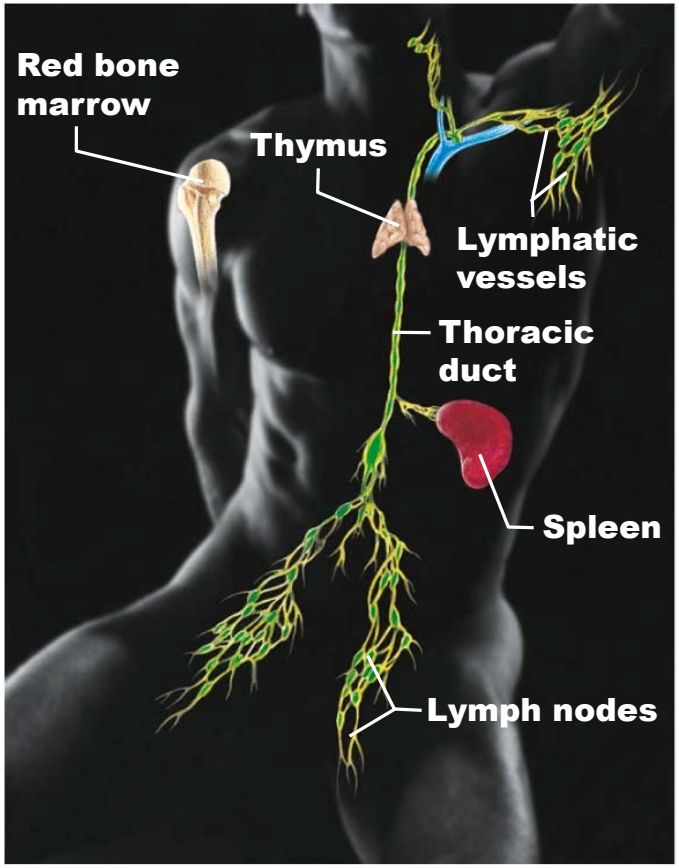
As the fast-acting control system of the body, it responds to internal and external changes by activating appropriate muscles and glands.



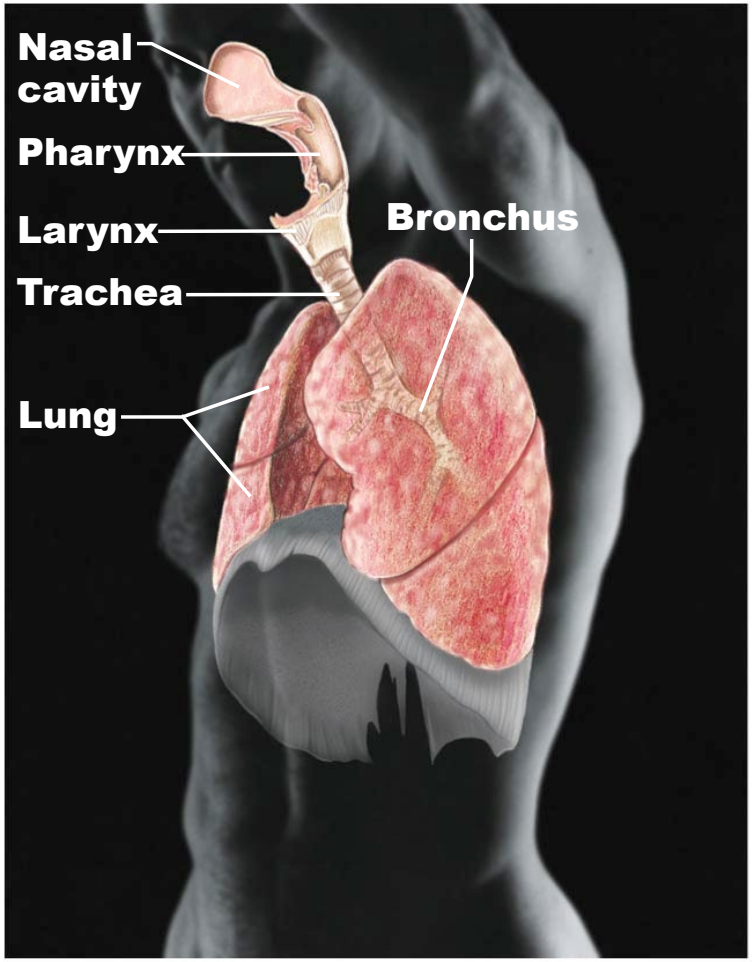
(e) Endocrine System
Glands secrete hormones that regulate processes such as growth, reproduction, and nutrient use (metabolism) by body cells.



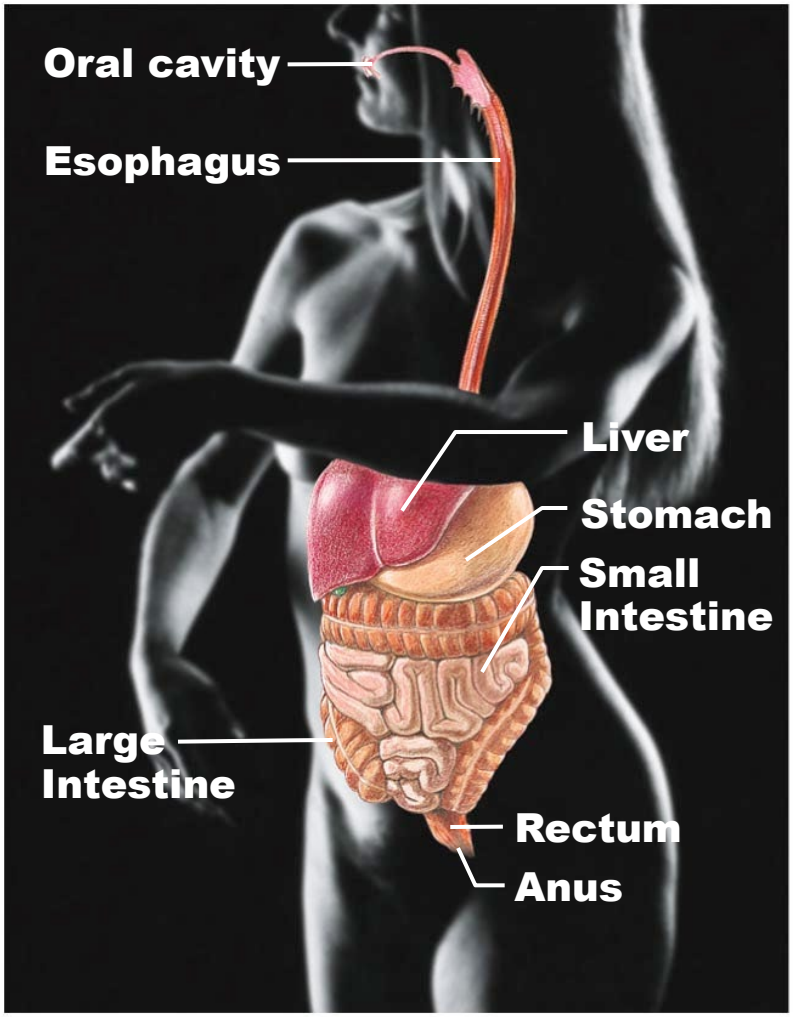
(f) Cardiovascular System
Blood vessels transport blood, which carries oxygen, carbon dioxide, nutrients, wastes, etc. The heart pumps blood.



(g) Lymphatic System/Immunity
Picks up fluid leaked from blood vessels and returns it to blood. Disposes of debris in the lymphatic stream. Houses white blood cells (lymphocytes) involved in immunity. The immune response mounts the attack against foreign substances within the body.

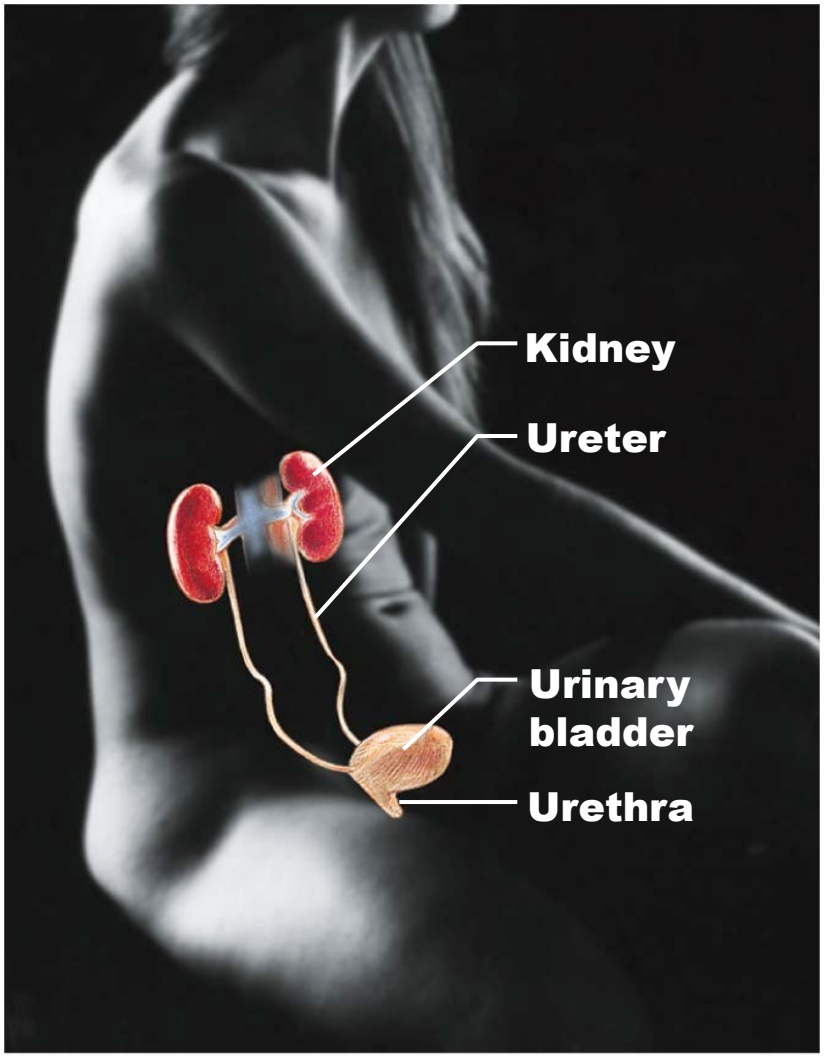


(h) Respiratory System
Keeps blood constantly supplied with oxygen and removes carbon dioxide. The gaseous exchanges occur through the walls of the air sacs of the lungs.



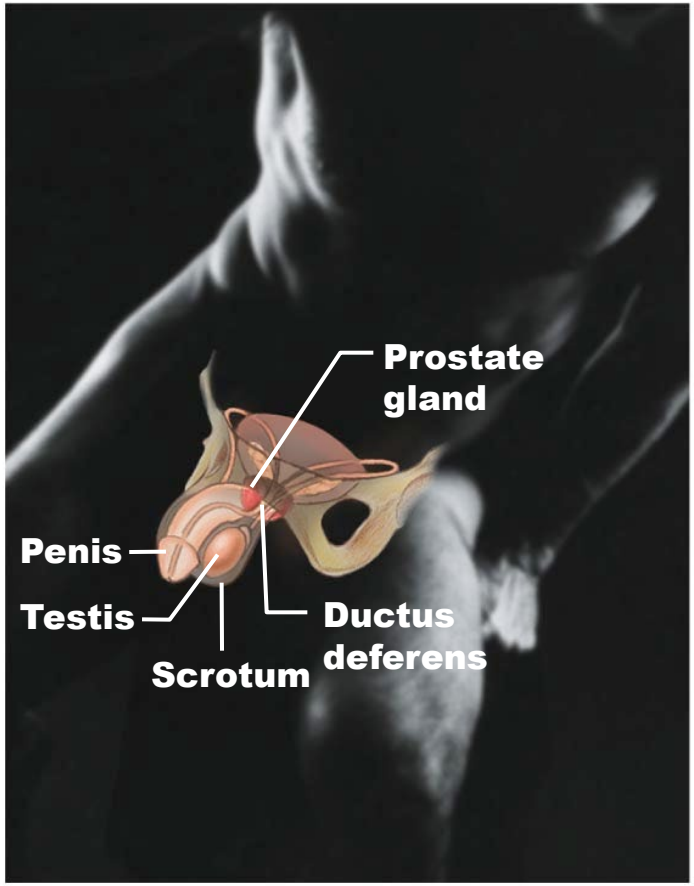
(i) Digestive System

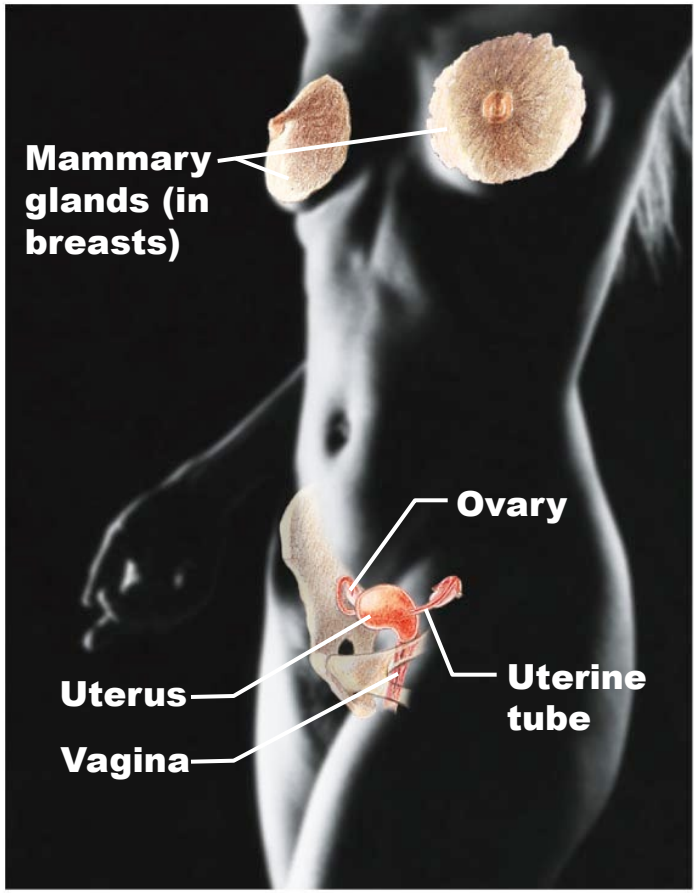
Breaks down food into absorbable units that enter the blood for distribution to body cells. Indigestible foodstuffs are eliminated as feces.



(j) Urinary System

Eliminates nitrogenous wastes from the body. Regulates water, electrolyte and acid-base balance of the blood.





(k) Male Reproductive System
Overall function is production of offspring. Testes produce sperm and male sex hormone, and male ducts and glands aid in delivery of sperm to the female reproductive tract. Ovaries produce eggs and female sex hormones. The remaining female structures serve as sites for fertilization and development of the fetus. Mammary glands of female breasts produce milk to nourish the newborn.

(l) Female Reproductive System
Overall function is production of offspring. Testes produce sperm and male sex hormone, and male ducts and glands aid in delivery of sperm to the female reproductive tract. Ovaries produce eggs and female sex hormones. The remaining female structures serve as sites for fertilization and development of the fetus. Mammary glands of female breasts produce milk to nourish the newborn.

Homeostasis

Homeostasis – the body's ability to detect change, activate mechanisms that oppose it, and thereby maintain a relatively stable internal environment around our cells.

