

Order | Unit V Animals: **Form and Function**

1. **Ch20 Unifying concepts**

Ch21 Nutrition and digestion

Ch22 Respiration

6. **Ch23 Circulation**

5. **Ch24 The immune system**

Ch25 Control the internal environment

2. **Ch26 Chemical regulation**

7. **Ch27 Reproduction and embryonic development**

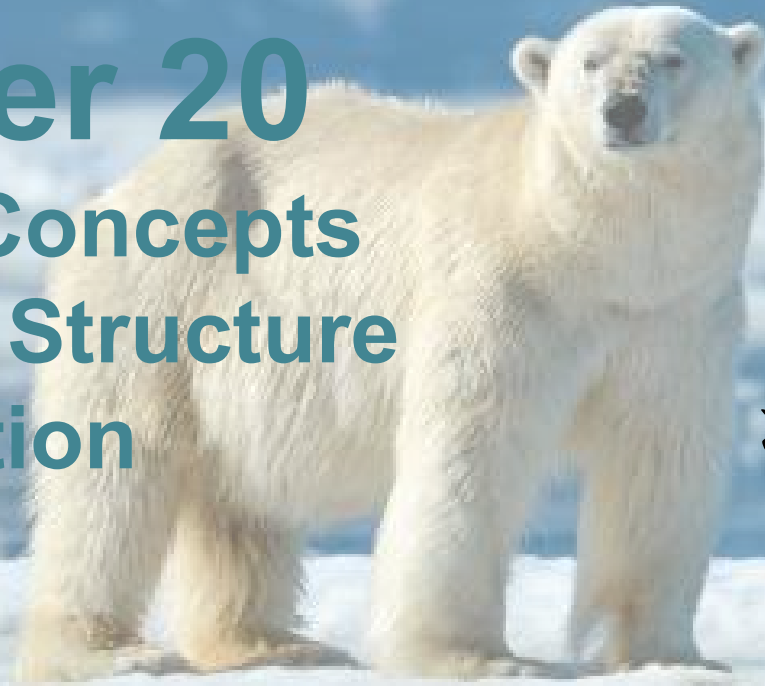
3. **Ch28 Nervous system**

4. **Ch29 The senses**

Ch30 How animals move

CAMPBELL BIOLOGY: CONCEPTS & CONNECTIONS, NINTH EDITION, GLOBAL EDITION PowerPoint Lectures

Chapter 20 Unifying Concepts of Animal Structure and Function



 全球暖化有多嚴重？北極海域溫度飆到攝氏29度
遠見雜誌 - 2019年5月14日
上周末全球氣候系統發出警報，俄羅斯西北部的北極海入口附近，氣溫上升到攝氏29度。美國夏威夷天文台近日數據顯示，地球大氣中二氧化碳 ...
跟台北一樣熱...北極海氣溫達29度
Yahoo奇摩新聞 (新聞發布) - 2019年5月14日

熱到不像話！北極海氣溫達攝氏29度全球暖化拉警報
udn 聯合新聞網 - 2019年5月14日

北極海氣溫熱達攝氏29度專家示警：二氧化碳濃度創新高
NOWnews - 2019年5月15日
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 「樂見冰帽消融帶來商機」 美國拒談氣候變遷北極理事會罕見發兩份...
環境資訊電子報 - 2019年5月14日
由於川普政府與其他北極國家對氣候的看法分歧，北極理事會有史以來首次 ... 即使我們知道氣候變遷的方向，我認為氣候變遷的程度、溫度變化的 ...

 北極融化弊大於利研究：氣候成本70兆美元，高於經濟收益十倍
環境資訊電子報 - 2019年4月24日
北極融化弊大於利研究：氣候成本70兆美元，高於經濟收益十倍 ... 永凍土層已釋放出10億噸碳，一旦溫度上升超過1.5°C，這種排放將迅速增長。

潘建源 Chien-Yuan Pan

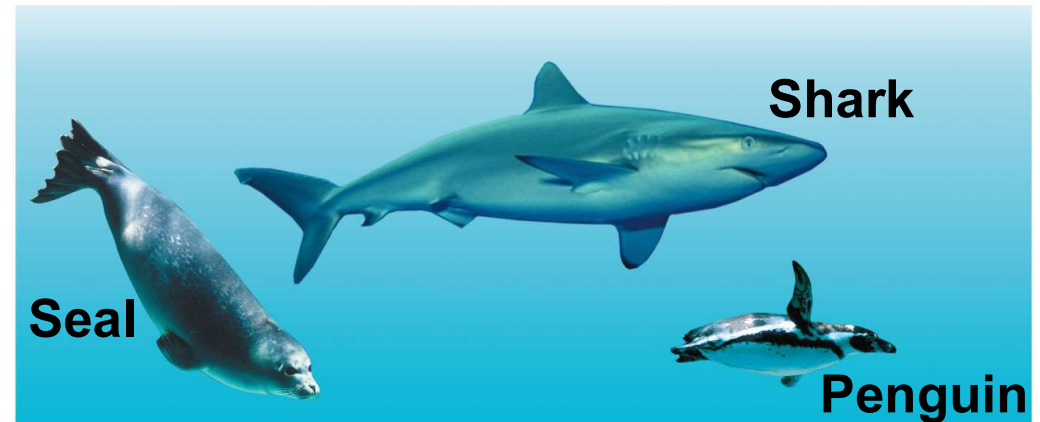
神經細胞生理研究室

生命科學系

生科館 Rm730

Introduction

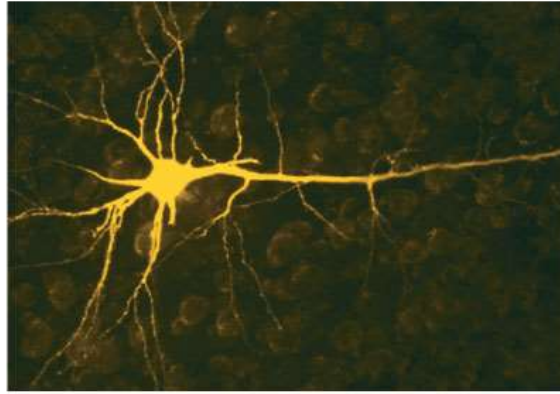
- Does evolution lead to the perfect animal form?
 - Physical structures are adaptations that enhance an animal's chances of survival and reproduction.
 - The correlation of structure and function is an overarching theme of biology.
 - Animal structures are often just “good enough” to function and not the ultimate in design.



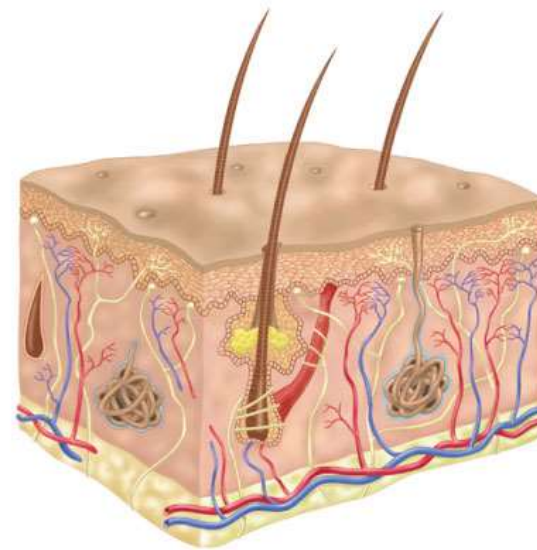
趨同演化 Convergent evolution:

Why? **Physical laws**

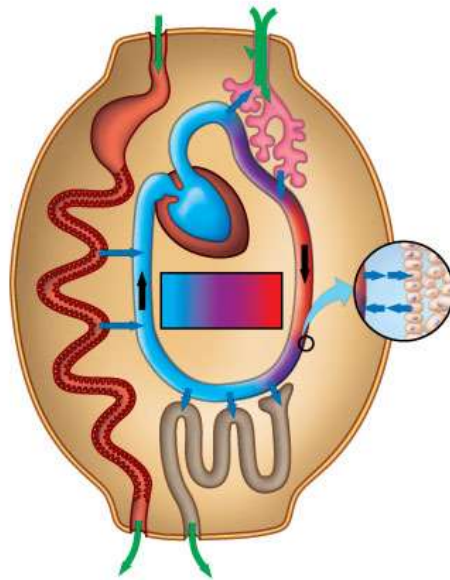
Chapter 20: Big Ideas



**Structure and Function
in Animal Tissues 20.1-20.7**



**Organs and Organ
Systems 20.8-20.12**

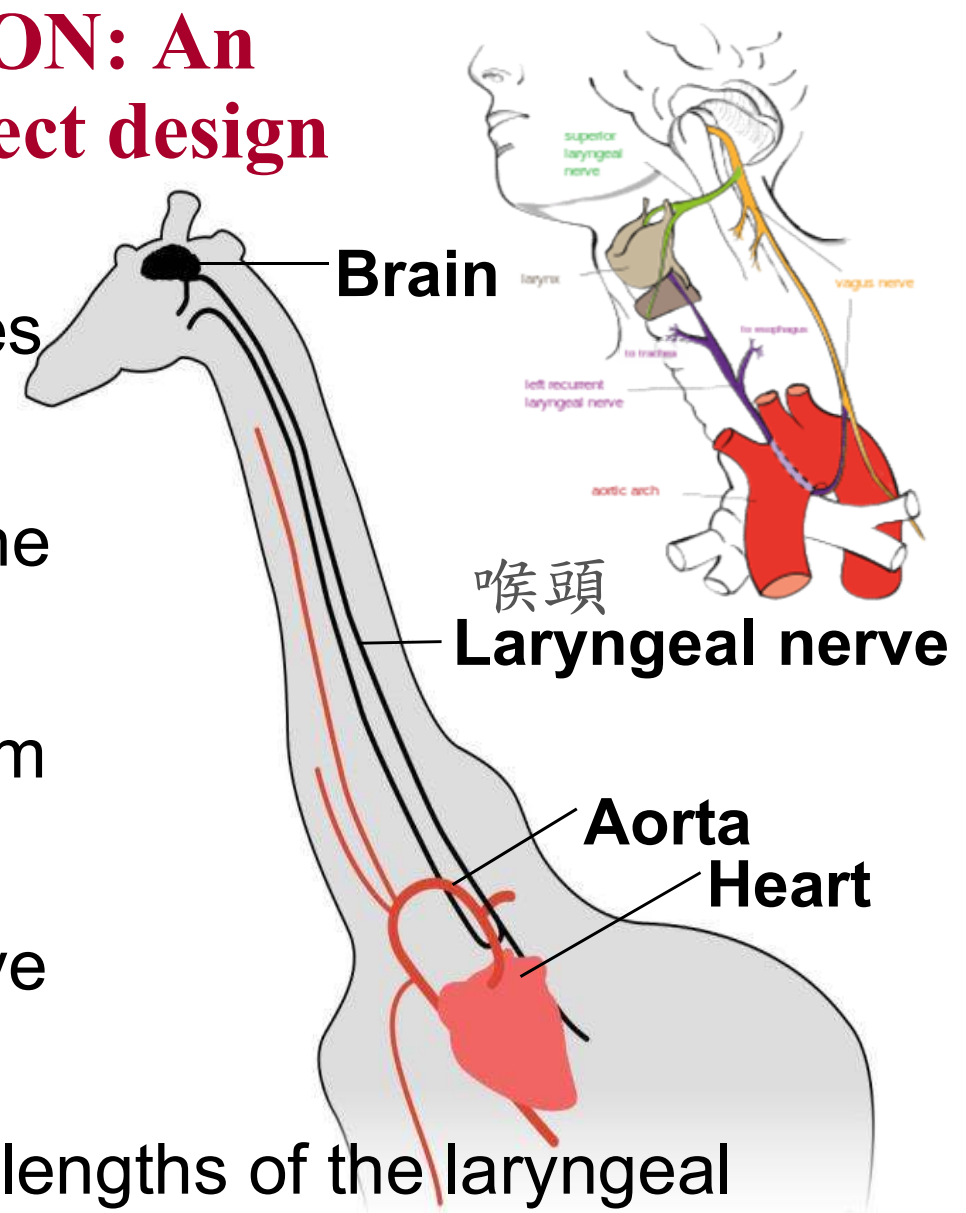


**External Exchange and
Internal Regulation 20.13-20.15**

STRUCTURE AND FUNCTION IN ANIMAL TISSUES

20.1 EVOLUTION CONNECTION: An animal's form is not the perfect design

- The laryngeal nerve of an adult giraffe travels from the brain, makes a U-turn around the aorta in the chest, and then extends back up the neck to muscles in the throat.
- The throat is about 1 foot away from the brain.
- Why, then, does the laryngeal nerve make about a 15-foot journey?
- Adaptations that led to the varying lengths of the laryngeal nerve in **tetrapods** can be illustrated with an analogy.