Claude Bernard (1813-78)

Recognized constant internal conditions regardless of external conditions /// internal body temperature ranges from 97 to 99 degrees F (38 C) despite variations in external temperature

Walter Cannon (1871-1945)

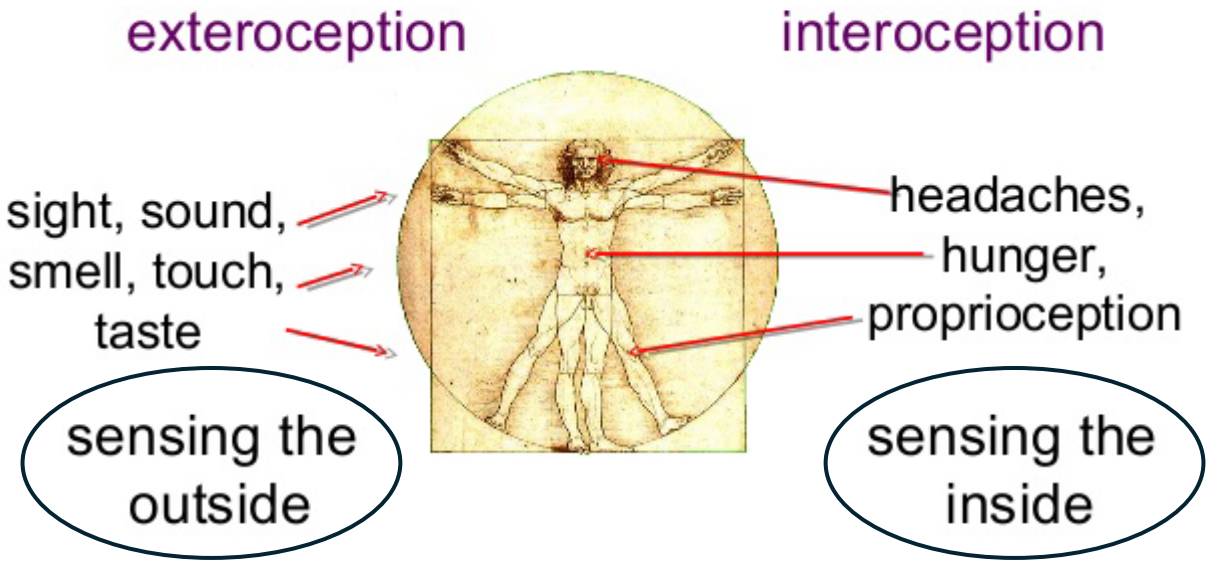
Coined the term '**Homeostasis and said that** the body fluctuates (**dynamic equilibrium**) within limited range around a **set point**

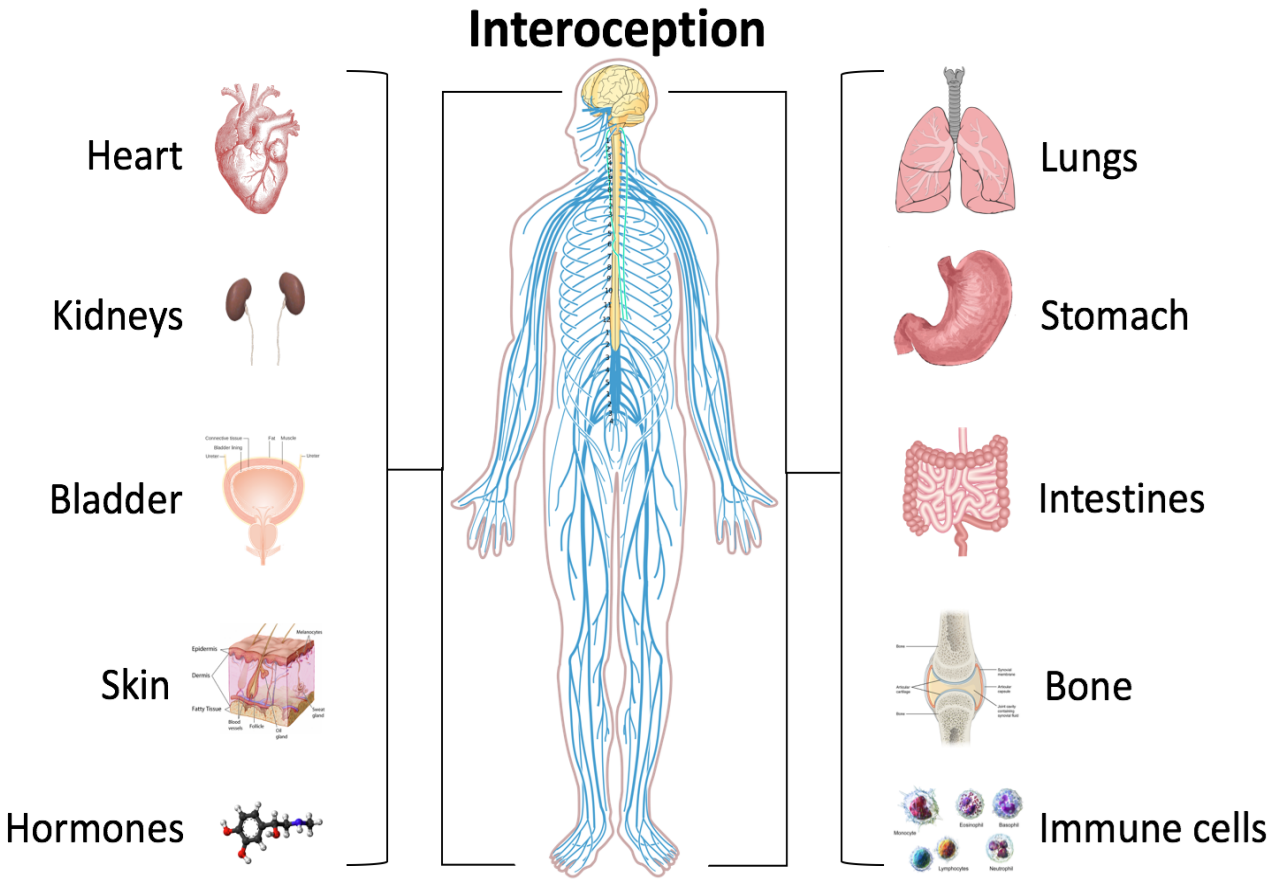
Homeostasis is the "foundation of medicine".

Loss of homeostasis causes illness and/or death

Exteroception VS Interoception

Interoception is the sense of the internal bodily state (hunger, heartbeat, breath), while exteroception is the awareness of the external world through the five senses (sight, sound, touch). Think of it as **internal focus (interoception)** versus **external focus (exteroception)**, both crucial for processing information, with practices like yoga or meditation helping to balance attention between the two for better well-being





Interoception is the collection of senses providing information to the organism about the internal state of the body. This can be both conscious and subconscious. It encompasses the brain's process of integrating signals relayed from the body into specific subregions—like the brainstem, thalamus, insula, somatosensory, and anterior cingulate cortex—allowing for a nuanced representation of the physiological state of the body This is important for maintaining homeostatic conditions[4] in the body and, potentially, facilitating self-awareness. (taken from Wiki)

The Relationship Between Organ Systems and Cells

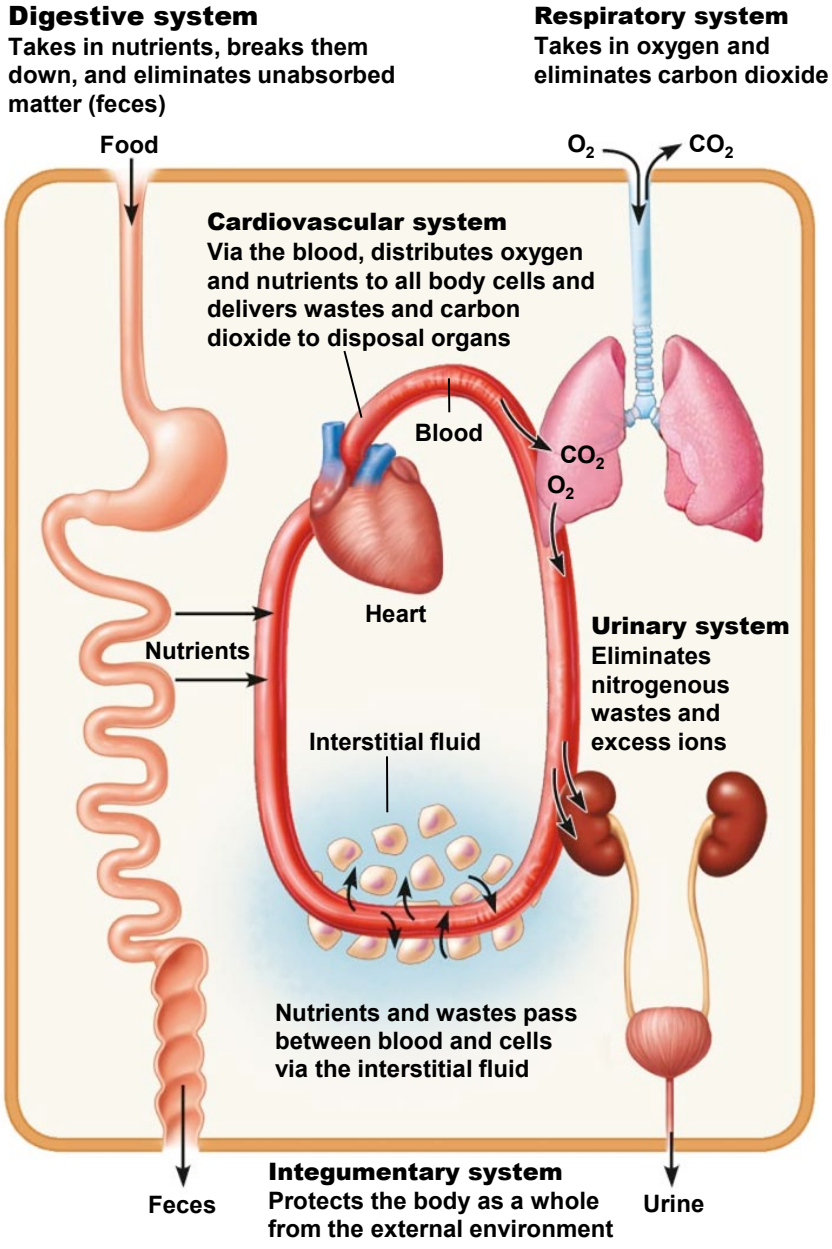
What is the purpose of homeostasis?

T*o create a stable internal environment around our cells.*

Homeostasis is a system's ability to resist change.

Homeostasis describes mechanisms that make adjustments using feedback loops to maintain a stable but dynamic equilibrium within the interstitial space (the gel state around our cells).

Nutrients must be brought to the cells, moved into the cells, metabolism occurs, waste products secreted out of cells space and excreted from body.



Homeostasis

Homeostasis is the ability of a system to resist change. Human organs resist change in the internal environment. This is the interstitial fluid around our cells.

The interstitial fluid is in a state of *"dynamic equilibrium"*. Some organs bring nutrients into the interstitial fluid. Nutrients are transported into the cell's cytoplasm. Cells metabolize the nutrients for growth, repair, or to make new cells.

Cellular metabolism creates toxic waste. These molecules are secreted back into the interstitial fluid. Organs excrete the waste products out of our bodies. Negative and positive feedback loops are used to regulate the organs and to make homeostasis possible.

Disease or death occurs when homeostasis fails.

3 Components of a Feedback Loop

Receptor - senses change in the body // the receptor is activated by a stimulus

Integrating Center (Control Center) - control center that processes the sensory information, 'makes a decision', and directs the response // this is the hypothalamus

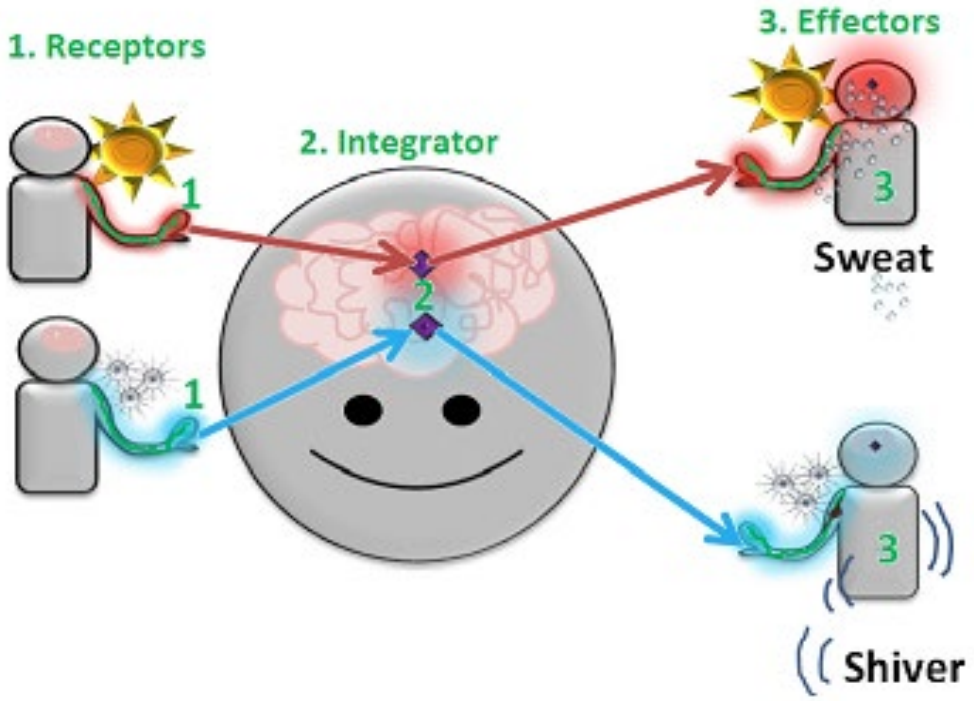
Effector – carries out the final corrective action to restore homeostasis

The Integrator = The Hypothalamus

The hypothalamus is part of the limbic system

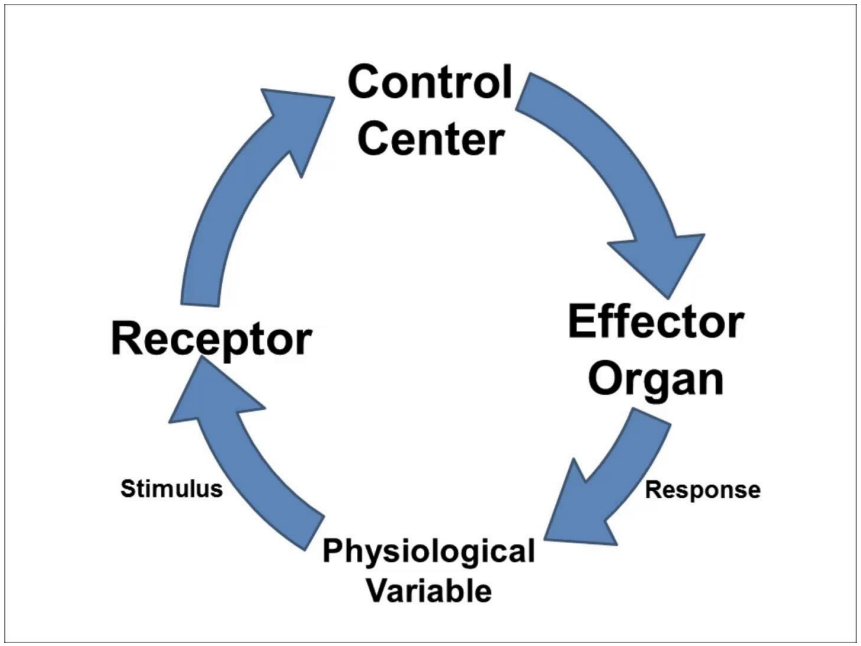
The hypothalamus uses interoception and exteroception signals to maintain homeostasis by using the autonomic nervous system and the endocrine system. These are both subconscious systems.

Both positive and negative feedback loops may be used by the ANS and endocrine system to maintain homeostasis.

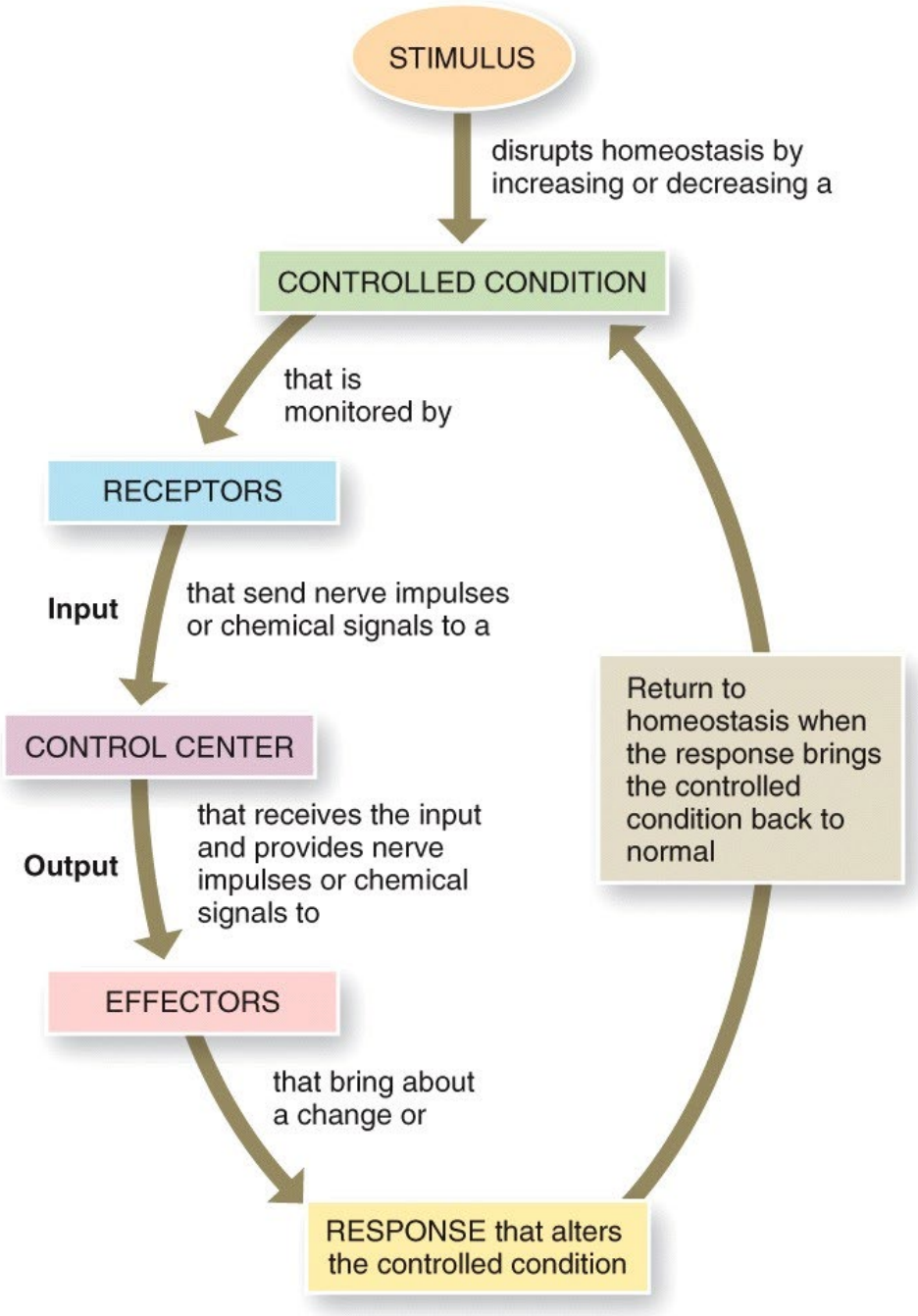


Key Components in a Feedback Loop

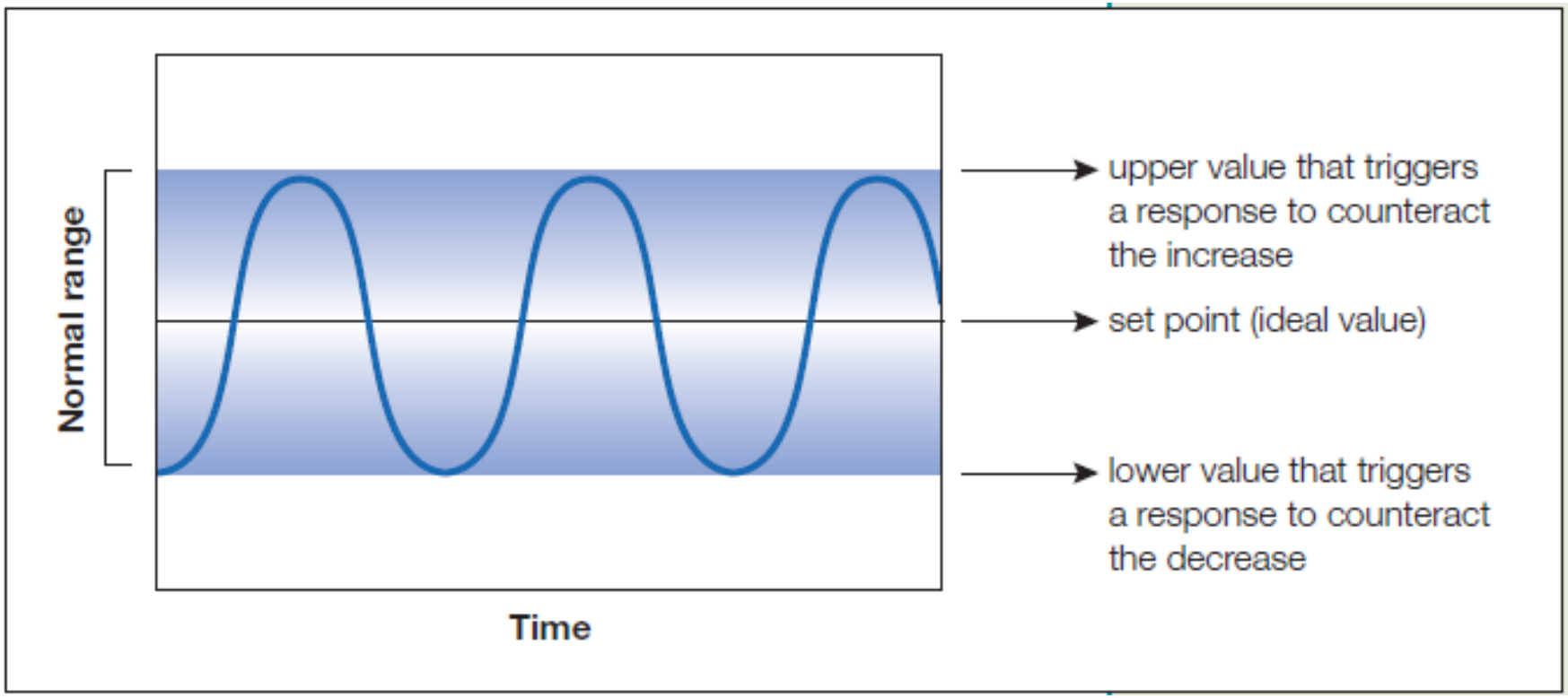
Receptor ----> Control Center ---> Effector



A stimulus is recognized by the receptor when there is a change in the “internal environment”


STIMULUS
disrupts homeostasis by increasing or decreasing a
CONTROLLED CONDITION
that is monitored by
RECEPTORS
Input
that send nerve impulses or chemical signals to a
CONTROL CENTER
Output
that receives the input and provides nerve impulses or chemical signals to
EFFECTORS
that bring about a change or
RESPONSE that alters the controlled condition
Return to homeostasis when the response brings the controlled condition back to normal

Negative Feedback



Negative Feedback Loop

Helps to return the variable to the “set point”

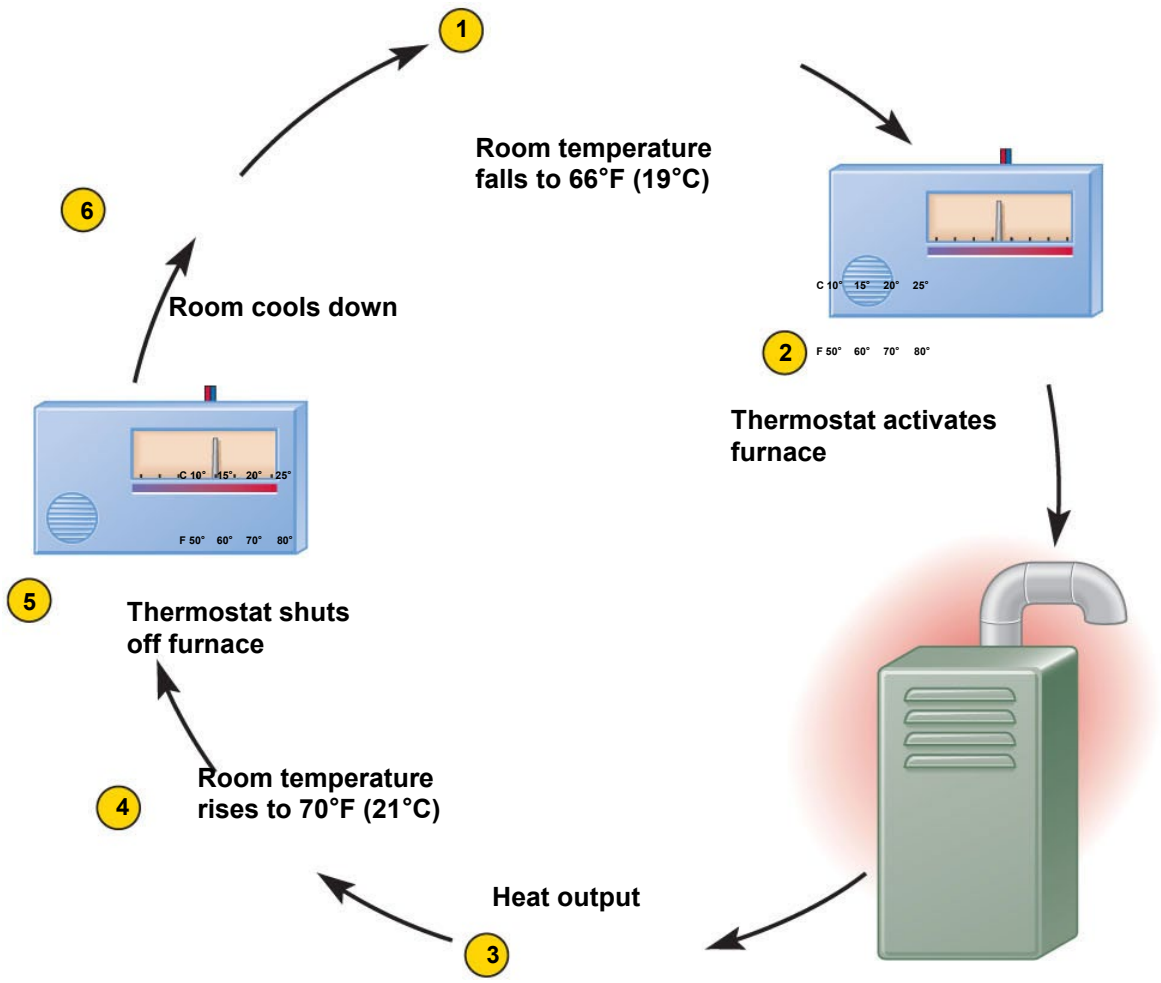
We want the room temperature at 68 degrees

The furnace does not keep the room temperature at 68 degrees

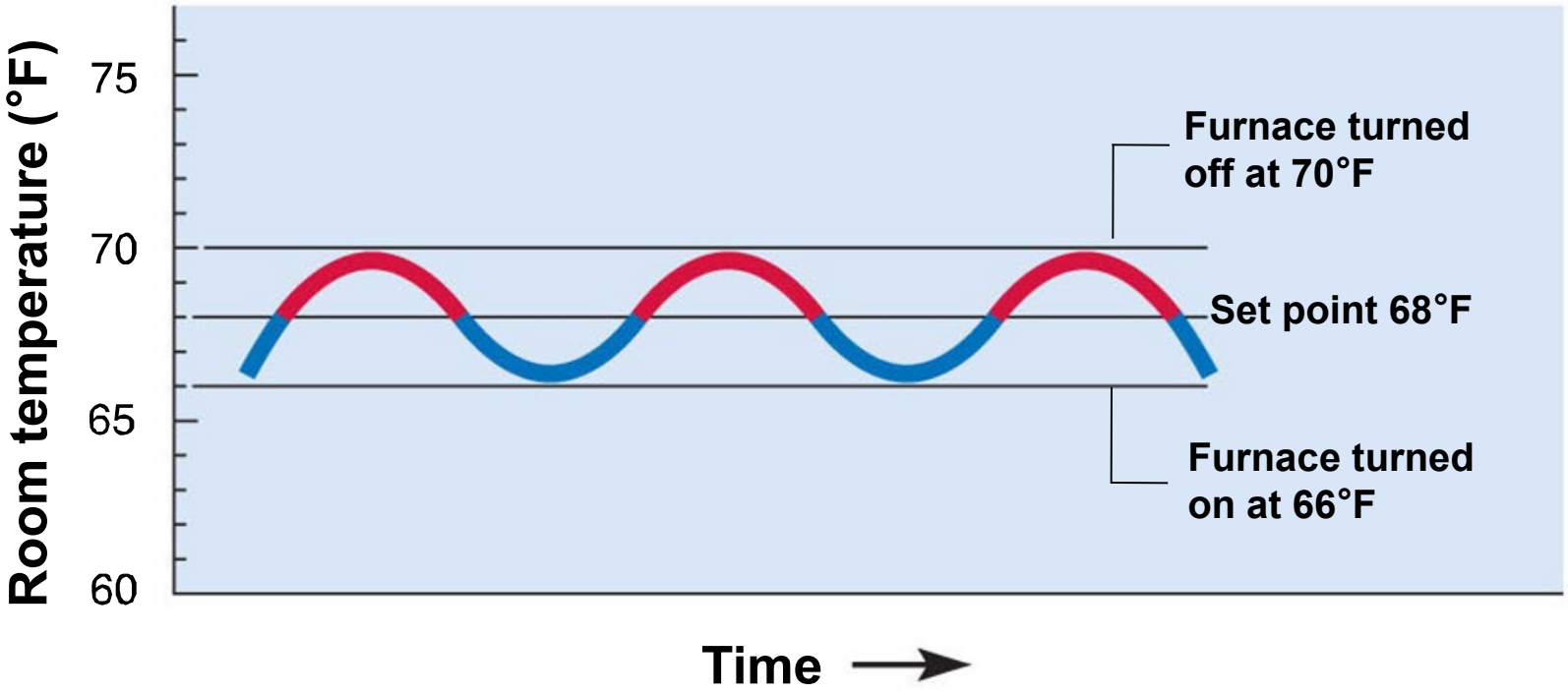
The thermostat senses changes and either turns furnace on or turns furnace off to adjust temperature

This is Dynamic equilibrium

Almost everything in your physiology is maintained within a “normal range”