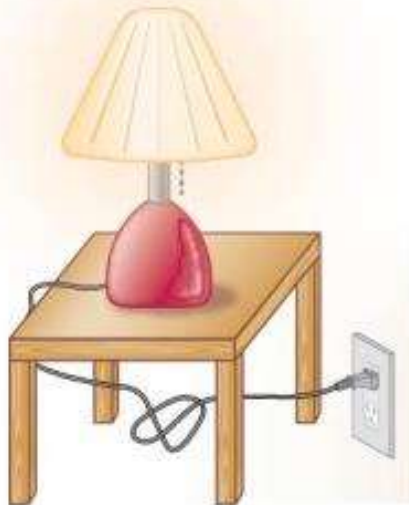


What about a dinosaur with a long long neck? (whale?)
The conduction rate? A single cell? Other way to solve this puzzle?

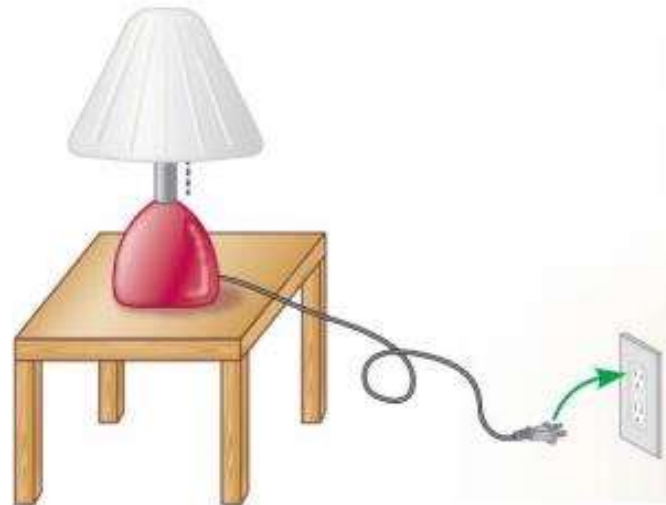
<https://whyevolutionistrue.wordpress.com/2011/05/28/the-longest-cell-in-the-history-of-life>6

- If a table is moved away from an outlet, two options are obvious for plugging in the lamp:
 1. unplug the cord and reposition the cord so that it runs directly from the lamp to the outlet, causing a temporary loss of light, or
 2. keep the cord plugged in while simply extending the cord to reach the outlet.

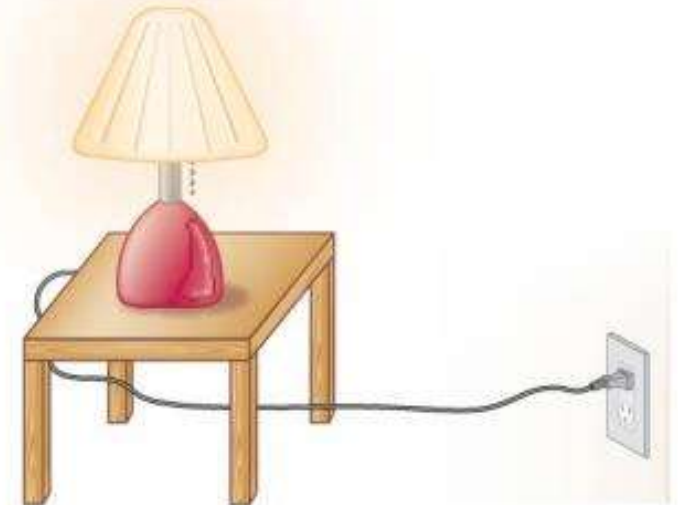
A table close to the wall outlet



Moving the table far from the wall outlet: Option 1

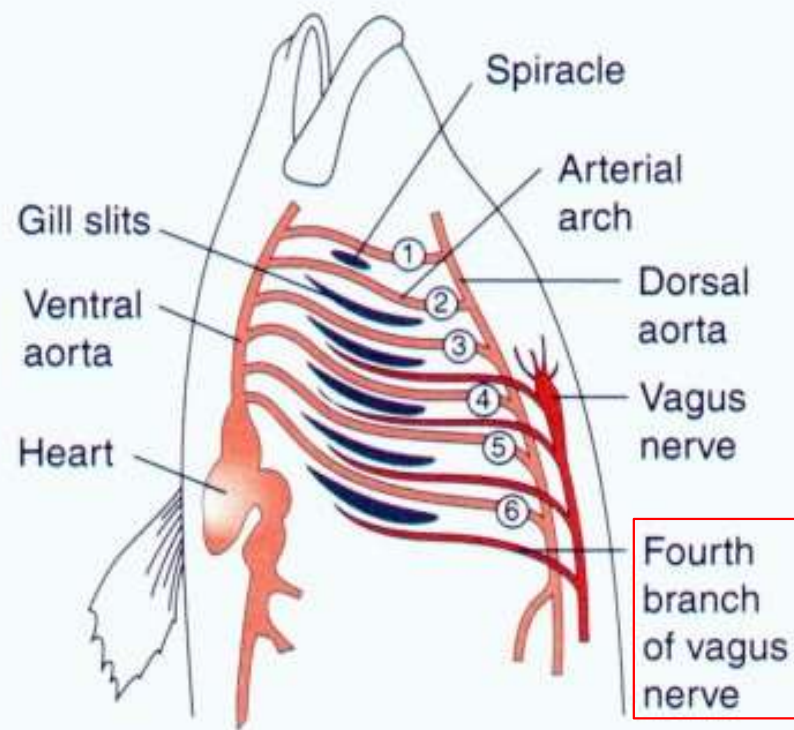


Moving the table far from the wall outlet: Option 2

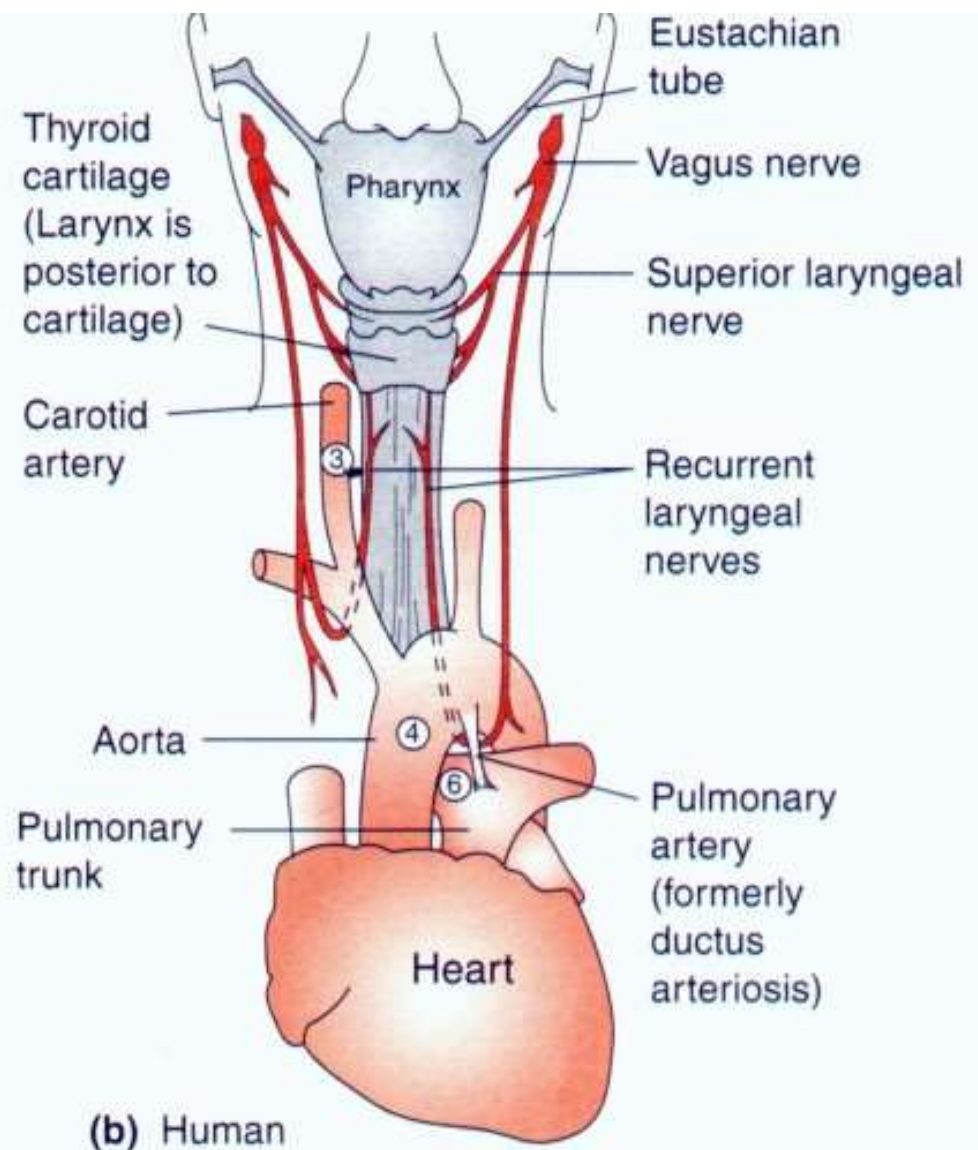


20.1 EVOLUTION CONNECTION: An animal's form is not the perfect design

- The early embryos of fish and tetrapods are very similar.
- In their embryos, the laryngeal nerve connects the brain to a rudimentary structure that
 - in fish will become the gills and
 - in tetrapods will develop into the larynx.
- In these embryos, the **nerve hooks under the aorta**.
 - This is not problematic in fish because they do not have necks.
 - But in tetrapods, the aorta ends up in the chest, resulting in an elongated laryngeal nerve in tetrapods.



(a) Fish



(b) Human

FIGURE 3-11 Schematic diagram showing the relationship between the vagus-cranial nerve and the arterial arches in fish (a) and human (b). Only the third, fourth, and part of the sixth arterial arches remain in placental mammals, the sixth acting only during fetal development to carry blood to the placenta. The fourth vagal nerve in mammals (the recurrent laryngeal nerve) loops around the sixth arterial arch just as it did in the original fishlike ancestor, but must now travel a greater distance since the remnant of the sixth arch is in the thorax.

<https://whyevolutionistrue.wordpress.com/2011/05/28/the-longest-cell-in-the-history-of-life/>

20.2 Structure fits function at all levels of organization in the animal body

- **Anatomy** is the study of **structure**. 解剖學、形態學、生理學
- **Physiology** is the study of **function**.
- Animals consist of a hierarchy of levels of organization.
 - **Tissues** are an integrated group of similar cells that perform a common function.
 - **Organs** perform a specific task and consist of two or more tissues.
 - **Organ systems** consist of multiple organs that together perform a vital body function.



A Cellular level
Muscle cell



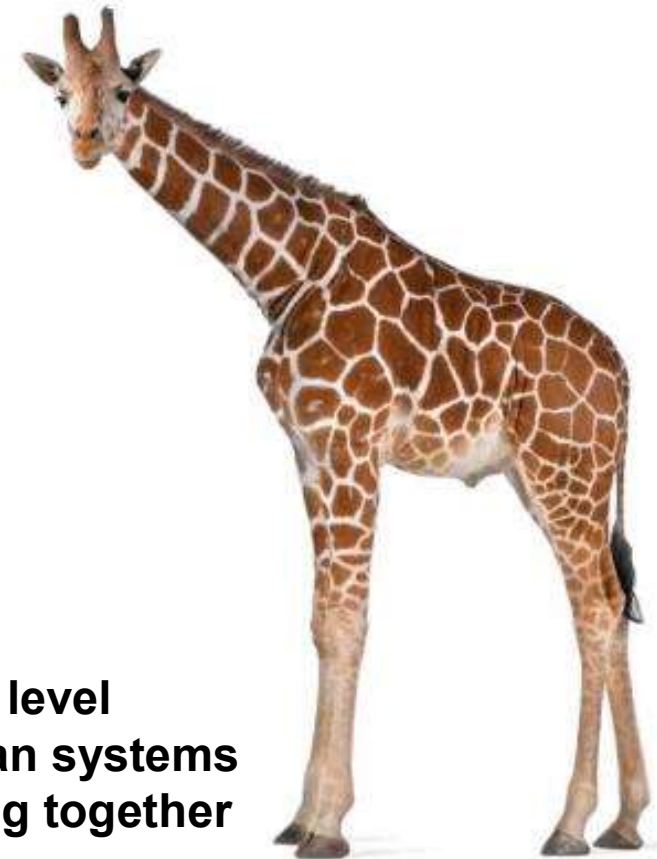
B Tissue level
Muscle tissue



C Organ level
Heart



D Organ system level
Circulatory system



E Organism level
Many organ systems
functioning together

Tyrannosaurus was not a fast runner. Nature (2002) 415, 1018-1021

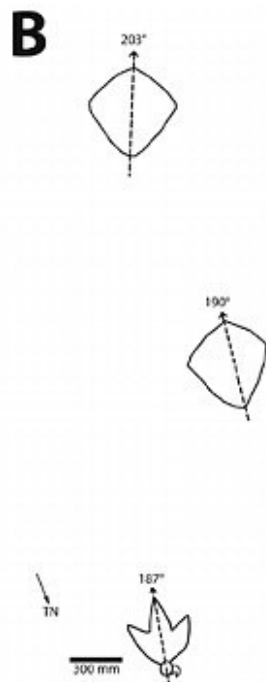
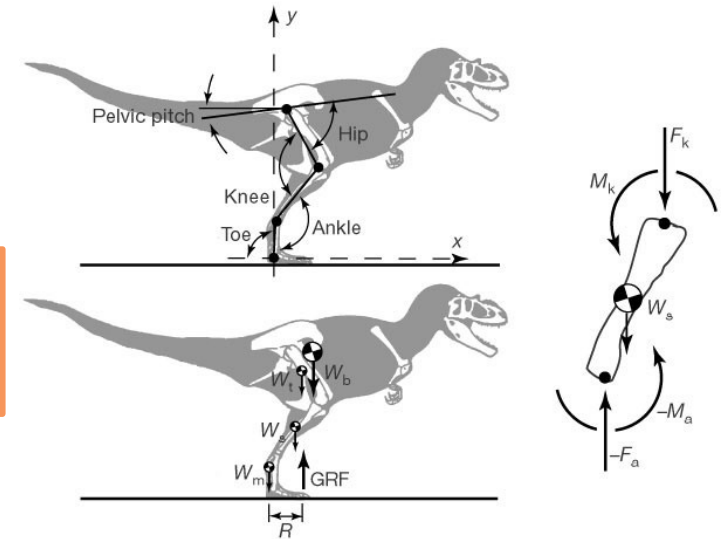
John R. Hutchinson & Mariano Garcia