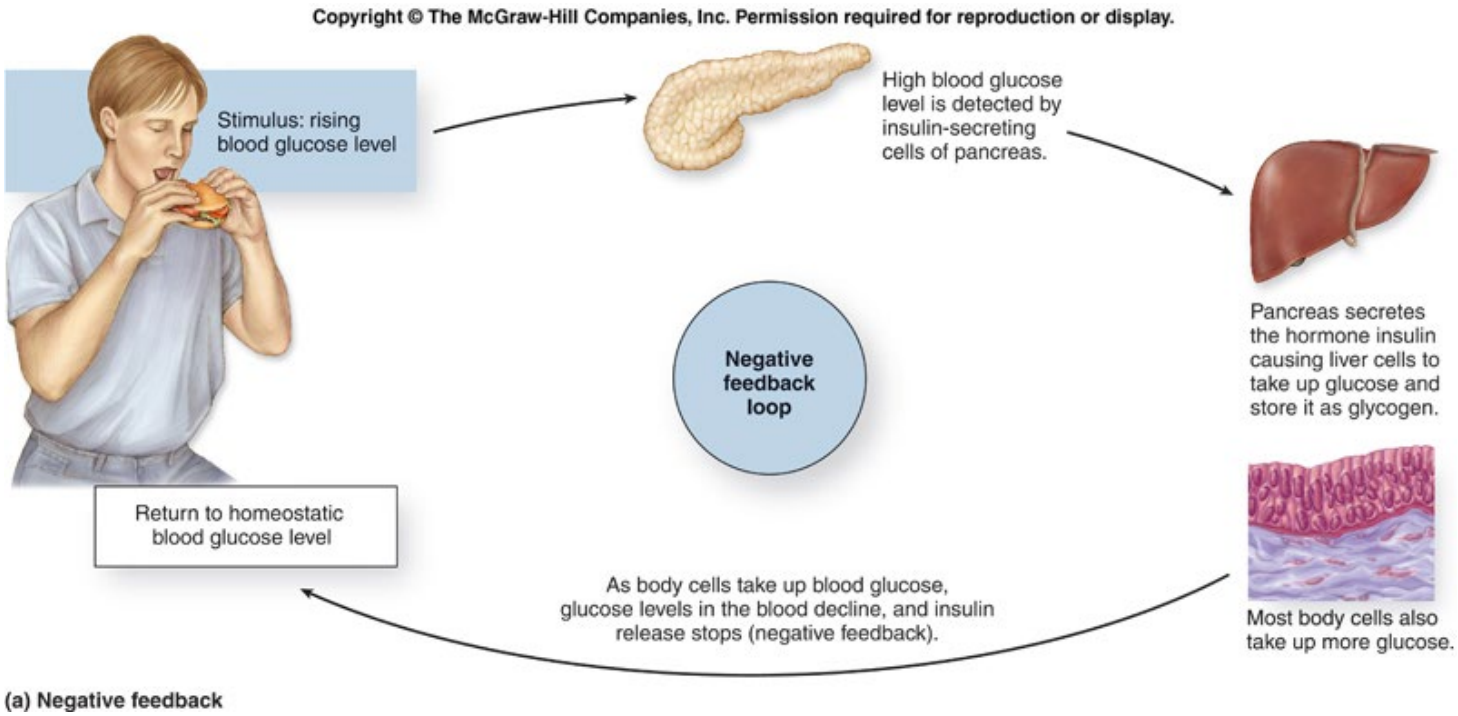
Negative Feedback, Set Point



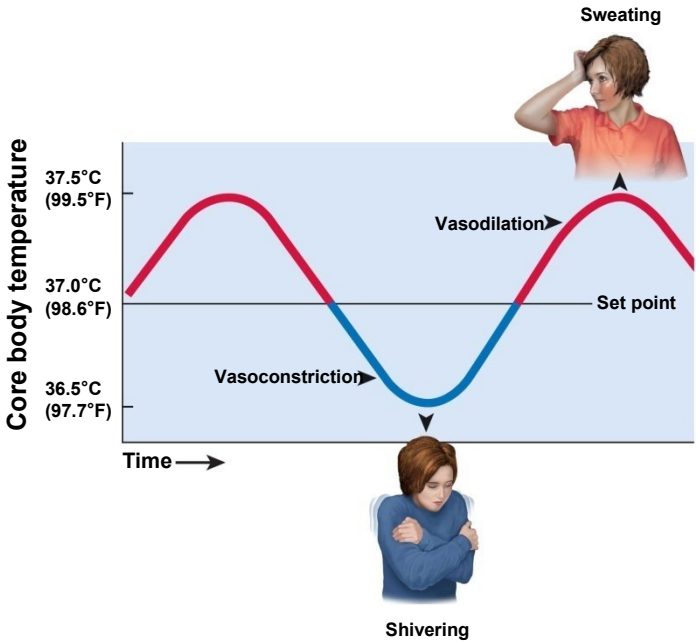
Room temperature does not stay at set point of 68 degrees -- it only averages 68 degrees

Similar graph for blood glucose concentration over time (70 to 100 mg/dl blood sugar vs time)

Negative Feedback Loop



Negative Feedback in Human Thermoregulation



- **Brain senses change in blood temperature**

–if to warm, vessels dilate (**vasodilation**) in the skin and sweating begins (heat losing mechanisms)

–if too cold, vessels in the skin constrict (**vasoconstriction**) and shivering begins (heat gaining mechanism)

Negative Feedback Control of Blood Pressure

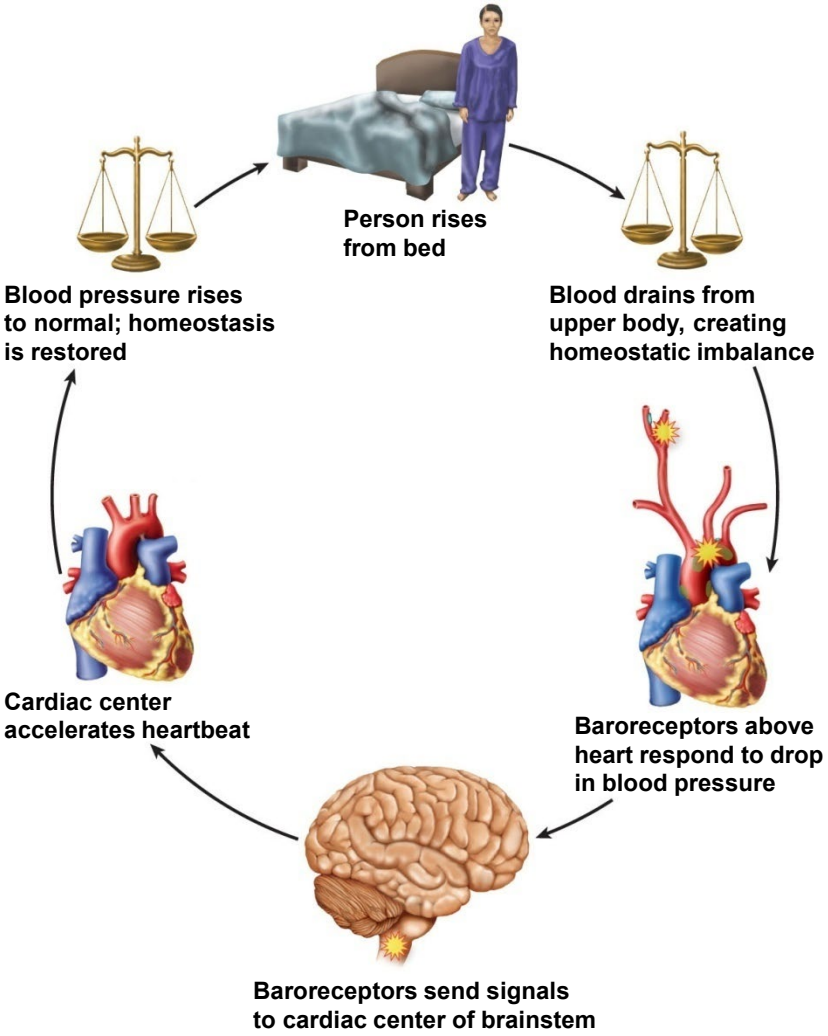
Sitting up in bed causes a drop in blood pressure in the head and upper thorax

Baroreceptors in the arteries near the heart alert the cardiac center in the brainstem

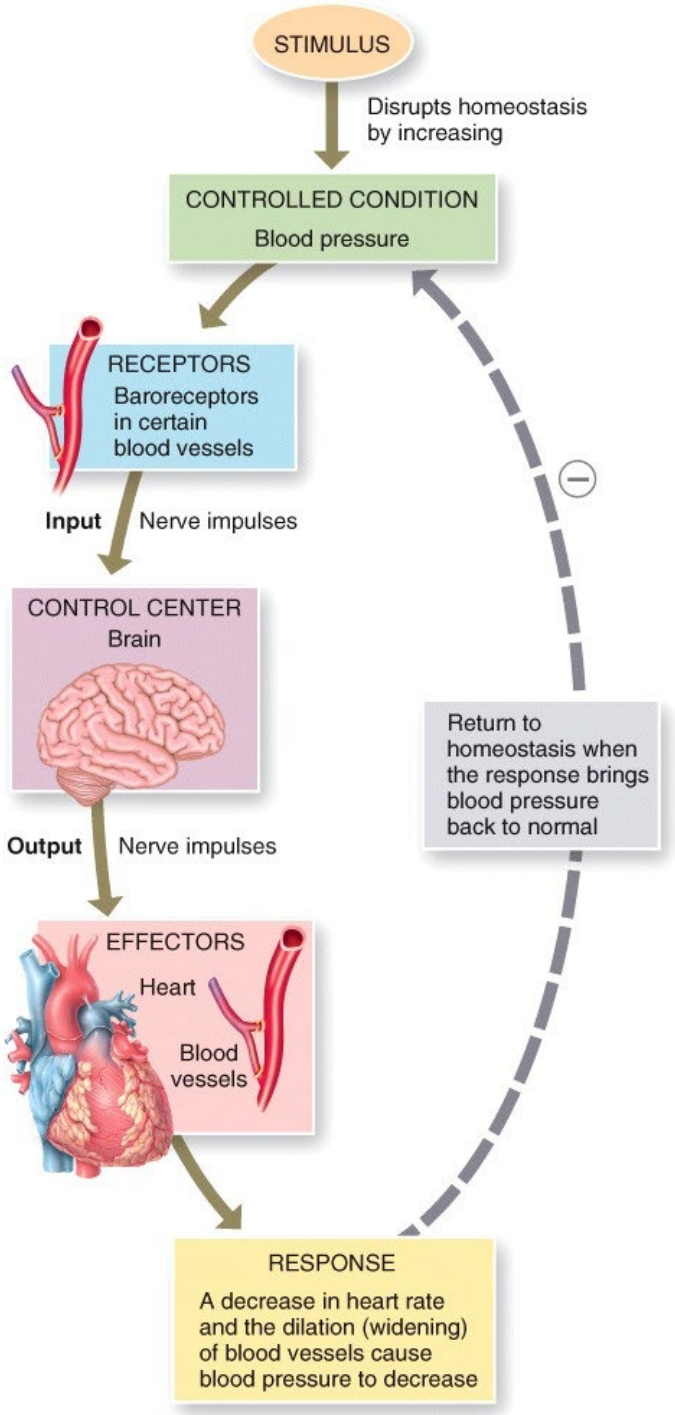
Cardiac center sends nerve signals that increase the heart rate and return the blood pressure to normal

Failure of this to feedback loop may produce dizziness in the elderly

Control of Blood Pressure



Negative Feedback



Positive Feedback Loops

Not a common mechanism

Described as a “Self-amplifying event”

Stimulus ---> Response ---> Stimulus ---> Response ---> Stimulus ---> Response

Leads to greater change in the same direction

This feedback loop is repeated – change produces more change / faster and faster!

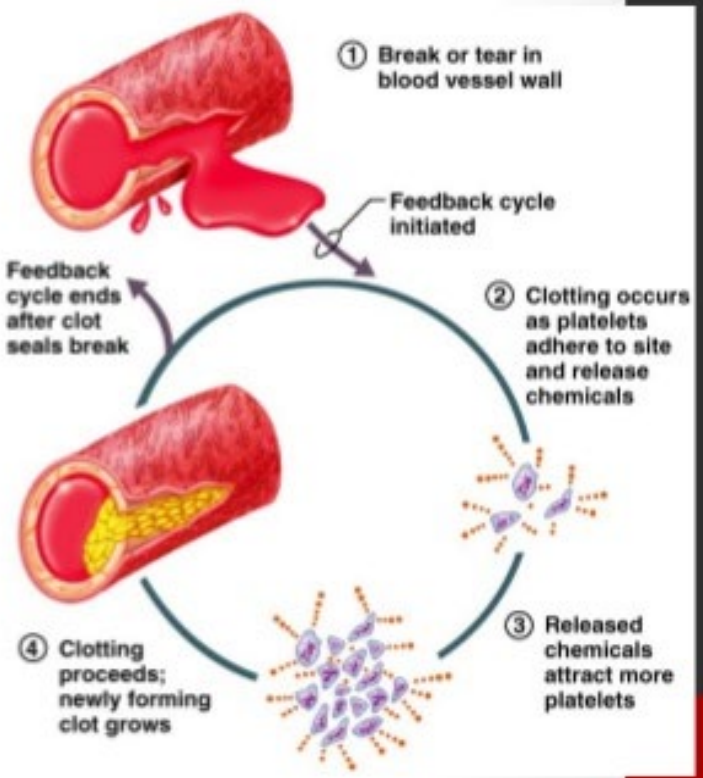
Producing rapid change to return body to normal state

Occurs with childbirth, blood clotting, protein digestion, fever, and the generation of nerve signals

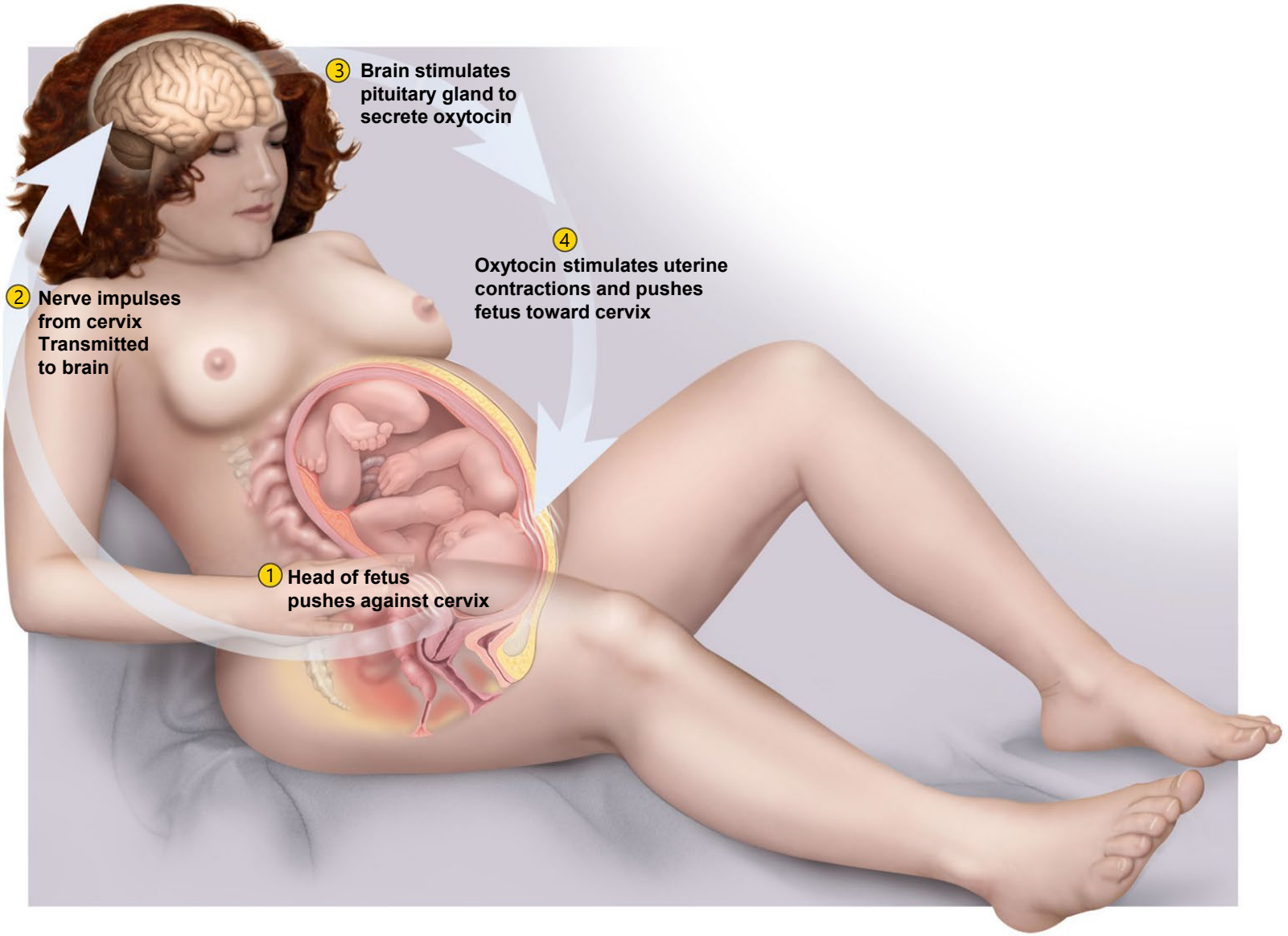
Some Physiologic Conditions Require Positive Feedback Loops Positive Feedback Loops

Positive Feedback

- In positive feedback systems, the output enhances or exaggerates the original stimulus
- Example: Regulation of blood clotting



Positive Feedback Loops



Positive Feedback Loops

Stimulus ---> Response ---> Stimulus ---> Response ---> Stimulus ---> Response

Positive feedback loops are *potentially more dangerous than negative feedback loops*

- Fever is a good example of a “potentially dangerous” positive feedback loop
- Pyrogens resets the “internal thermostat” - you generate more “heat”
- Higher temp increases rate of “chemical reactions” in cells
- Exothermic chemical reactions further increases temperature
- Now we are trapped a in positive feedback loop
- Eventually, high temperatures denatures proteins
- Denature proteins stops metabolism // cause death

A Dangerous Positive Feedback Loop

Fever > 104 degrees F

Bacteria and WBC release pyrogens (reset body's thermostat to higher temperature and body makes more heat)

Higher temp increases metabolic rate as extra heat speeds up metabolism.

Now body is producing even more heat as body continues to increase metabolic rate.

Body temperature continues to rise // further increasing metabolic rate // more heat generated --- positive feedback!

Self-amplifying cycle and becomes fatal at 113 degrees F // denatures proteins and this stops cellular metabolism.

Medicine and Homeostasis

Disease occurs when homeostasis fails. Doctors apply there understanding about homeostasis to understand the cause of the disease.

There is a direct link between the mind and the body. The mind may upset homeostasis and cause disease.

What is stress? Stress is not a disease, but stress makes all diseases worst.

The Mind-Body Axis
(Stress & Homeostasis)

The Conscious Brain

(Cerebral Cortex)

Our Subconscious Brain

The Paleomammalian Brain = (Limbic System)

Hypothalamus (part of the limbic system)

(The “boss” of both the endocrine system and autonomic nervous system)

Endocrine System

Autonomic

Nervous System

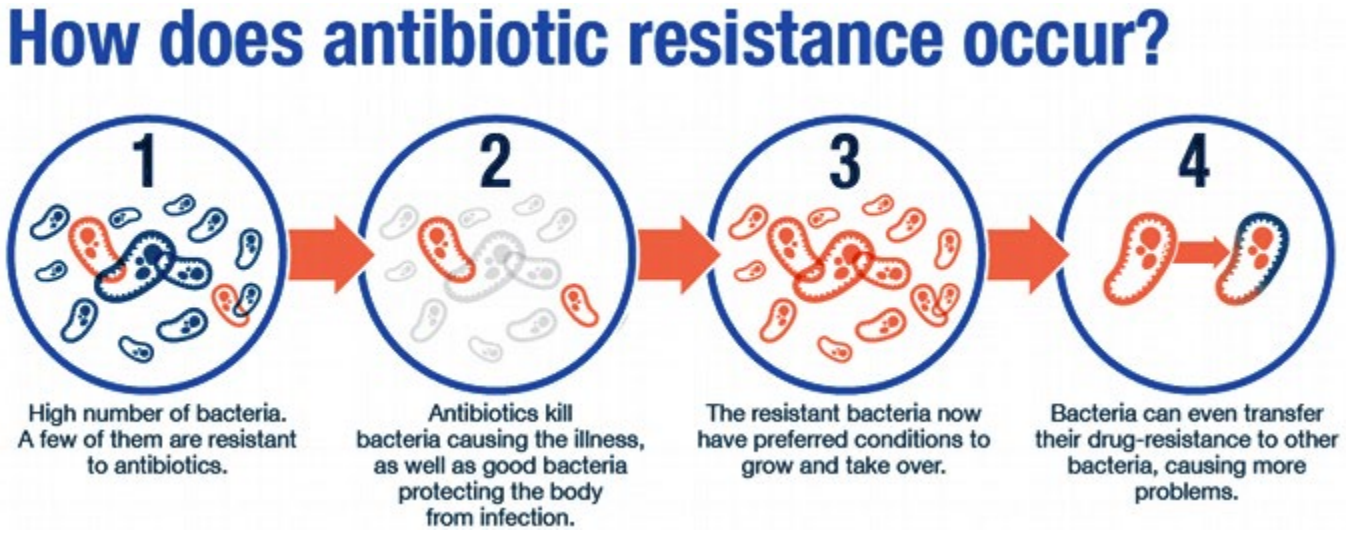
Evolution & Natural Selection

The Foundation of Biology

Evolution

Evolution // change in genetic composition (i.e. DNA) in an organisms population over time

•These are examples of evolution: development of bacterial resistance to antibiotics // appearance of new strains of AIDS virus and coronal virus // brown bears become polar bears



Natural Selection

Natural Selection // **is the mechanism of evolution (how it occurs)** // some individuals within a species have hereditary advantage over their other species

Better camouflage // disease resistance // better shape of bird beaks to pick seeds out of cracks // polar bears vs brown bears // wolf vs dog

Change in genetic code followed by natural selection allows for one group to produce more offspring /// their genes more likely to be passed on to next generation

What is selection pressures? – natural forces that promote the reproductive success of some individuals more than others // adaptation

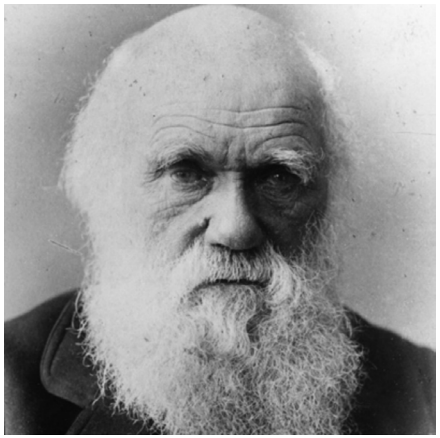
Classical Genetics Started with Mendel

Gregor Johann Mendel was curious and had a pea garden. He was also an Augustinian friar and abbot of St. Thomas' Abbey in Brno, Margraviate of Moravia. Gregor Mendel is usually considered to be the founder of classical genetics.

Farmers had known for centuries that crossbreeding of animals and plants could favor certain desirable traits. Mendel's pea plant experiments conducted between 1856 and 1863 established many of the rules of heredity and the fundamental laws of inheritance. Mendel deduced that genes come in pairs and are inherited as distinct units, one from each parent. Mendel tracked the segregation of parental genes and their appearance in the offspring as dominant or recessive traits. // 100 years before the discovery of DNA's structure

Born: July 20, 1822, Hynčice, Vražné, Czech Republic Died: January 6, 1884, Brno, Czech Republic

Darwin Added More Insight About Classical Genetics



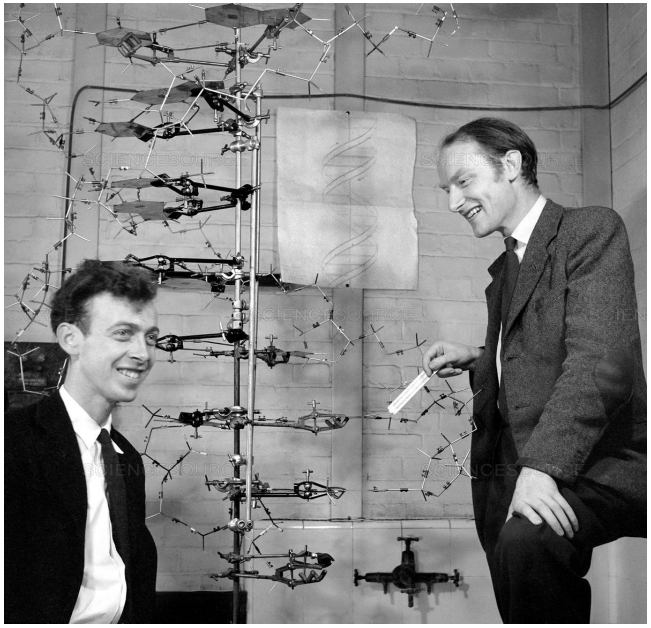
Charles Robert Darwin, was an English naturalist, geologist and biologist, best known for his contributions to the science of evolution. Darwin formulated his bold theory in private in 1837–39, after returning from a voyage around the world aboard HMS Beagle. It was not until two decades later that he finally gave it full public expression in On the Origin of Species (1859), a book that has deeply influenced modern Western society and thought.

Darwin explain how "natural selection" decided which genes would be selected and passed on to the next generation after "evolution altered the DNA sequence". He also wrote the Ascent of Man (1871) about human evolution

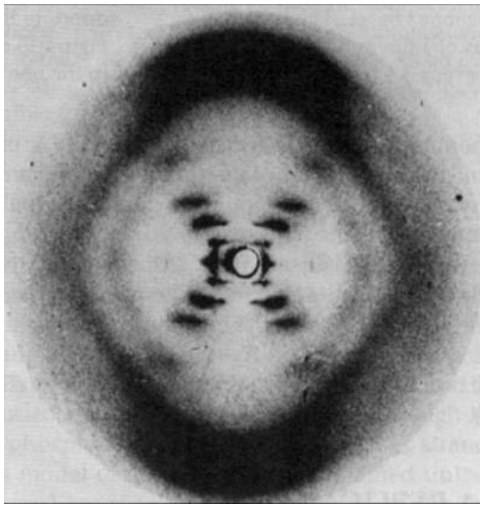
Born: February 12, 1809, The Mount, Shrewsbury, United Kingdom

Died: April 19, 1882, Down House, Downe, United Kingdom

Modern Genetics Adds Molecular Biology

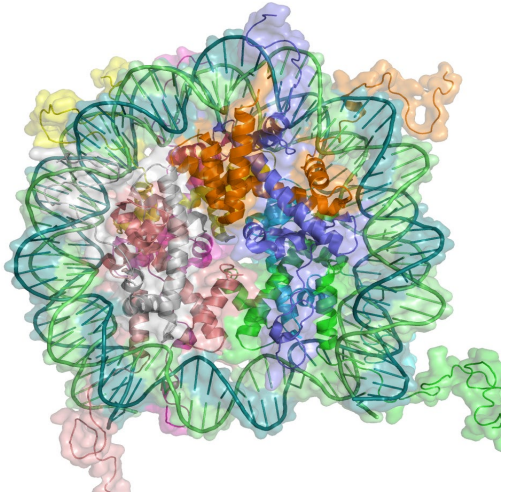


The discovery in 1953 of the double helix twisted-ladder like structure of deoxyribonucleic acid (DNA), by James Watson and Francis Crick, marked a milestone in the history of science. This discovery gave rise to modern molecular biology, which is largely concerned with understanding how genes control the chemical processes of cells.



Rosalind Elsie Franklin was an English chemist and X-ray crystallographer who made contributions to the understanding of the molecular structures of DNA // Watson and Crick saw Franklin's work and used it to solve the structure of DNA – they became famous and she became a footnote in history!

Epigenetics

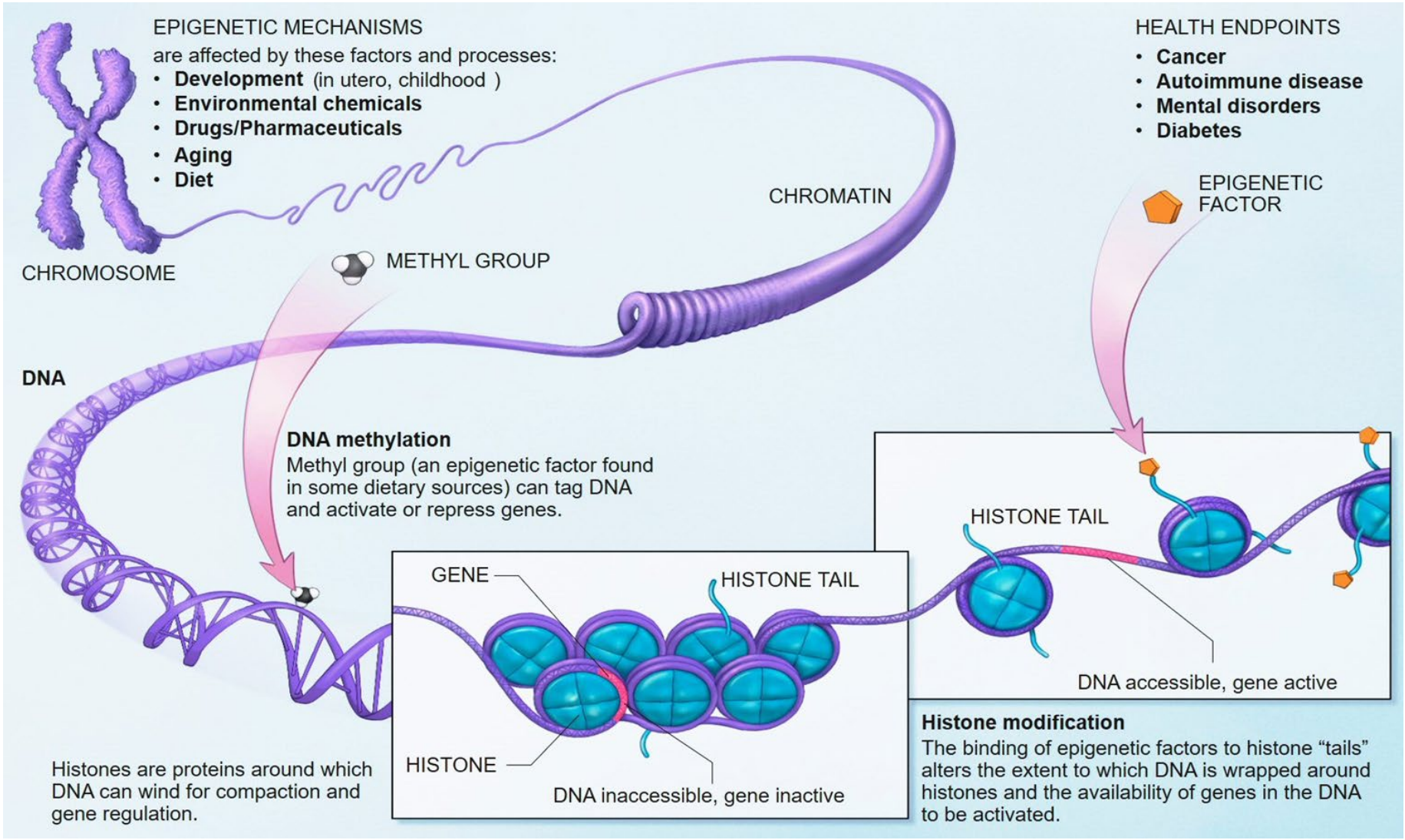


Epigenetics is the study of heritable phenotype changes that do not involve alterations in the DNA sequence.

The Greek prefix epi- (ἐπι- "over, outside of, around") in epigenetics implies features that are "on top of" or "in addition to" the traditional genetic basis for inheritance. Epigenetics most often denotes changes that affect gene activity and expression, but can also be used to describe any heritable phenotypic change.