Department of Integrative Biology, UC Berkeley

Speed and extensor muscle

- ~6000 kg
- 5 m/s (18 km/hr)
- turning 45° in about 1–2 s
- too slow to prey on large contemporaries

2013 new model
simulation: 29 Km/hr



Jurassic Park 1: Must go faster
<https://www.youtube.com/watch?v=rxqHVoZ0fzc>

The prints found in Wyoming reveal a young or adolescent tyrannosaurus traveling at 4.5 to 8 Km/hr. (Note. This is not the top speed)

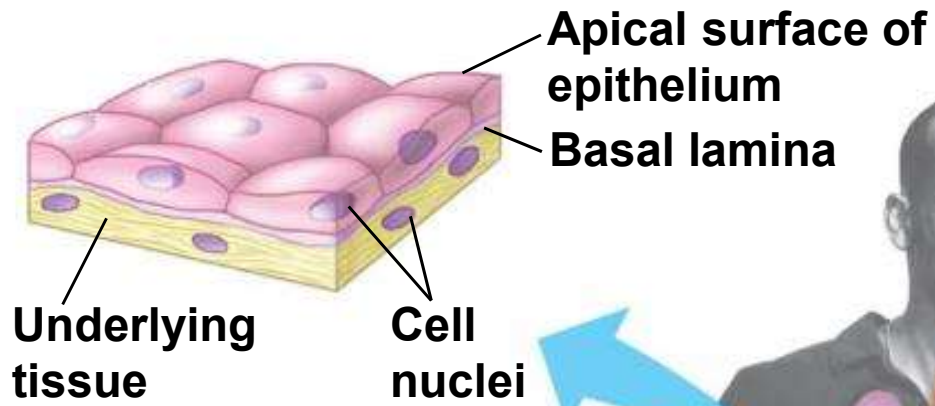
<http://www.dailymail.co.uk/sciencetech/article-3419984/Could-outrun-T-rex-Researchers-reveal-dinosaur-s-walk-slower-human-run-say-terrifying-predator-s-speed-mystery.html>

20.3 Tissues are groups of cells with a common structure and function

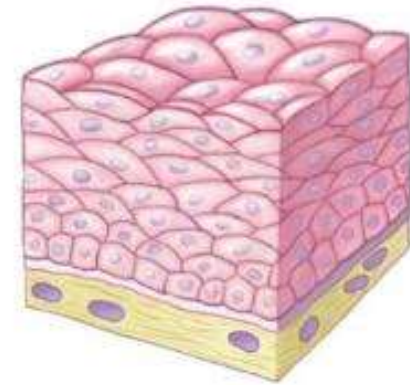
- Tissues
 - are an integrated group of **similar cells** that perform a **common function** and
 - combine to form organs.
- Animals have four main categories of tissues:
 1. epithelial tissue, 表皮
 2. connective tissue, 結締
 3. muscle tissue, and
 4. nervous tissue.

20.4 Epithelial tissue covers the body and lines its organs and cavities 表皮組織

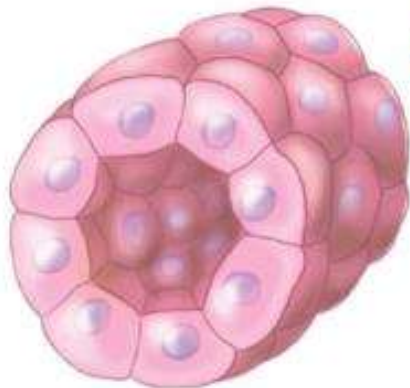
- **Epithelial tissues**, or epithelia, are sheets of closely packed cells that
 - cover **body surfaces** and
 - line **internal** organs and cavities.
- Epithelial cells come in **three shapes**:
 1. squamous—like a fried egg,
 2. cuboidal—as tall as they are wide, and
 3. columnar—taller than they are wide.
- Epithelial tissues are named according to the
 - number of **cell layers** they have and
 - **shape** of the cells on their apical surface.



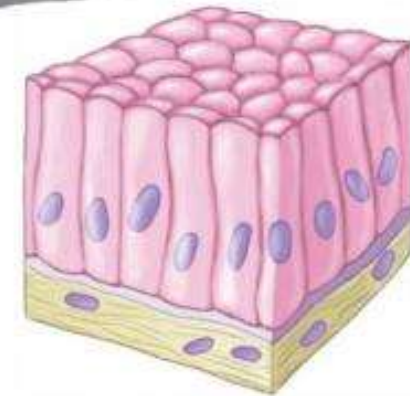
A Simple squamous epithelium



D Stratified squamous epithelium



B Simple cuboidal epithelium



C Simple columnar epithelium

20.5 Connective tissue binds and supports other tissues

Connective tissue can be grouped into six major types.

Cells + extracellular matrix

1. Loose connective tissue

- is the most widespread, 膠原蛋白 彈性纖維
- consists of ropelike collagen and **elastic fibers** that are strong and resilient, 彈性
- helps to join skin to underlying tissues.

2. Fibrous connective tissue

- has **densely packed** collagen fibers 肌腱 & 韌帶
- forms **tendons** that attach muscle to bone. **Ligaments**: link bone at joints

3. Adipose tissue stores fat in large, closely packed cells held in a matrix of fibers.

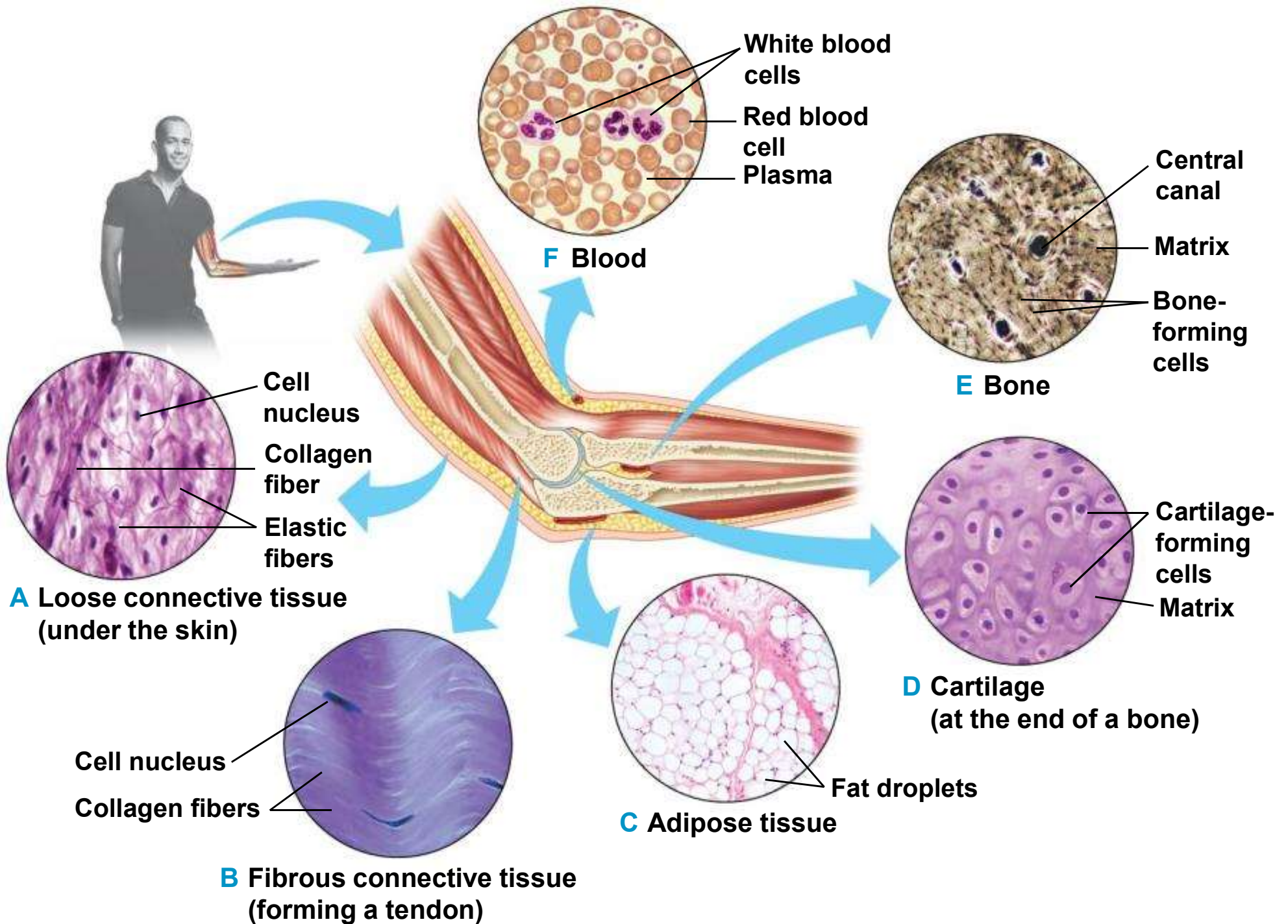
4. Cartilage 軟骨

- is a strong and flexible skeletal material and
- commonly surrounds the **ends of bones**.

5. Bone

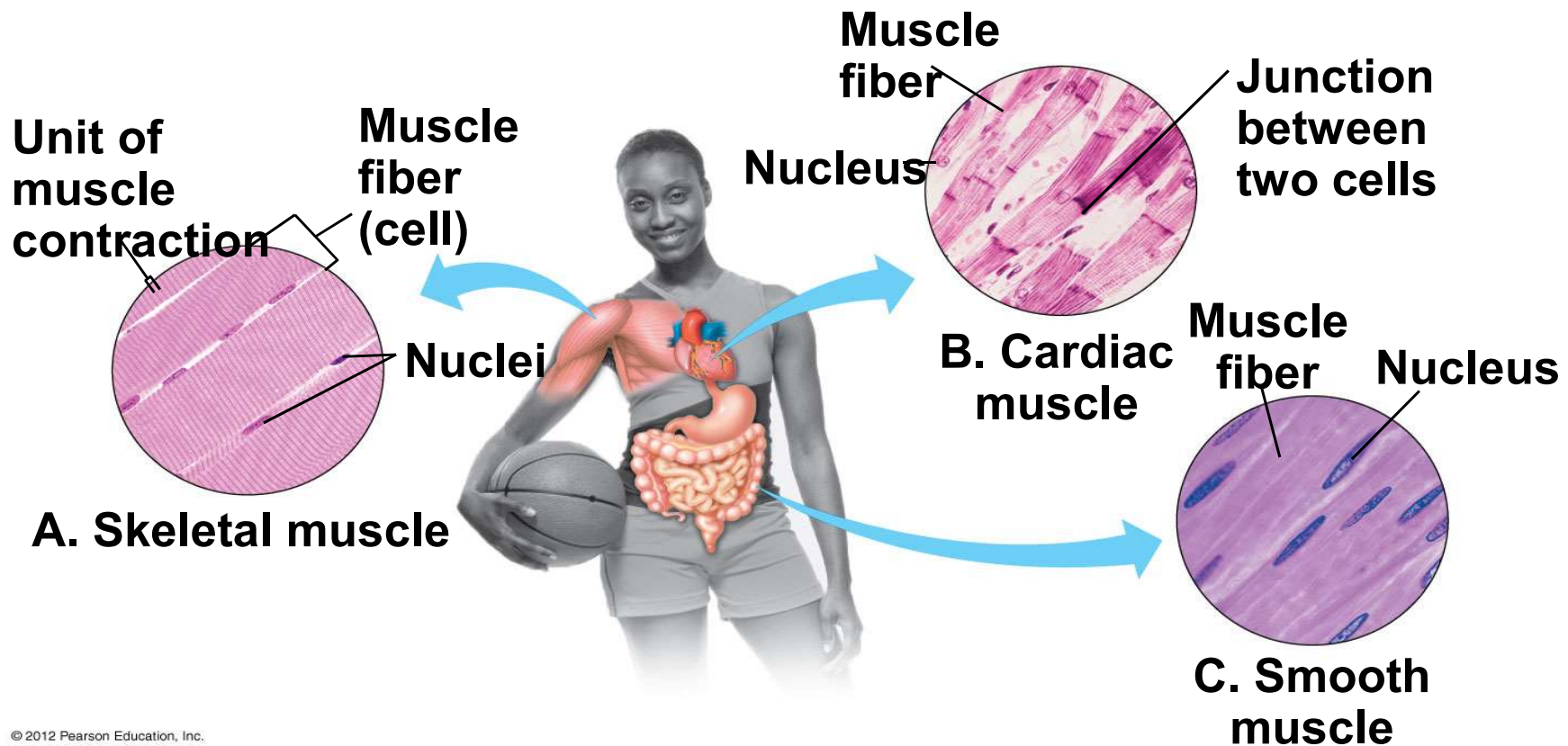
- has a matrix of collagen fibers
- embedded in a hard mineral substance containing calcium, magnesium, and **phosphate**.