A consensus definition of the concept of an epigenetic trait is a "stably heritable phenotype resulting from changes in a chromosome without alterations in the DNA sequence". This was formulated at a Cold Spring Harbor meeting in 2008

Epigenetics



Our Animal Relations

Human's closest relative - chimpanzee

–difference of only 1.6% in DNA structure

–chimpanzees and gorillas differ by 2.3%

–Bonobos, chimpanzees, and humans share 98.7% of their genes

Study of evolutionary relationships

–help us chose animals for biomedical research (the animal model)

–rats and mice used extensively due to issues involved with using chimpanzees

Vestiges of Human Evolution

Vestigial Organs – remnants of organs that apparently were better developed and more functional in the ancestors of a species, and now serve little or no purpose

–piloerector muscle

–auricularis muscles

What happens when you place your finger in the palm of a newborn baby? What is this called? When and why did this evolutionary trait develop?

Life in the Trees

Primates – order of mammals to which humans, monkeys, and apes belong

Earliest Primates = squirrel-sized, arboreal, insect-eating African mammals // moved to trees due to safety, food supply and lack of competition

Adaptations for arboreal (treetop) life style

– mobile shoulders // opposable thumbs made hands prehensile to grasp branches and encircle them with the thumb and finger

– forward-facing eyes (stereoscopic vision) // depth perception for leaping and catching prey

– color vision // distinguish ripe fruit and young, less toxic foliage

– larger brains and good memory // remember food sources and improved social organization

Walking Upright

African forest became grassland 4-5 million years ago // producing more predators and less protection

Bipedalism - standing and walking on 2 legs // helps spot predators, carry food or infants

Adaptations for bipedalism

–skeletal and muscular modifications

–increased brain volume

–family life and social changes

Walking Upright

Ardipithecus – transitional primate between chimpanzees and Australopithecus // foot anatomy similar to chimps but able to stand upright and live on ground. // 6 MYA – around time of controlled fire

Australopithecus – range 4 to 2 MYA // oldest truly bipedal primate // the famous skeleton called “Lucy” walked the earth 2 million years ago

Homo genus (appeared 2.5 million years ago) // taller, larger brain volume, probable speech, tool-making

Homo erectus *(*appeared 1.8 million years ago) // migrated from Africa to parts Asia

Other Homo species discovered recently still matter of considerable debate how these species fit into the puzzle // the homo genus is described as being “bushy” and less “branching”

Homo sapiens originated in Africa 200,000 years ago // humans are Homo sapiens // sole surviving hominid species // We are hominids!

Evolutionary (Darwinian) medicine traces some of our diseases and imperfections to our past

Analyzing Medical Terms

Terminology based on word elements

- lexicon of 400 word elements on the inside of the back cover of textbook

Scientific terms

- one root (stem) with core meaning
- combining vowels join roots into a word
- prefix modifies core meaning of root word
- suffix modifies core meaning of root word

Acronyms formed from first letter, or first few letters of series of words // Calmodulin comes from the phrase - calcium modulating protein

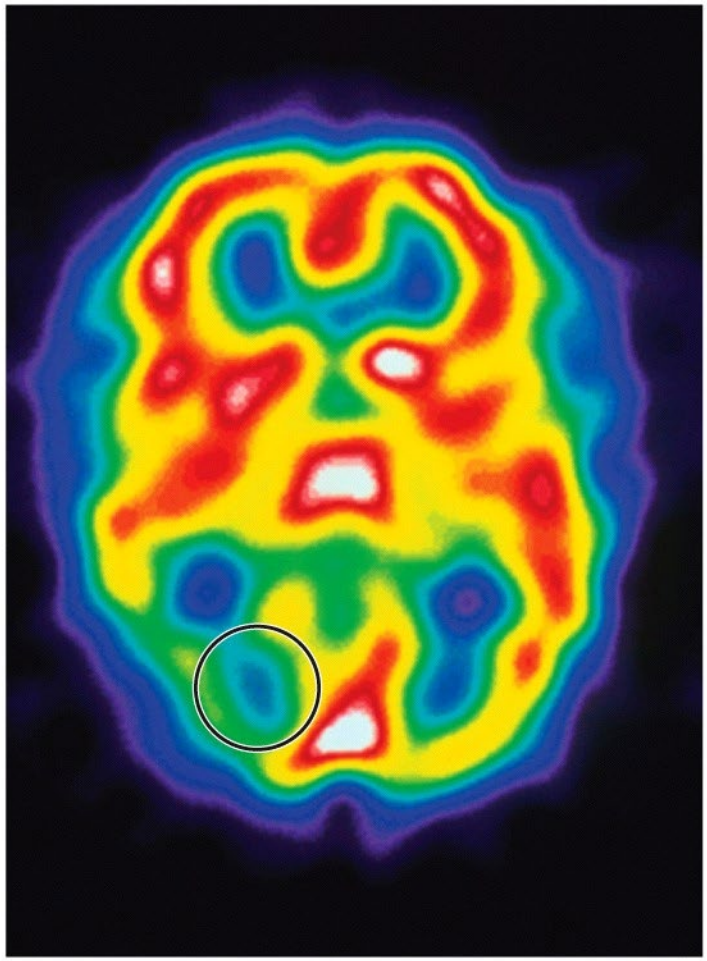
TABLE 1.2 Singular and Plural Forms of Some Noun Terminals

Singular Ending	Plural Ending	Examples
-a	-ae	axilla, axillae
-ax	-aces	thorax, thoraces
-en	-ina	lumen, lumina
-ex	-ices	cortex, cortices
-is	-es	diagnosis, diagnoses
-is	-ides	epididymis, epididymides
-ix	-ices	appendix, appendices
-ma	-mata	carcinoma, carcinomata
-on	-a	ganglion, ganglia
-um	-a	septum, septa
-us	-era	viscus, viscera
-us	-i	villus, villi
-us	-ora	corpus, corpora
-x	-ges	phalanx, phalanges
-y	-ies	ovary, ovaries
-yx	-yces	calyx, calyces

Useful Tables in Textbook

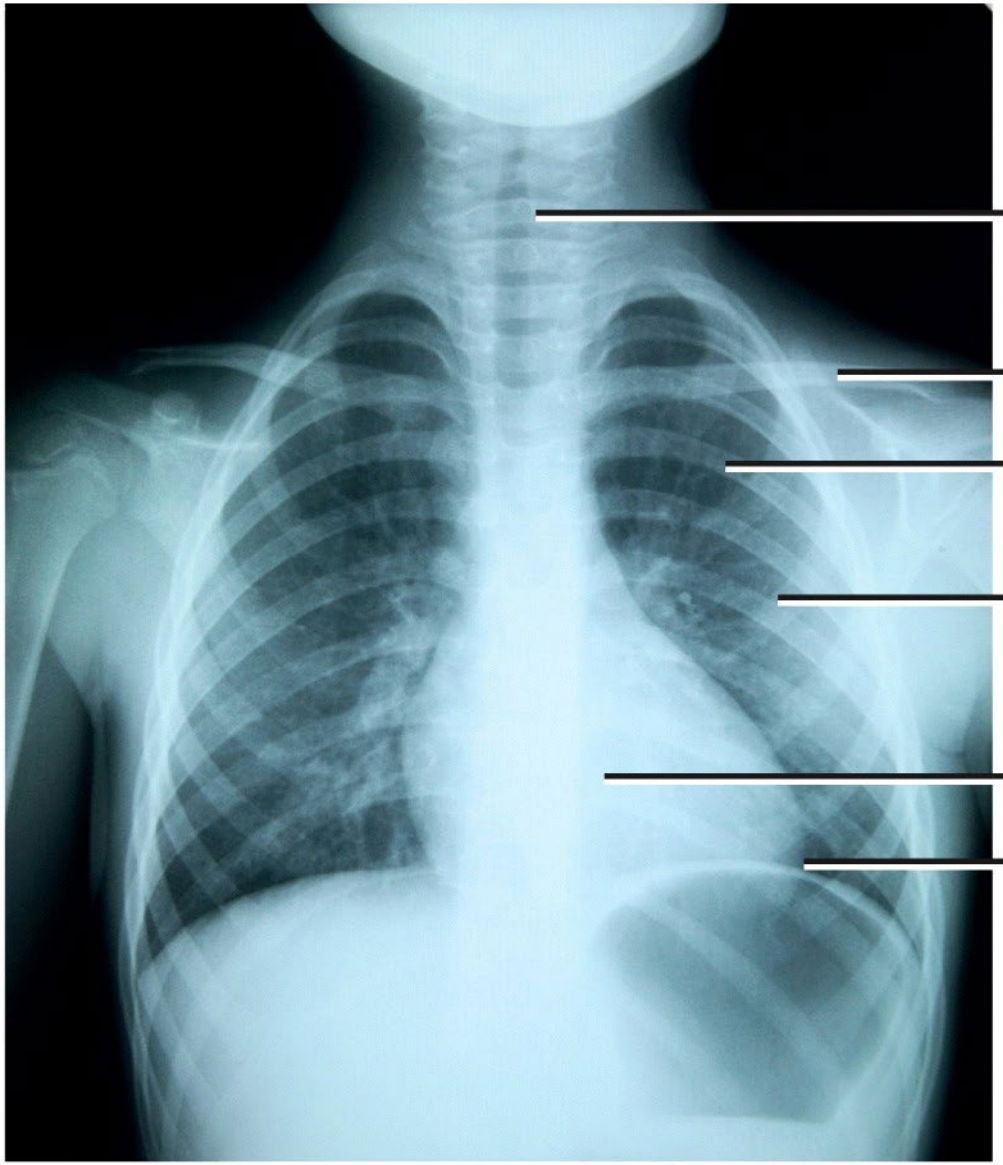
Imaging Technology

Not Learning Objectives



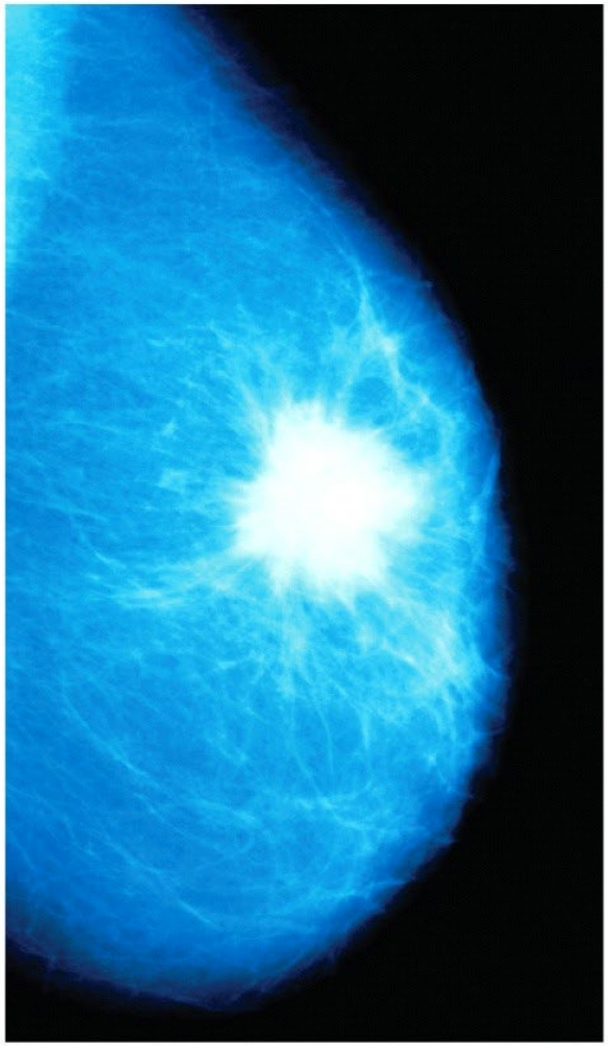
Dept. of Nuclear Medicine, Charing Cross Hospital/Photo Researchers, Inc.

Single-photon-emission computed tomography (SPECT) scan of transverse section of the brain (the almost all green area at lower left indicates migraine attack)



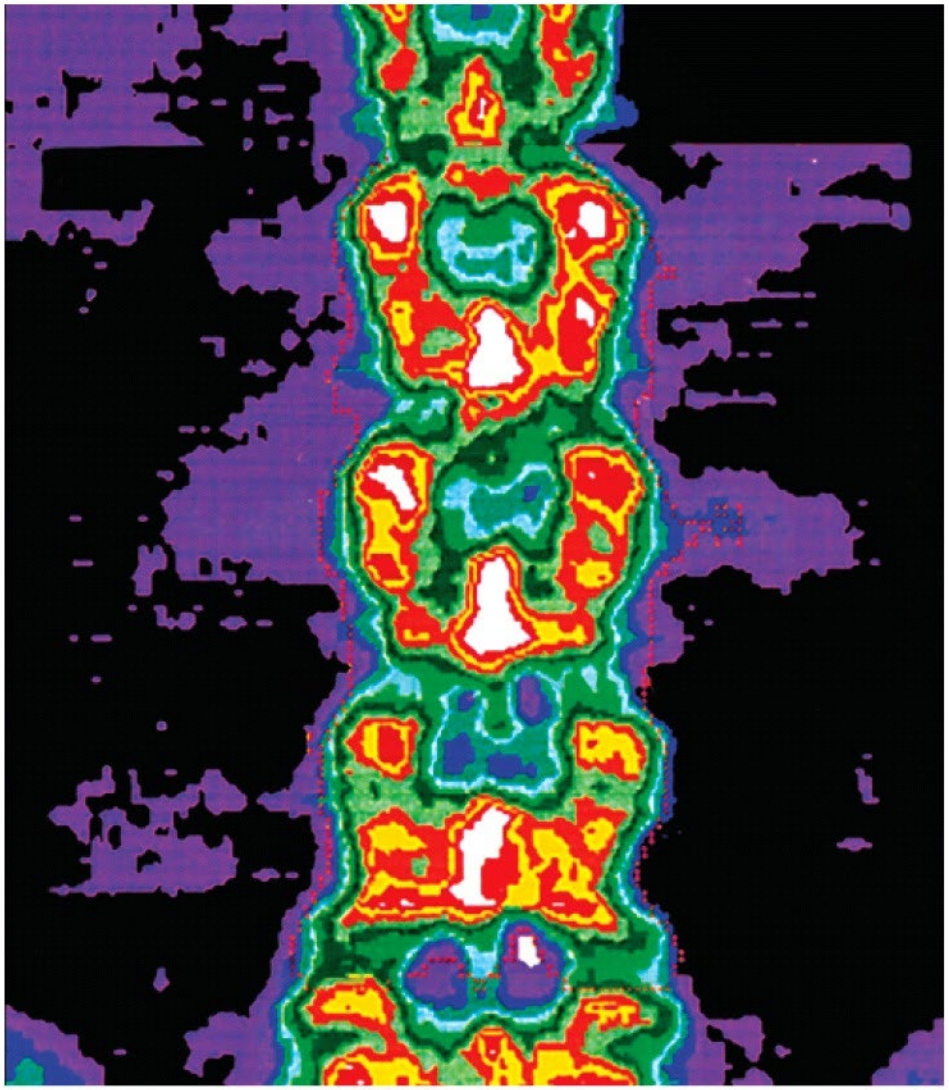
Warwick G./Photo Researchers, Inc.

Radiograph of thorax in anterior view



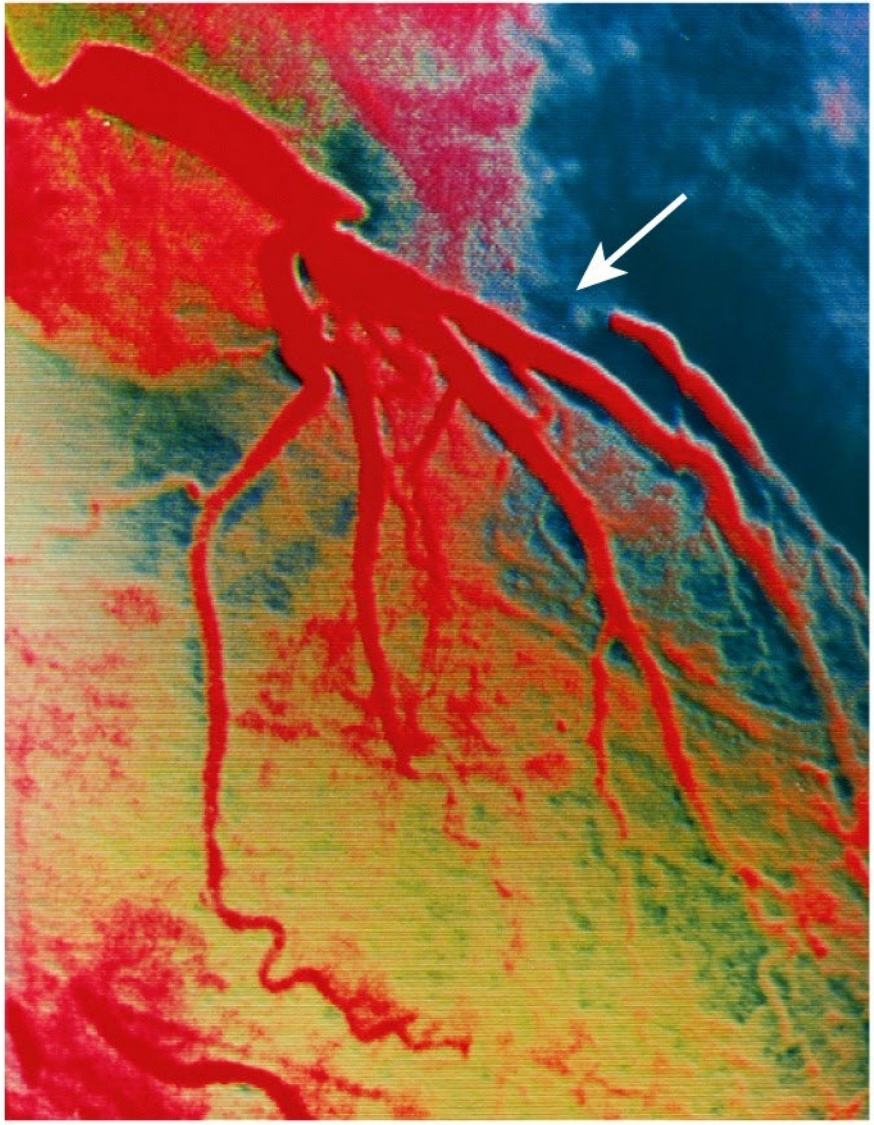
Breast Cancer Unit, Kings College Hospital, London/Photo Researchers, Inc.

Mammogram of female breast showing cancerous tumor (white mass with uneven border)



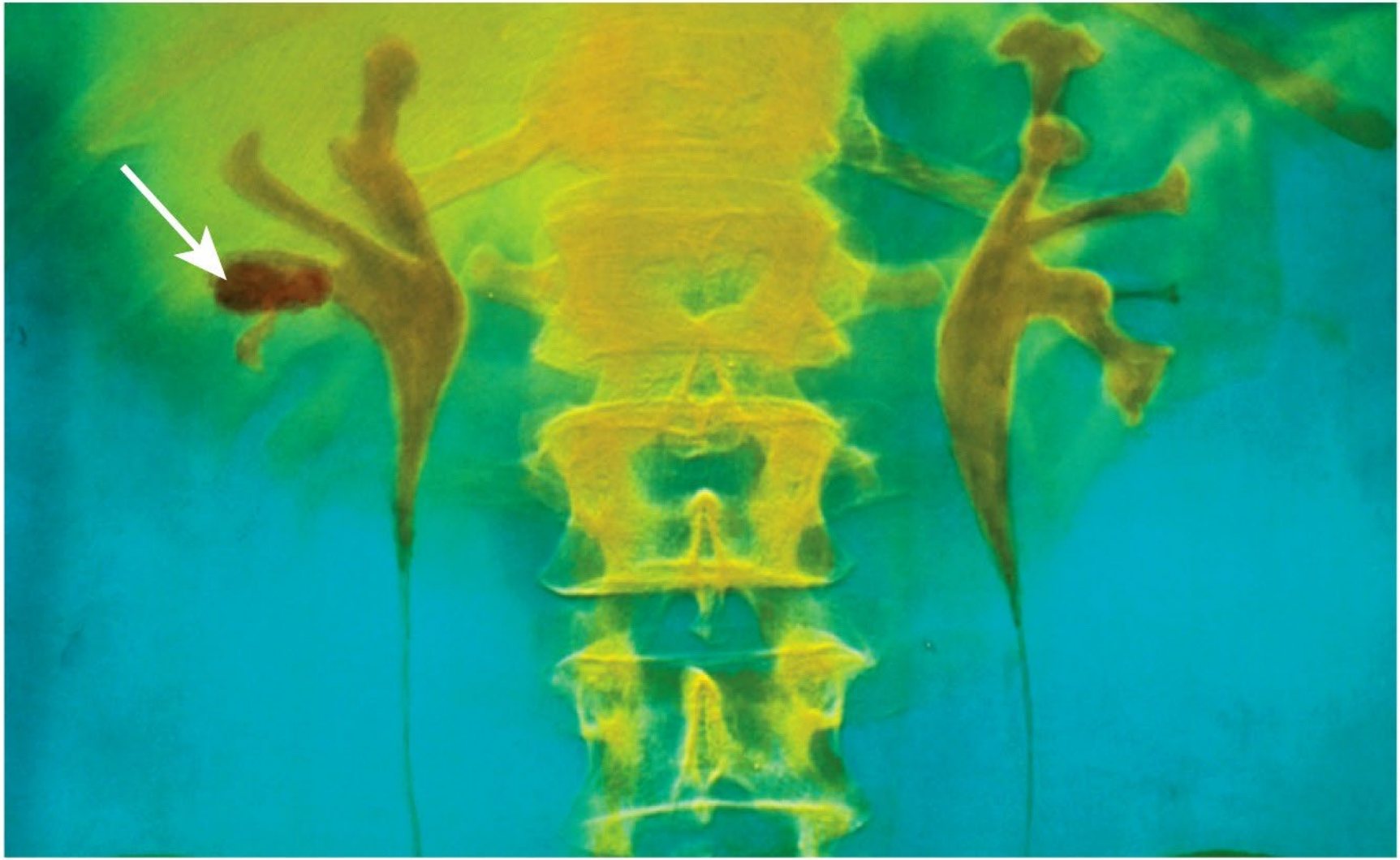
Zephyr/Photo Researchers, Inc.

Bone densitometry scan of lumbar spine in anterior view



Cardio-Thoracic Centre, Freeman Hospital, Newcastle-Upon-Tyne/Photo Researchers, Inc.

Angiogram of adult human heart showing blockage in coronary artery (arrow)

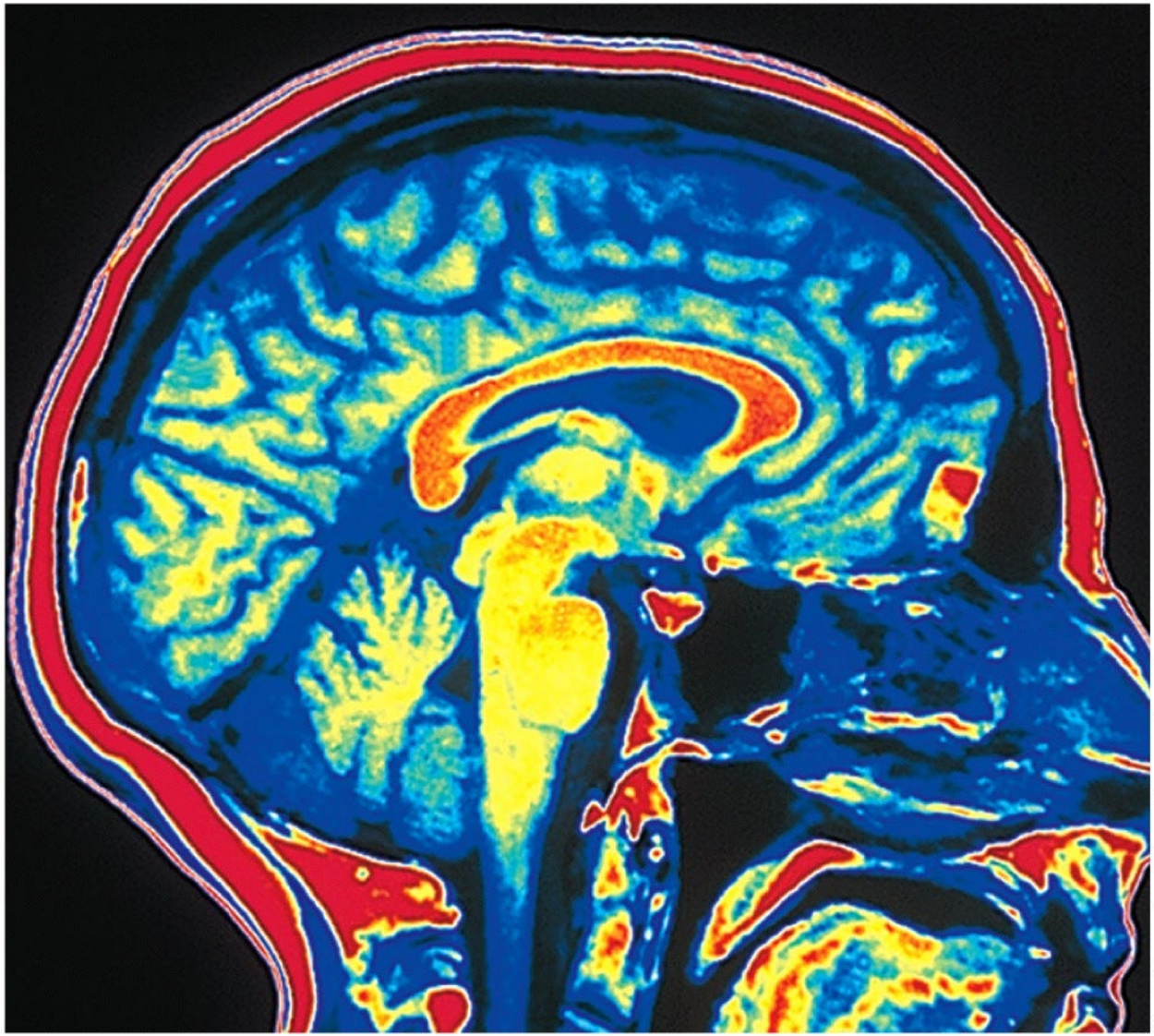


CNRI/Science Photo Library/Photo Researchers, Inc.

Intravenous urogram showing kidney stone (arrow) in right kidney

Science Photo Library/Photo Researchers, Inc.

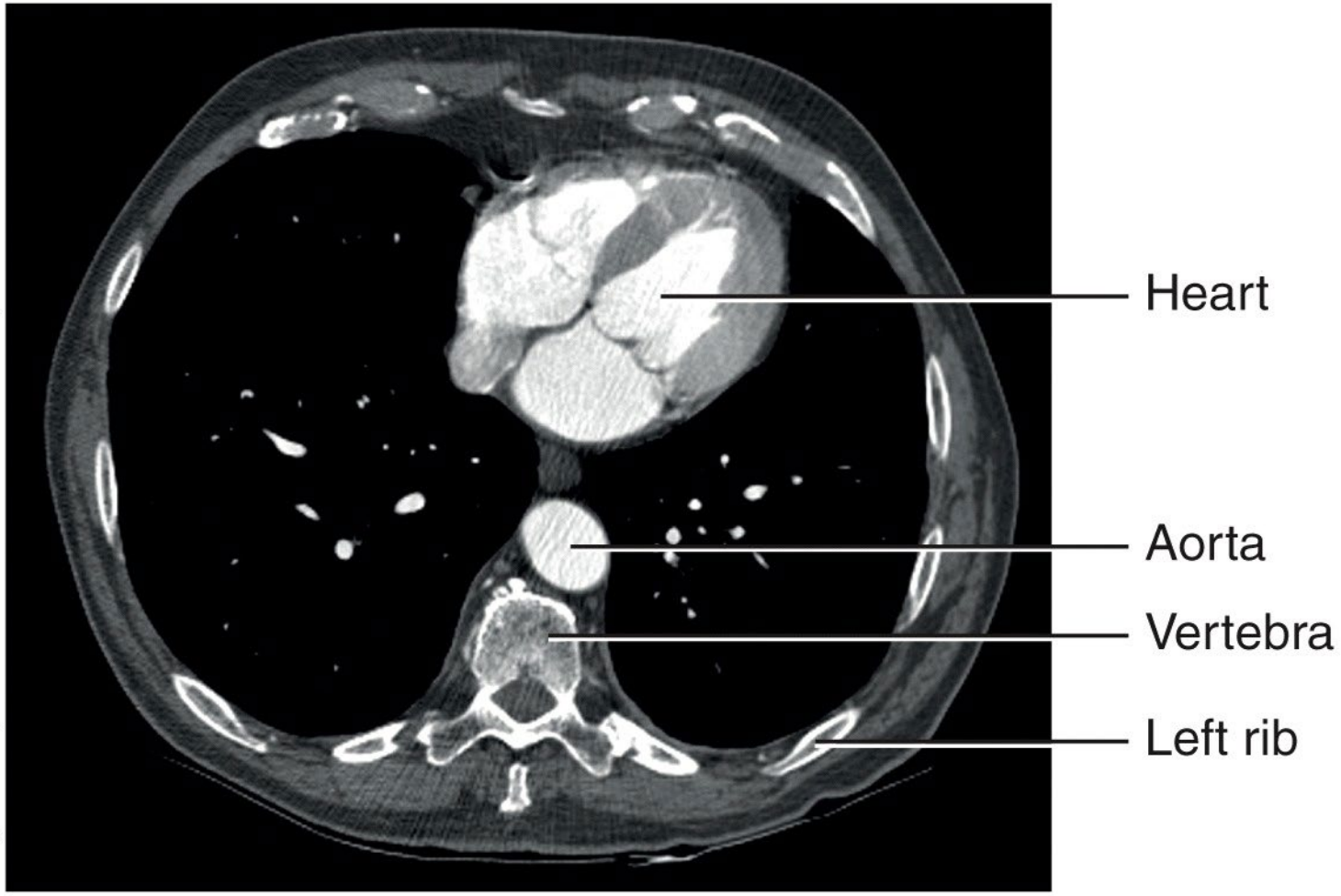
Barium contrast x-ray showing cancer of the ascending colon (arrow)



Scott Camazine/Photo Researchers, Inc.