6. Blood transports substances throughout the body.



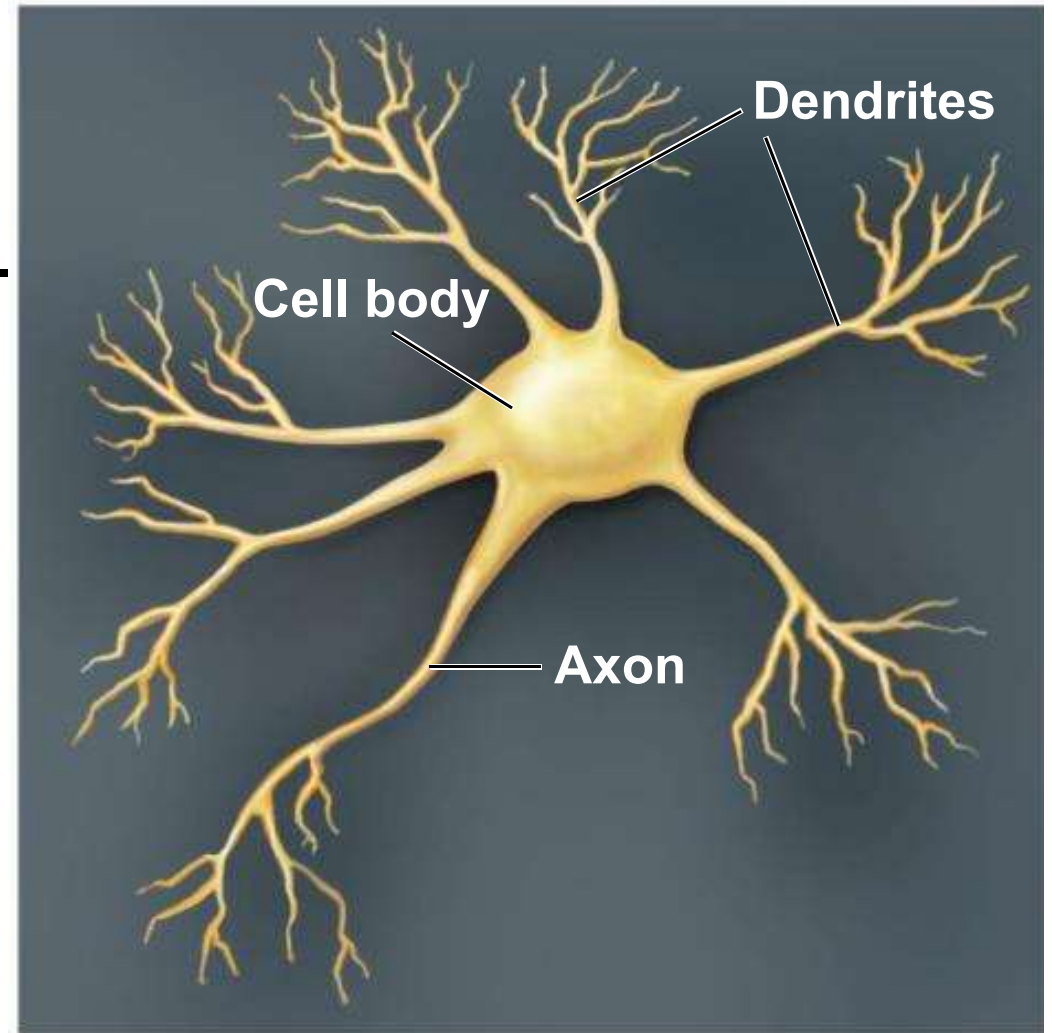
20.6 Muscle tissue functions in movement

- **Muscle tissue** is the most abundant tissue in most animals.
- There are three types of vertebrate muscle tissue:
 1. **Skeletal muscle** causes voluntary movements.
 2. **Cardiac muscle** pumps blood.
 3. **Smooth muscle** moves walls of internal organs, such as the intestines.



20.7 Nervous tissue forms a communication network

- **Nervous tissue**
 - senses stimuli and
 - rapidly transmits information.
- **Neurons** carry signals by conducting electrical impulses.
- Other cells in nervous tissue
 - insulate axons,
 - nourish neurons,
 - regulate the fluid around neurons.

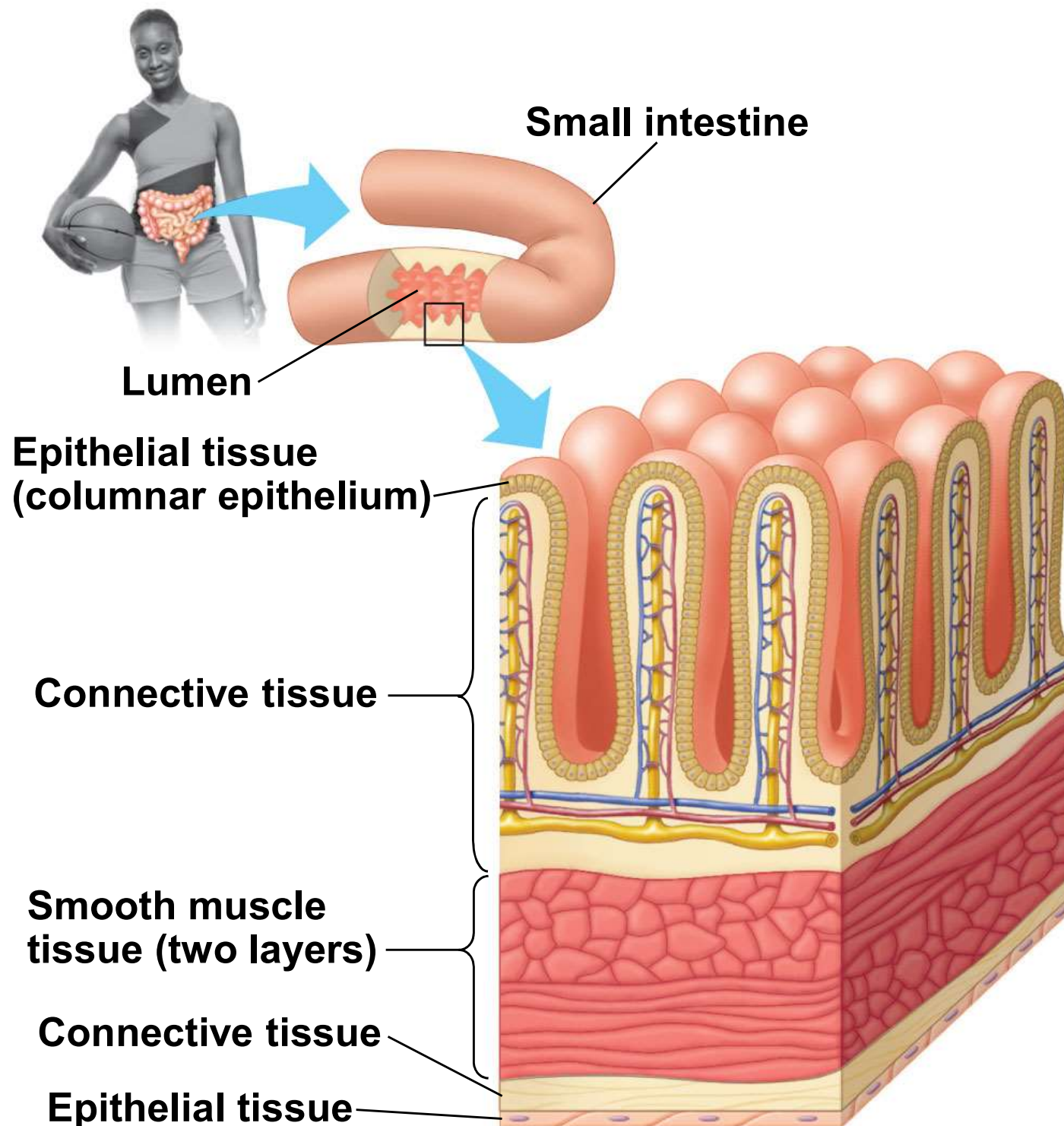


ORGANS AND ORGAN SYSTEMS

20.8 Organs are made up of tissues

- Each tissue performs specific functions.
- The heart has
 - extensive **muscle** that generates contractions,
 - **epithelial** tissues that line the heart chambers,
 - **connective** tissues that make the heart elastic, and
 - **neurons** that regulate contractions.
- The small intestine
 - is lined by a columnar **epithelium**,
 - includes **connective** tissues that contain blood vessels, and
 - has two layers of smooth **muscle** that help propel food.
- The inner surface of the small intestine has many fingerlike projections that increase the surface area for absorption.

Figure 20.8



20.9 CONNECTION: Bioengineers are learning to produce tissues and organs for transplants

- Bioengineering is seeking ways to repair or replace damaged tissues and organs.
- New tissues and organs are being grown on a scaffold of connective tissue from donated organs.
- Other researchers are using desktop printers to create layers of different cells resembling the structure of organs.
- These techniques
 - remove the risk of tissue rejection and
 - may someday reduce the shortage of organs available for transplants.

To make a bladder

1. From intestine: but the intestine absorb “nutrients”
2. Artificial pack

Tissue-engineered autologous bladders for patients needing cystoplasty.

(2006) Lancet, 367, 1241-1246. Atala et al. Wake Forest University

- 7 patients, 4~19 yrs old, need cytoplasty (擴大術)

- 尿道上皮細胞及肌肉細胞

- seeded on a biodegradable bladder-shaped scaffold made of collagen

- Takes 7 days

- Follow-up 21~61 months

Tissue Engineering

2008 Windpipe (氣管) from patient's own stem cell

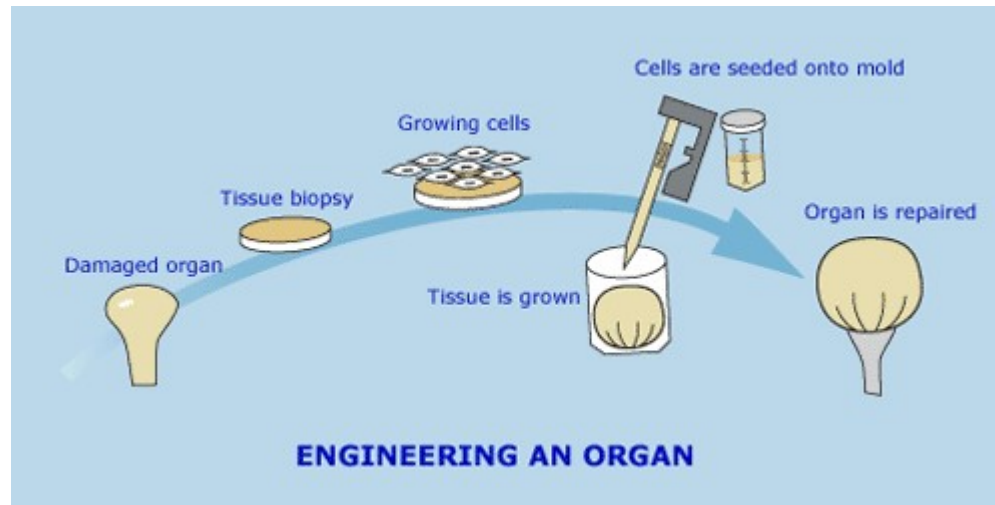
In vitro meat

2013 1st hamburger, 1.2 million per pound

2017 Memphis Meats say

9,000 USD and 1.000 2018

2019 Aleph Farms say 100



Lab-Grown Meat Is Coming, but the Price Is Hard to Stomach

Wall Street Journal - 2019年5月2日

Lab-grown, or “cultured,” meat is not yet available for sale, but within five ... Mr. Selden and other makers of cultured meat, such as Memphis Meats, Ultimately, however, the success of the market will come down to taste.



The first cell-cultured meat will cost about \$50 (a hamburger)

Quartz - 2019年4月17日

The price of cell-cultured meat depends on a company's ability to produce ... In March 2017, Memphis Meats told the Wall Street Journal that it'd ...

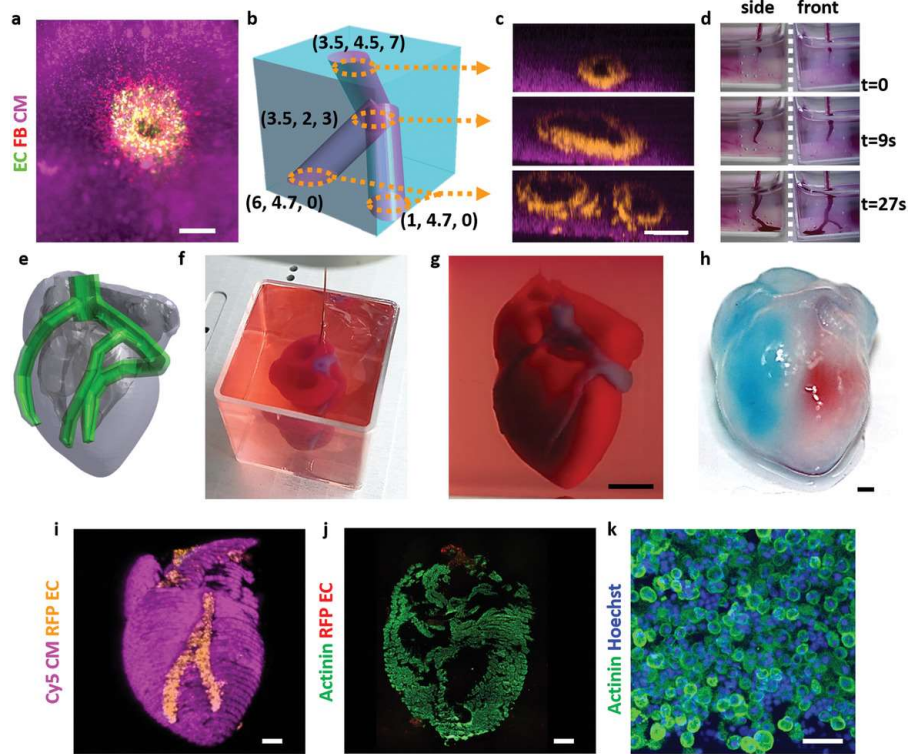


Beyond Meat preps for IPO as rivals take bite out of food industry

The Guardian - 2019年4月27日

At some point in the next four weeks, Beyond Meat, a pioneering ... together with poultry and sausage substitutes that taste far closer to the real thing ... Memphis Meats, another company developing cultured meats, boasts the ...

3D Printing of Personalized Thick and Perfusable Cardiac Patches and Hearts. *Advanced Science*, 2019; 1900344 DOI: [10.1002/advs.201900344](https://doi.org/10.1002/advs.201900344)



Printing thick vascularized tissues. a) A top view of a lumen entrance (CD31; green) in a thick cardiac tissue (actinin; pink). b) A model of a tripod blood vessel within a thick engineered cardiac tissue (coordinates in mm), and c) the corresponding lumens in each indicated section of the printed structure. d) Tissue perfusion visualized from dual viewpoints. e–k) A printed small-scaled, cellularized, human heart. e) The human heart CAD model. f,g) A printed heart within a support bath. h) After extraction, the left and right ventricles were injected with red and blue dyes, respectively, in order to demonstrate hollow chambers and the septum in-between them. i) 3D confocal image of the printed heart (CMs in pink, ECs in orange). j,k) Cross-sections of the heart immunostained against sarcomeric actinin (green). Scale bars: (a,c,h, i,j) = 1 mm, (g) = 0.5 cm, (k) = 50 μm .



Scientists 'print' 3D heart using patient's tissue

Medical News Today - 2019年4月16日

Scientists 'print' 3D heart using patient's tissue ... describe their method in a recent paper published in the journal *Advanced Science*.

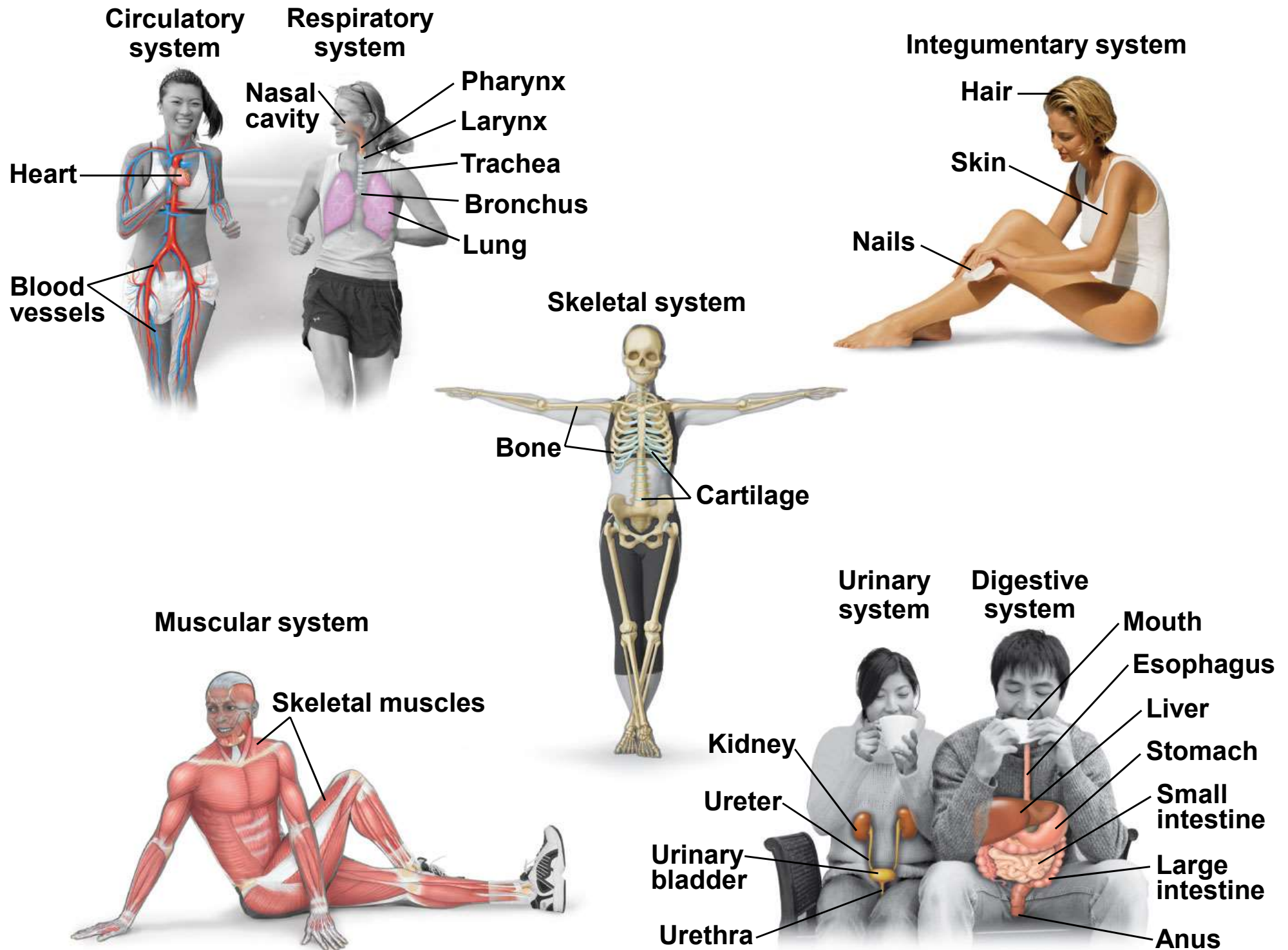
World's first 3D-printed heart with human tissue revealed

euronews - 2019年4月18日

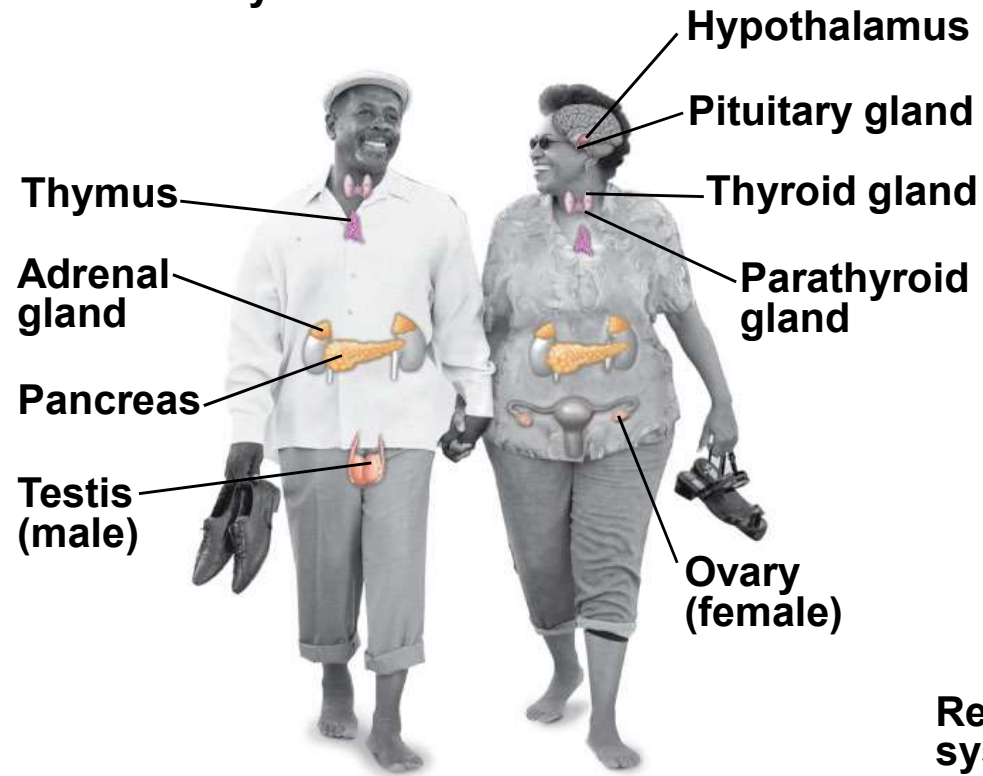
20.10 Organ systems work together to perform life's functions

- Each organ system
 - typically consists of many organs,
 - has one or more functions, and
 - works with other organ systems to create a functional organism.
- The **circulatory system**
 - delivers oxygen and nutrients to body cells,
 - transports carbon dioxide to the lungs, and
 - carries metabolic wastes to the kidneys.
- The **respiratory system** exchanges gases with the environment,
 - supplying the blood with oxygen and
 - disposing of carbon dioxide.