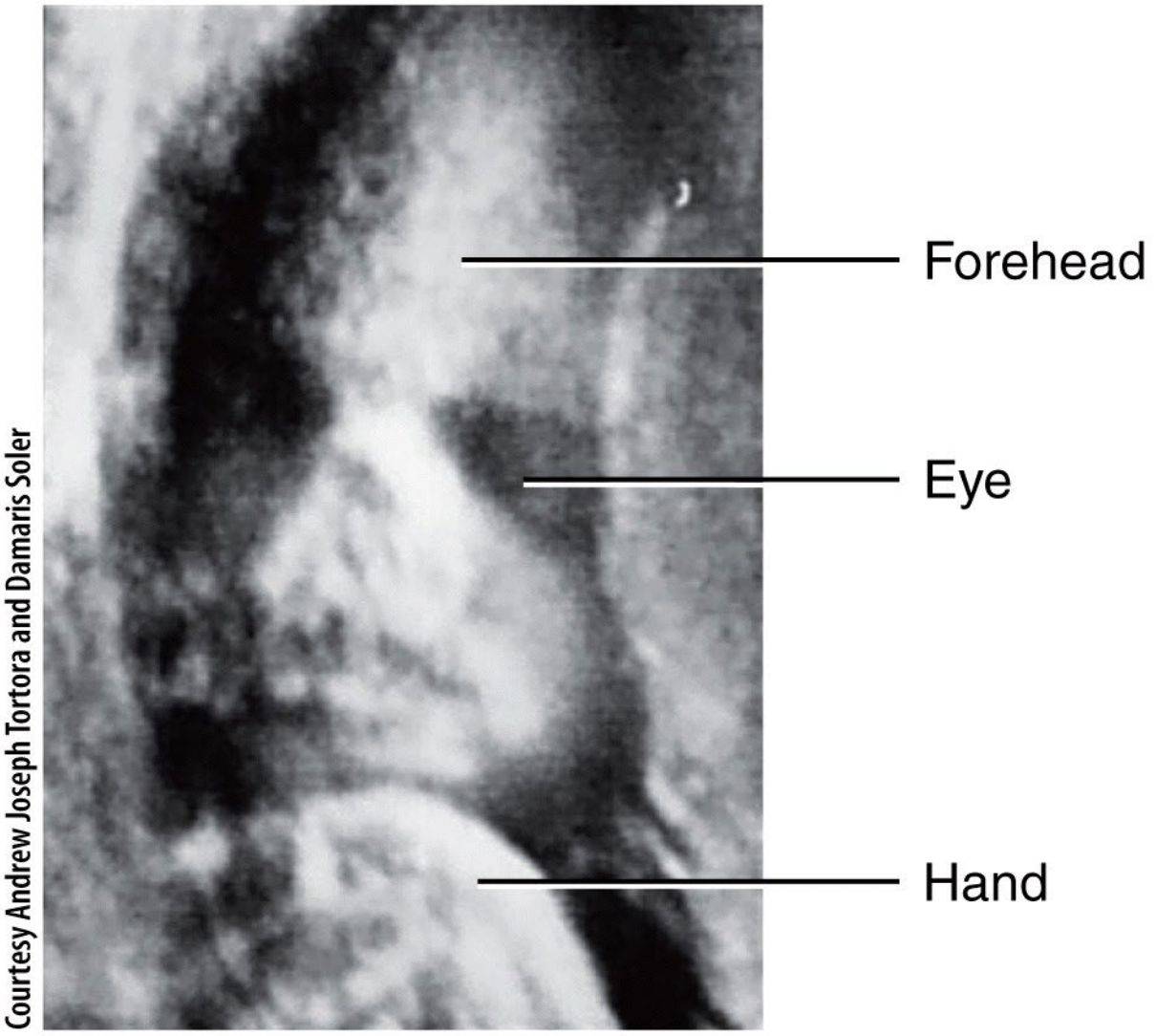
Magnetic resonance image of brain in sagittal section

ANTERIOR

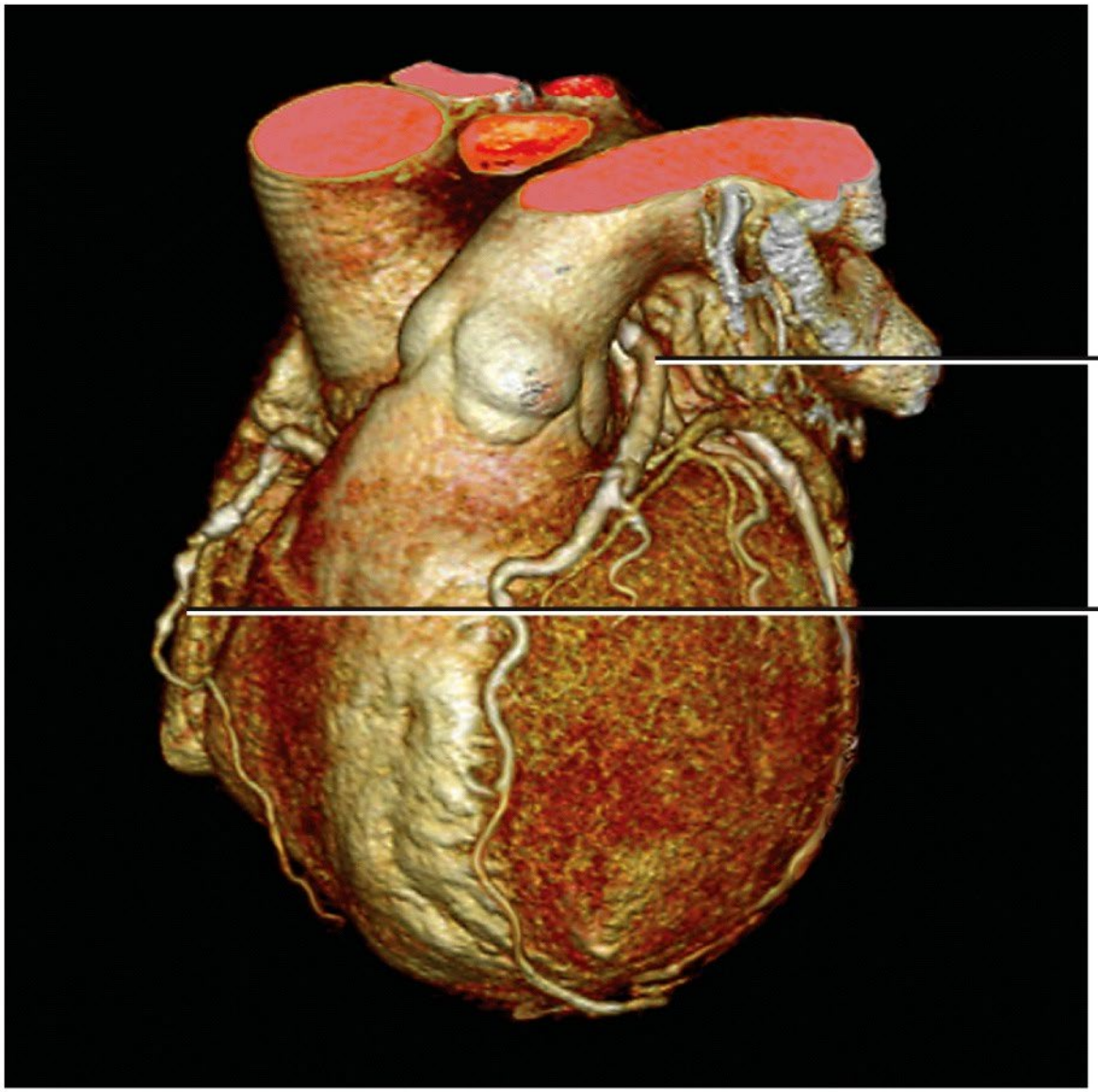


POSTERIOR

Computed tomography scan of thorax in inferior view



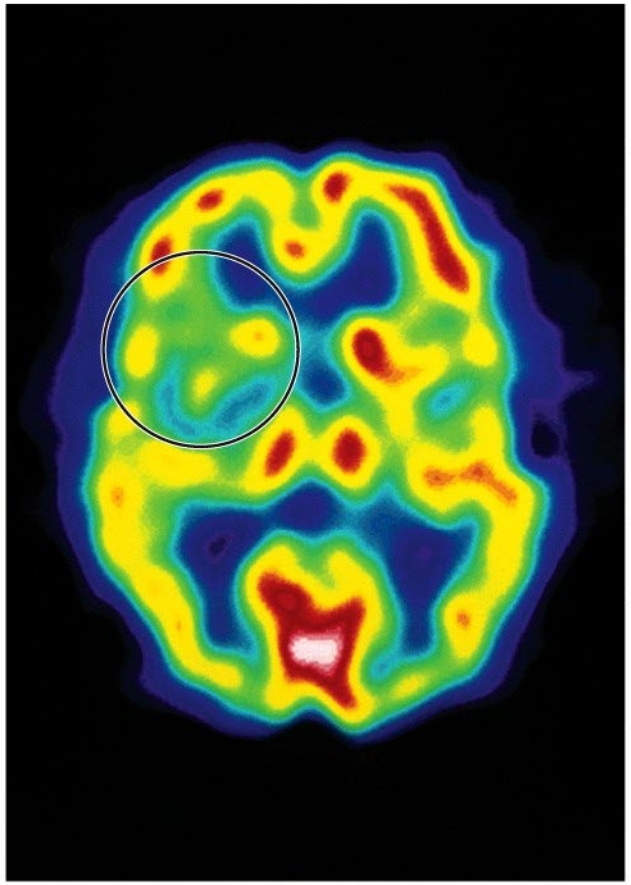
Sonogram of fetus (Courtesy of Andrew Joseph Tortora and Damaris Soler)



ISM/Phototake

CCTA scan of coronary arteries

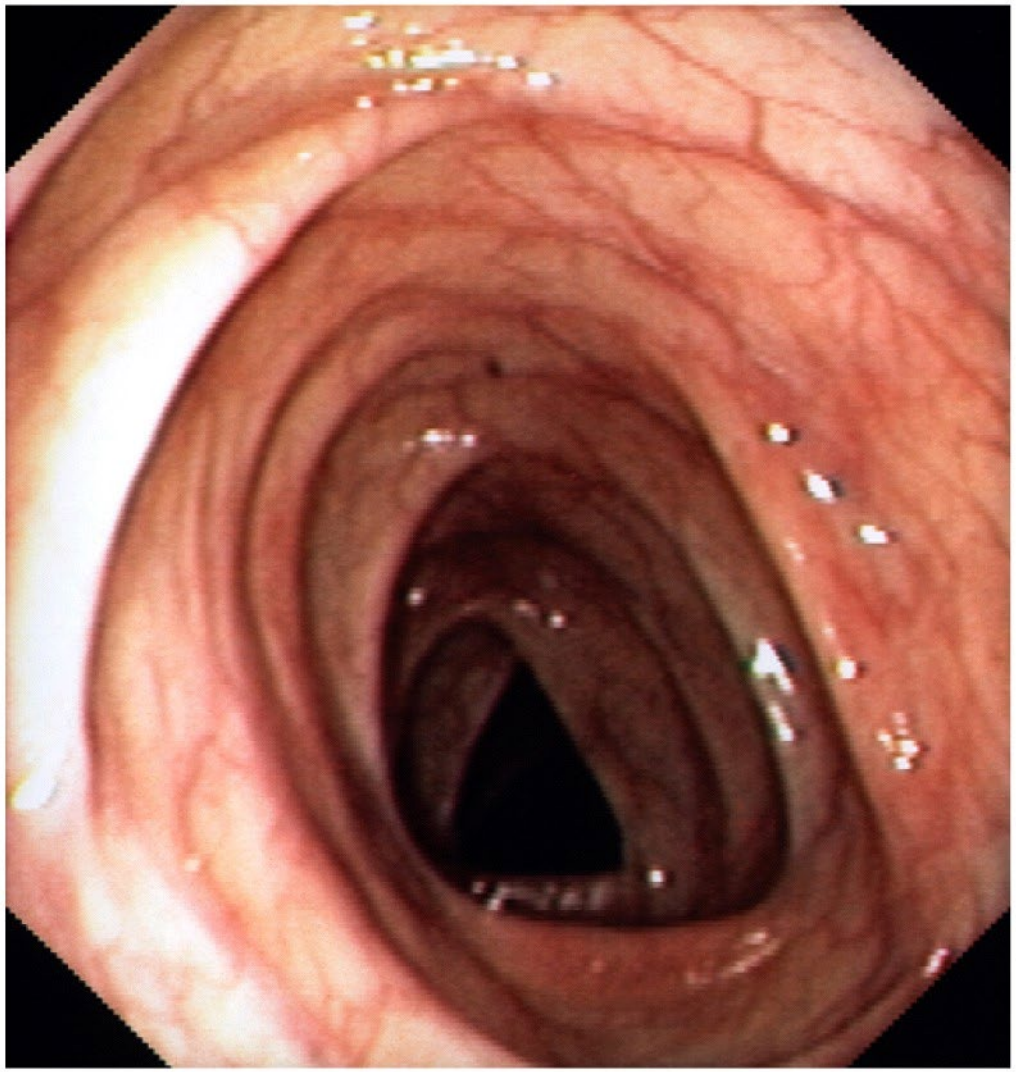
ANTERIOR



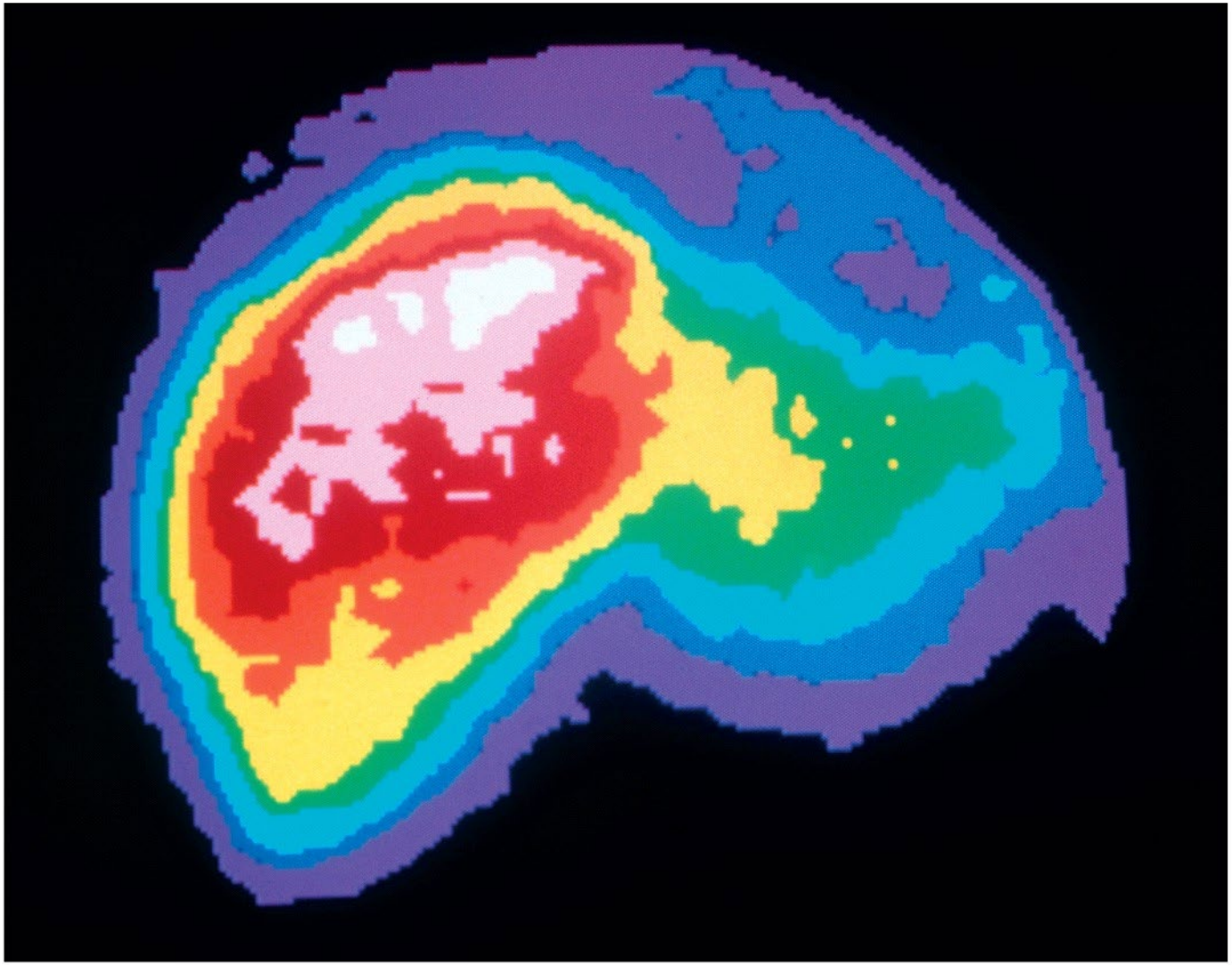
Department of Nuclear Medicine, Charing Cross Hospital/Photo Researchers, Inc.

POSTERIOR

Positron emission tomography scan of transverse section of brain (circled area at upper left indicates where a stroke has occurred)



Interior view of colon as shown by colonoscopy



Publiphoto/Photo Researchers, Inc.

Radionuclide (nuclear) scan of normal human liver