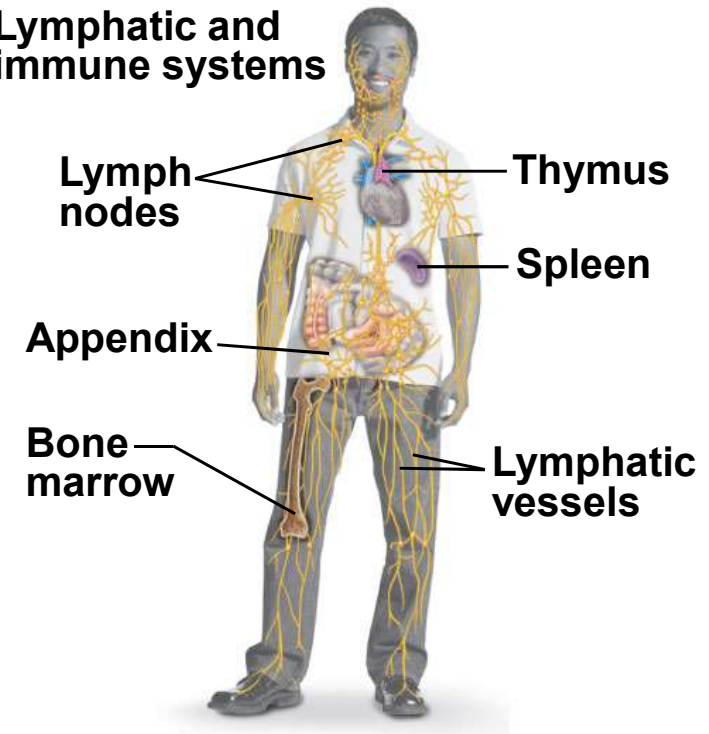
Figure 20.10_L



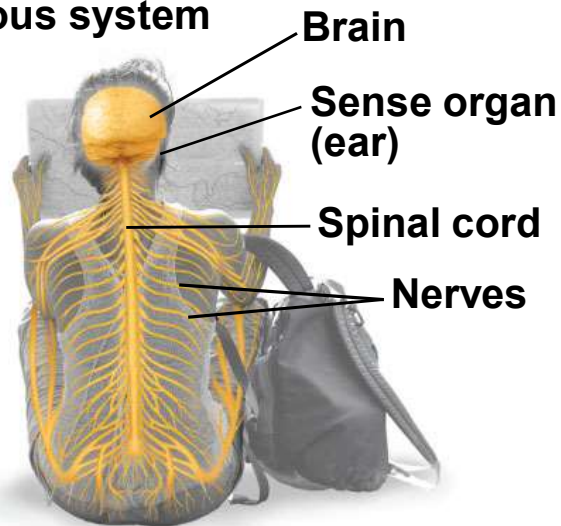
Endocrine system



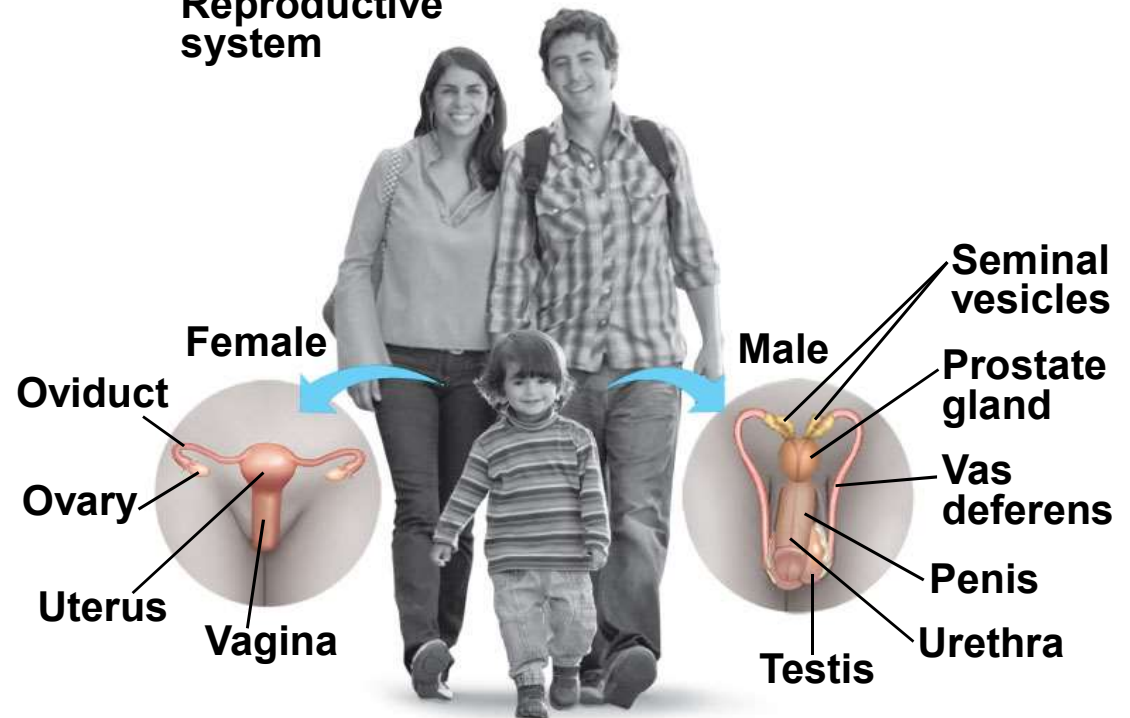
Lymphatic and immune systems



Nervous system



Reproductive system



20.10 Organ systems work together to perform life's functions

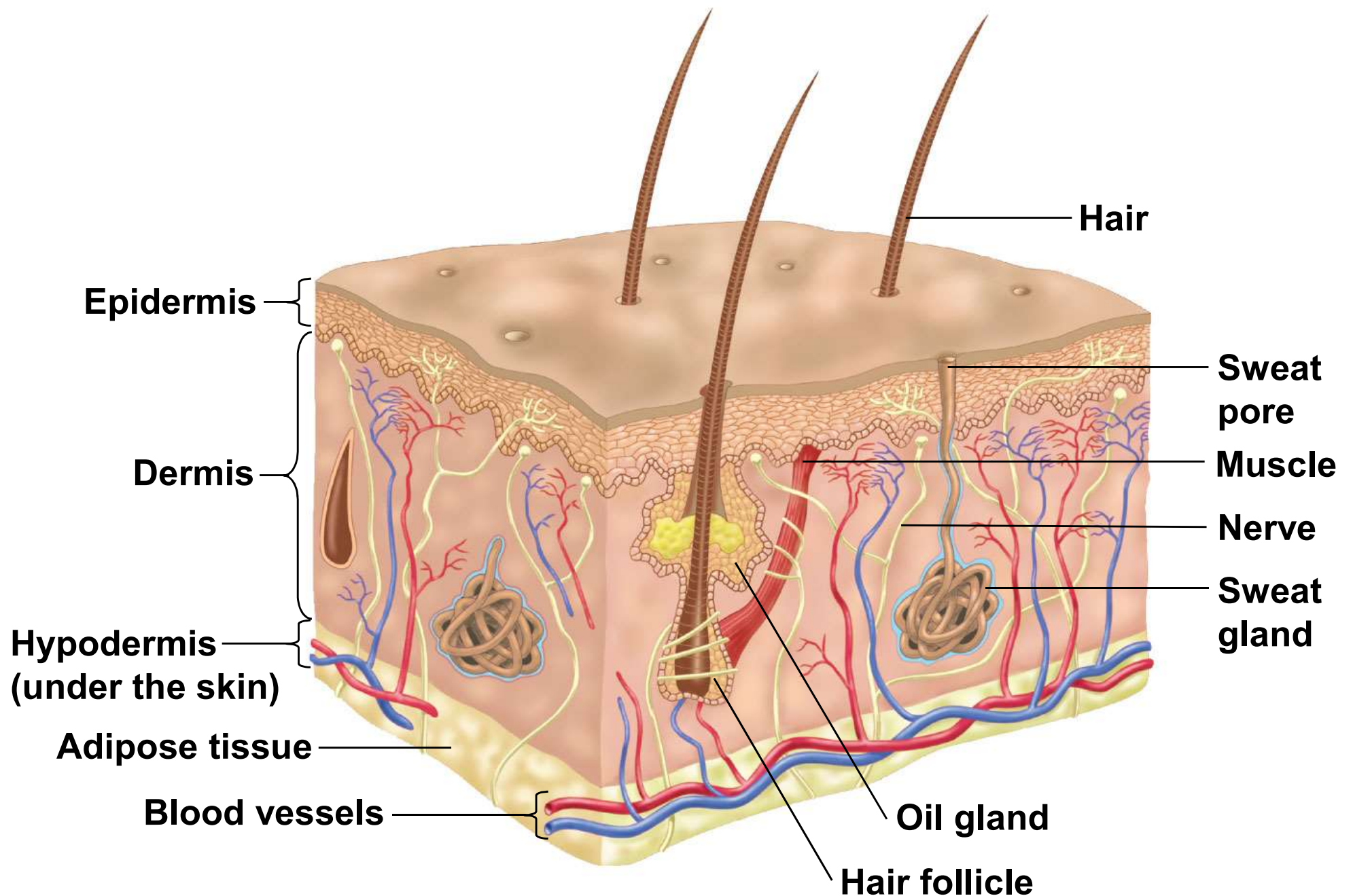
- The **integumentary system** protects against
 - physical injury,
 - infection,
 - excessive heat or cold, and
 - drying out.
- The **skeletal system**
 - supports the body,
 - protects organs such as the brain and lungs, and
 - provides the framework for muscle movement.
- The **muscular system**
 - moves the body,
 - maintains posture, and
 - produces heat.

- The **urinary system**
 - removes waste products from the blood,
 - excretes urine, and
 - regulates the chemical makeup, pH, and water balance of blood.
- The **digestive system**
 - ingests and digests food,
 - absorbs nutrients, and
 - eliminates undigested material.
- The **endocrine system** secretes hormones that regulate body activities.
- The **lymphatic** and **immune systems** protect the body from infection and cancer.
- The lymphatic system also returns excess body fluid to the circulatory system.

- The **nervous system** coordinates body activities by
 - detecting stimuli,
 - integrating information, and
 - directing responses.
- The **reproductive system** produces
 - gametes and
 - sex hormones.
- The female reproductive system
 - supports a developing embryo and
 - produces milk.

20.11 The integumentary system protects the body

- The skin consists of two layers:
 1. The epidermis 表皮
 - is a stratified squamous epithelium and
 - forms the surface of the skin.
 2. The dermis 真皮
 - forms a deeper skin layer and
 - is composed of dense connective tissue with many resilient elastic fibers and strong collagen fibers.
 - The dermis contains hair follicles, oil and sweat glands, muscle cells, nerves, sensory receptors, and blood vessels.
- Skin has many functions.
 - The epidermis
 - resists physical damage, decreases water loss, and prevents penetration by microbes.
 - The dermis
 - collects sensory information, synthesizes vitamin D, and helps regulate body temperature.

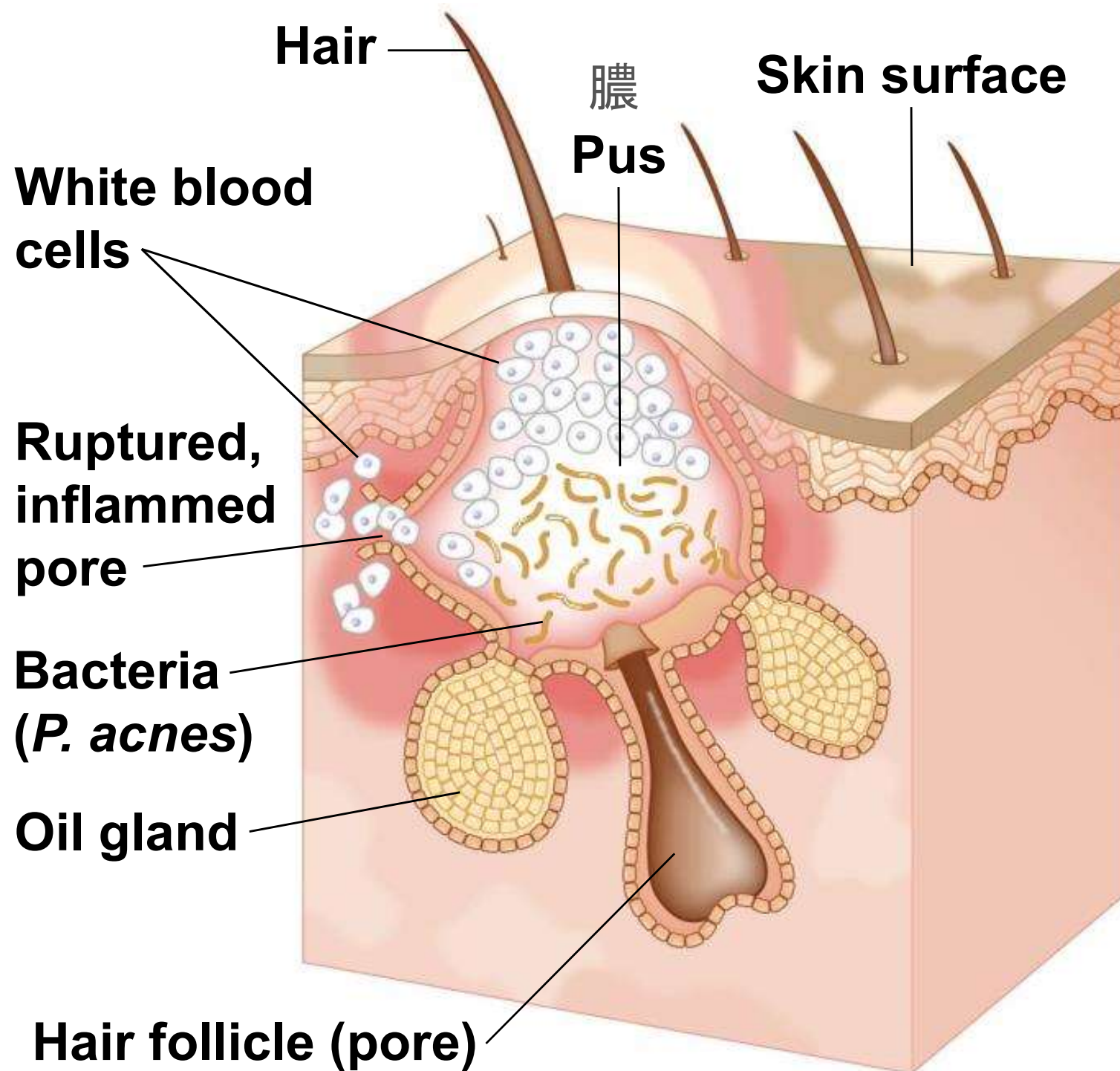


20.11 The integumentary system protects the body

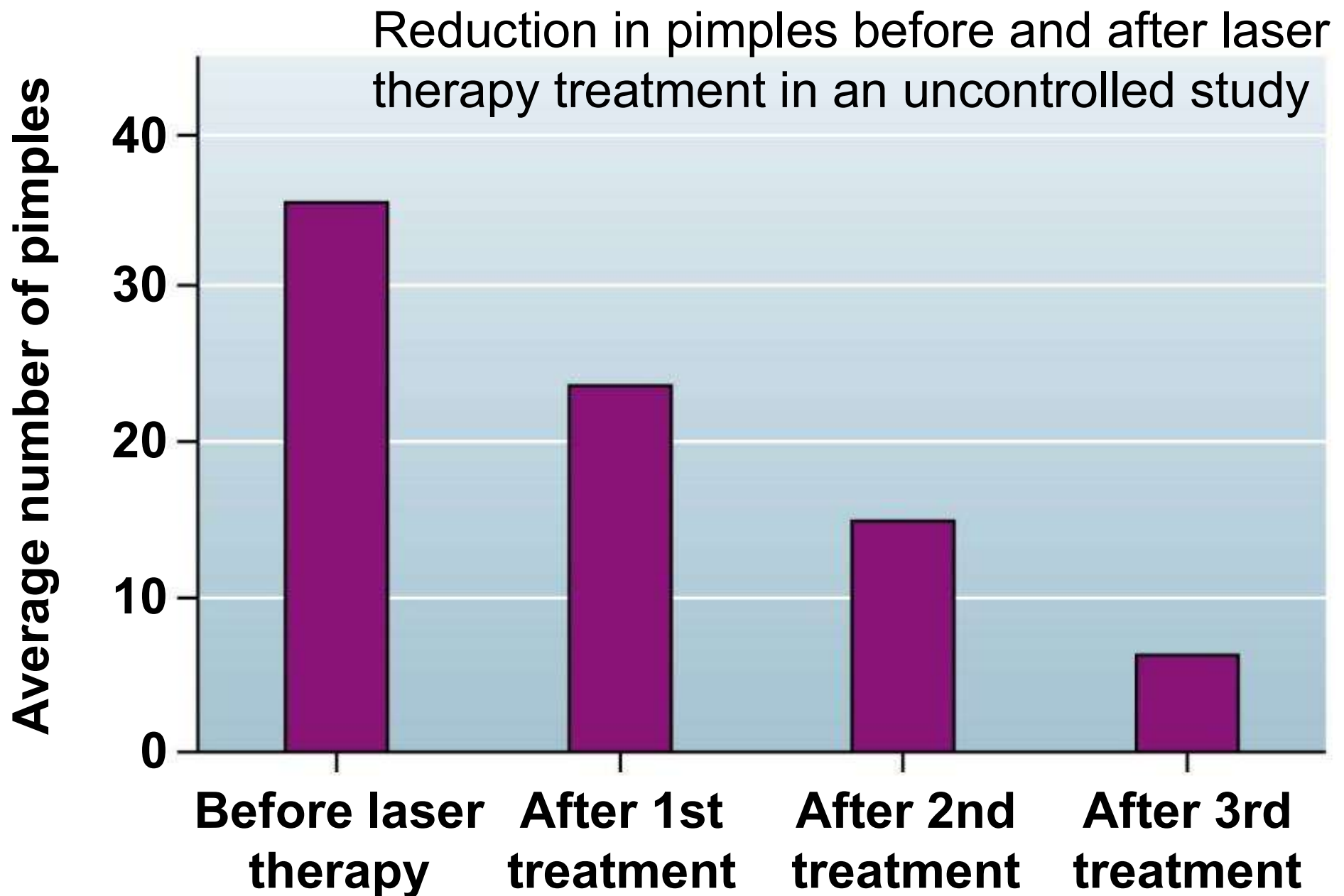
- Exposure of the skin to ultraviolet light
 - causes skin cells to release **melanin**, which contributes to a visible **tan**, and 黑色素
 - damages DNA of skin cells and can lead to
 - premature aging of the skin, cataracts, and skin cancers.
- Hair
 - is an important component of the integumentary system of mammals,
 - helps to **insulate** their bodies, and
 - consists of a shaft of keratin-filled dead cells. 角蛋白
- Oil glands release oils that
 - are associated with hair follicles, lubricate hair,
 - condition surrounding skin, and
 - inhibit the growth of bacteria.

20.12 SCIENTIFIC THINKING: Well-designed studies help answer scientific questions

- As consumers, we are bombarded with claims daily.
- To make informed decisions and behave as responsible consumers, we should evaluate information as scientists do.
- For example, consider claims for **acne treatment**.
- Acne results when the **hair follicles** that produce oil become **clogged** with dead cells and oil.
- When the pore is plugged, bacteria of the species *Propionibacterium acnes* (*P. acnes*) become trapped in the follicle.
- If the follicle ruptures into the dermis and white blood cells are recruited from the immune system, the pore is said to be inflamed in what we commonly call a “pimple” or “zit.”

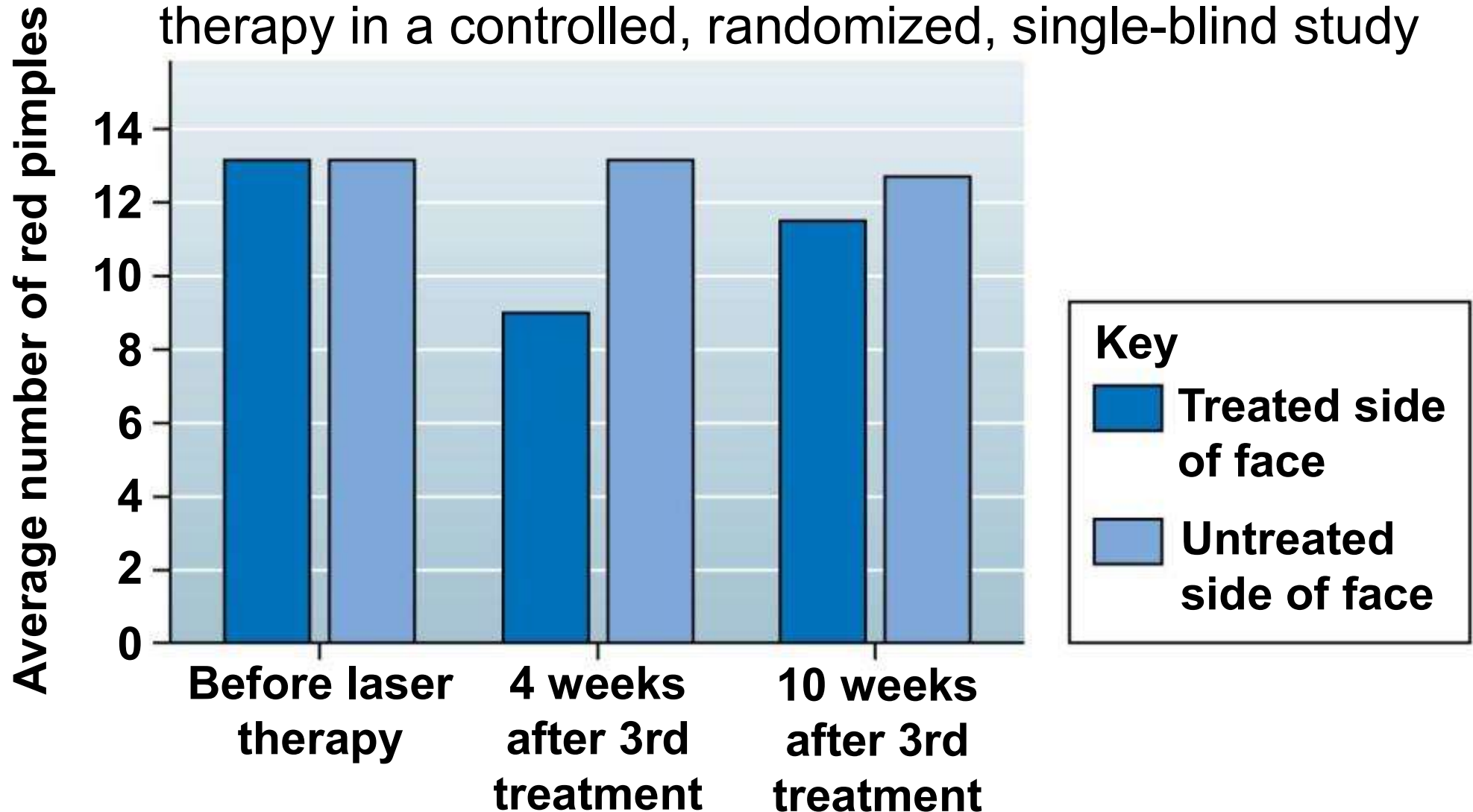


- Consider a study involving 19 individuals, all chosen because they had at least five pimples.
- After three treatments, all participants had a significant reduction in the total number of pimples.
- But the study **did not have a control group** that could reveal if individuals who had undergone laser therapy would have had the same reduction in pimples if they had not had the procedure.
- The study also failed to control variables. The participants were allowed to continue using acne medications over the course of the study.



Reprinted from P. M. Friedman et al., Treatment of inflammatory facial acne vulgaris with the **1450-nm** diode laser: A pilot study, *Dermatologic Surgery* 30: 147–51 (2004), with permission.

Reduction in a subtype of pimple before and after laser therapy in a controlled, randomized, single-blind study



Data from J. S. Orringer et al., Photodynamic therapy for acne vulgaris: A randomized, controlled, **split-faced** clinical trial of topical aminolevulinic acid and **pulsed dye** therapy, *Journal of Cosmetic Dermatology* 9: 28–34 (2010).

EXTERNAL EXCHANGE AND INTERNAL REGULATION

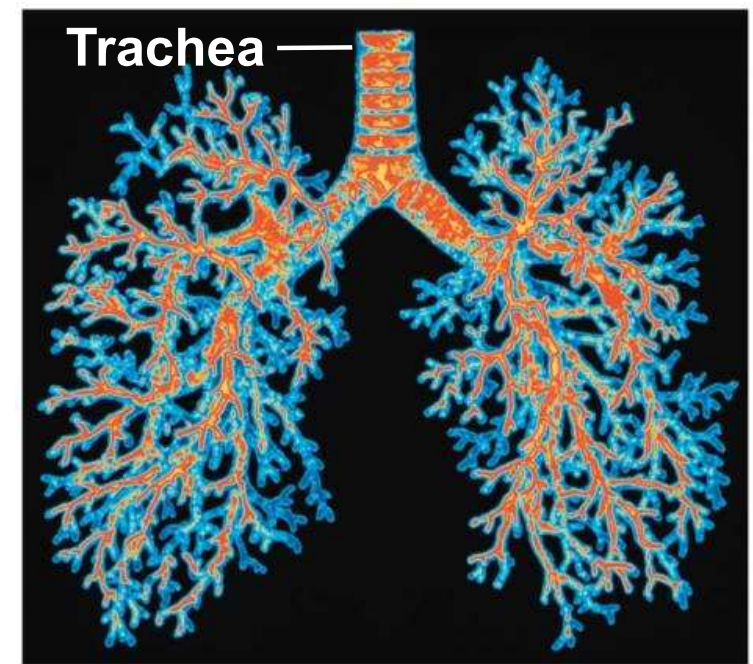
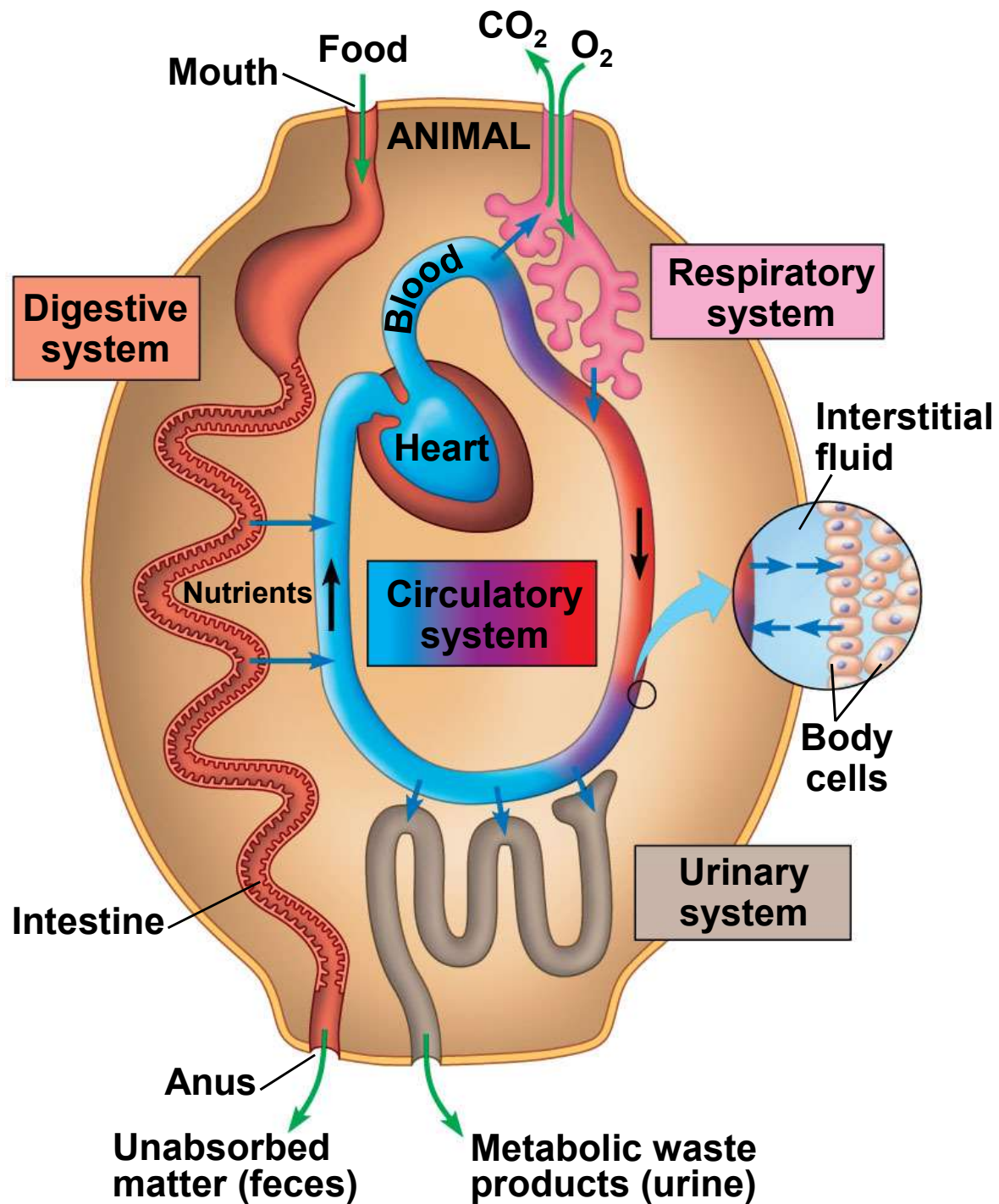
20.13 Structural adaptations enhance exchange with the environment

- Every organism is an **open system** that must exchange matter and energy with its surroundings.
- Cells in small and flat animals can exchange materials directly with the environment.
- However, as organisms increase in size, the **surface area**
 - is too small for the corresponding volume and
 - too far away from the deepest cells of the body.
- In these larger organisms, evolutionary adaptations
 - consist of extensively branched or folded surfaces, which **increase the area of these surfaces** and
 - provide for **sufficient environmental exchange**.

20.13 Structural adaptations enhance exchange with the environment

- The respiratory system exchanges gases between the external environment and blood.
- The digestive system acquires food and eliminates wastes.
- The urinary system eliminates metabolic waste.
- The circulatory system
 - distributes gases, nutrients, and wastes throughout the body and
 - exchanges materials between blood and body cells through the **interstitial fluid** that bathes body cells.

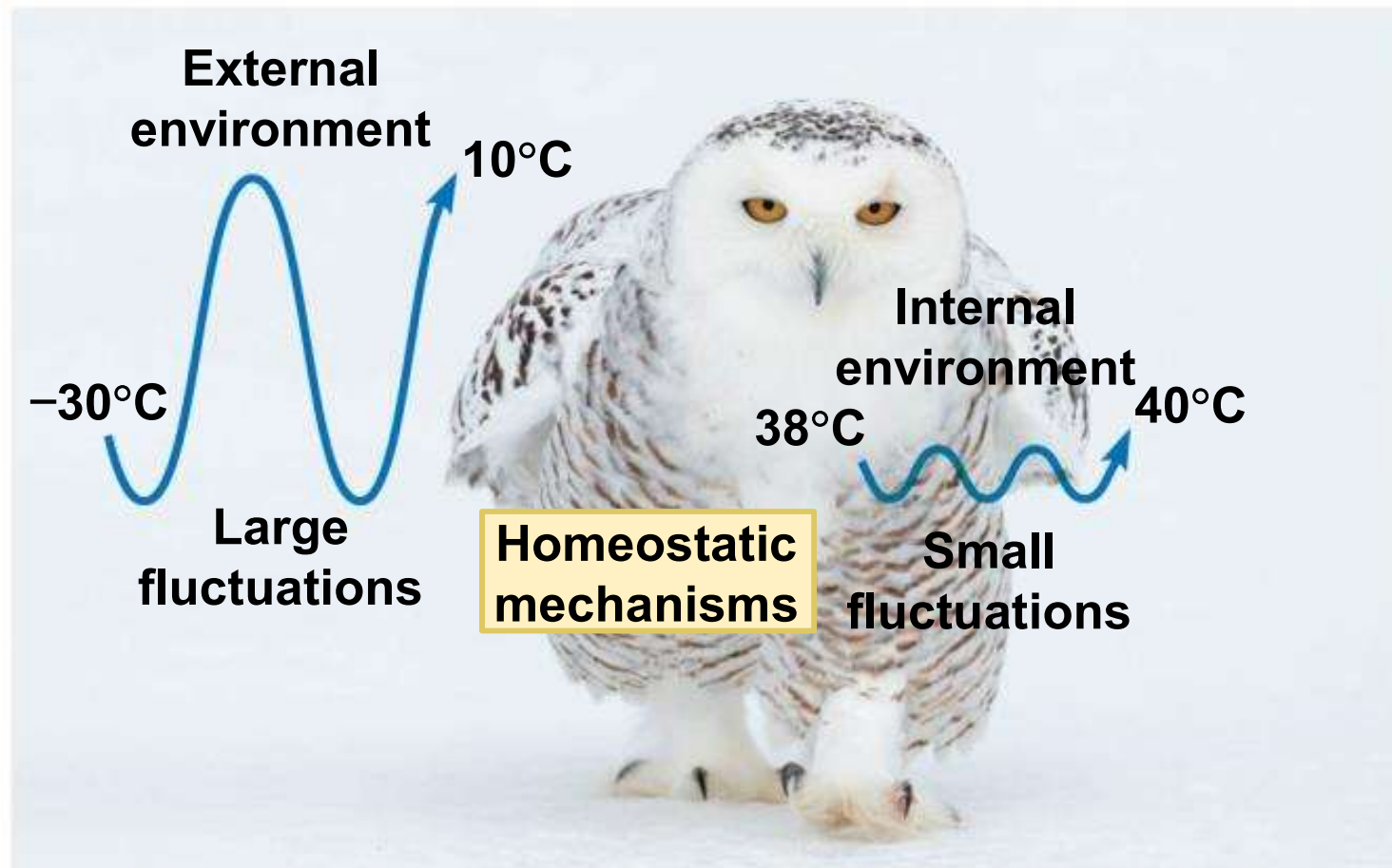
EXTERNAL ENVIRONMENT



Coordination!

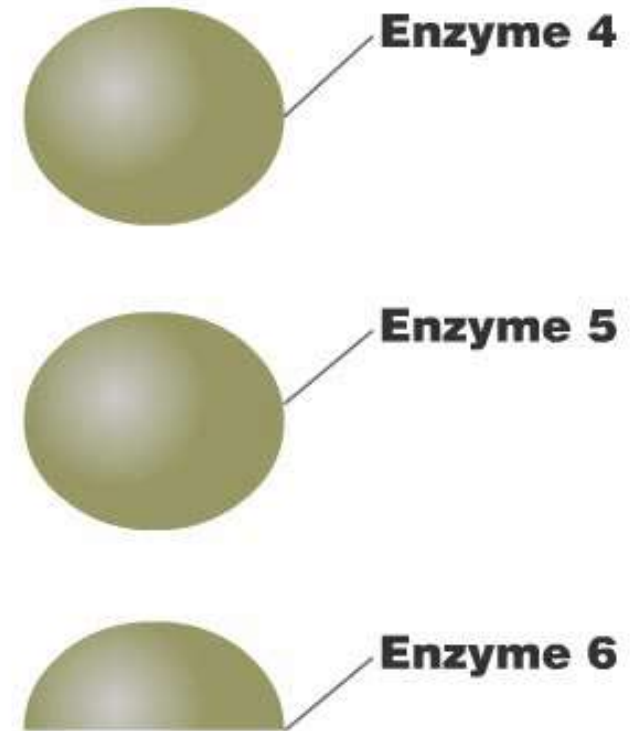
20.14 Animals regulate their internal environment

- **Homeostasis** is the active maintenance of a steady state within the body.
 - External environmental conditions may fluctuate wildly.
 - Homeostatic mechanisms regulate **internal conditions**.



20.15 Homeostasis depends on negative feedback

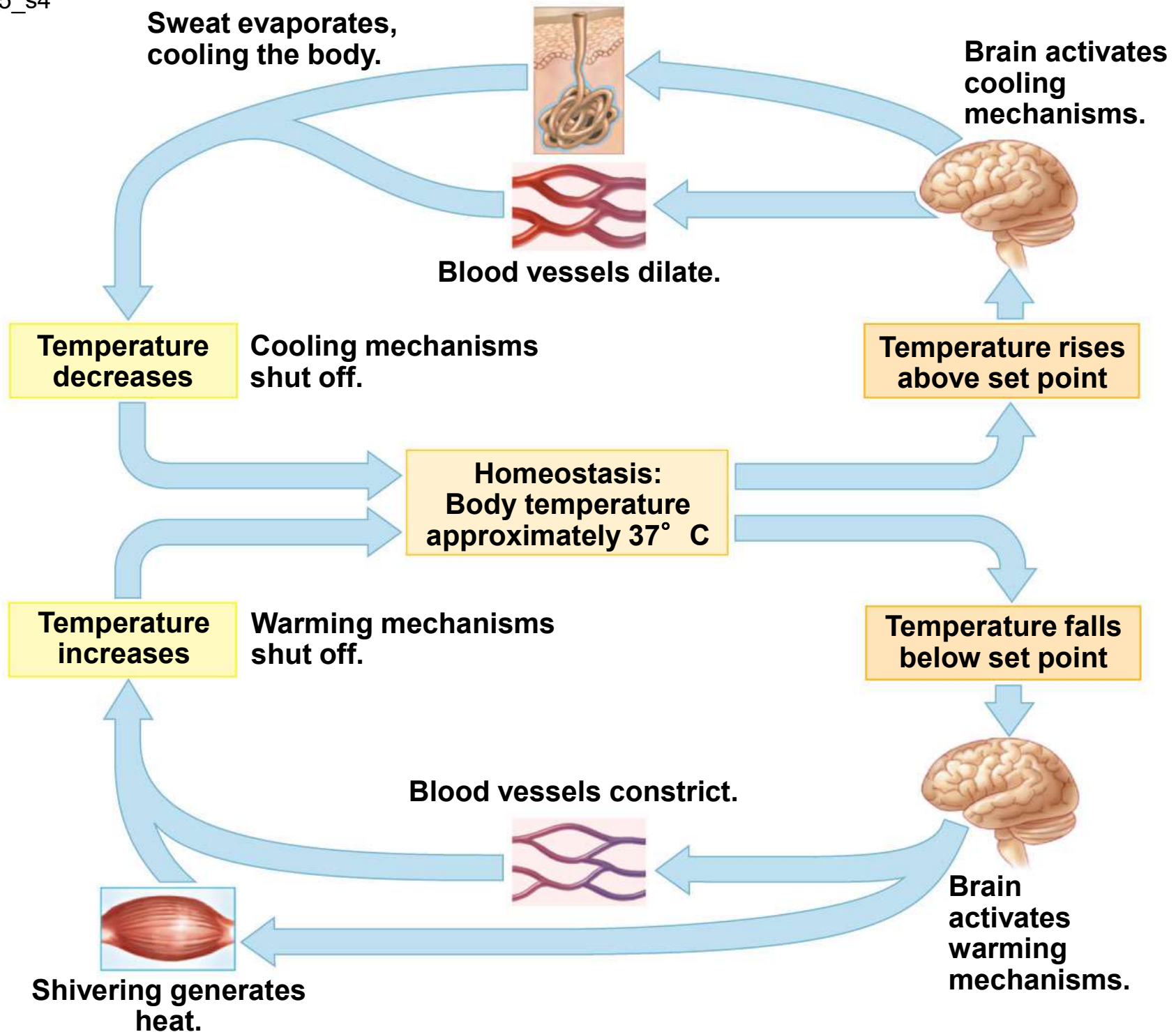
- Control systems
 - detect change and
 - direct responses.
- **Negative-feedback** mechanisms
 - keep internal variables steady and
 - permit only small fluctuations around set points.



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Animation: Positive Feedback

分娩、哺乳、凝血



You should now be able to

1. Explain why evolution does not lead to perfection.
2. Describe the levels of organization in an animal's body.
3. Describe the four main types of animal tissues. Note their structures and their functions.
4. Explain how the structure of organs is based on the cooperative interactions of tissues.
5. Explain how artificial tissues are created and used.
6. Explain how organ systems work together to perform life's functions.
7. Describe the general structures and functions of the 12 major vertebrate organ systems.
8. Relate the structure of the skin to its functions.
9. Describe the components of well-designed scientific studies.
10. Describe the systems that help an animal exchange materials with its environment.
11. Define the concept of homeostasis and illustrate it with examples.
12. Explain how negative feedback is used to regulate internal body temperature.