An Introduction to Animal Structure and Function

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本章節授課教材圖片主要來源摘自：Reece et. al. (2011) Campbell Biology, 9th ed, P820~843

Key Concepts of This Lecture

- 何謂組織學？
- 如何製作與進行顯微樣本之觀察與研究？
- 動物之構造、形態與體型受到那些因素之限制？
- 動物在構造與功能上所具備的關係與共同性？
- 動物體的結構與生理性階層
- 動物基本組織的介紹
- 恆定狀態與調控
- 代謝、體溫與能量利用
- 食慾、肥胖、基因與演化

Histology

This lecture will be leading students to understand the microanatomy（顯微解剖學）of cells, tissues and organs, and to correlating their structures with functions.

Methods (Microscopic techniques)

- **Tissue preparation :**
  - **In vivo (活體)**
  - **In vitro (離體)**
- **Auxiliary (輔助) techniques :**
  - **Histochemistry (組織化學) and cytochemistry(細胞化學)**
  - **Immunocytochemistry (免疫細胞化學) and insu hybridization (原位雜合- DNA or RNA)**
  - **autoradiography**
- **Microscopy :**
  - **Light microscope (LM)**
  - **Electron microscope (SEM, TEM)**
  - **Atomic force microscope (原子力學顯微鏡-AFM)**

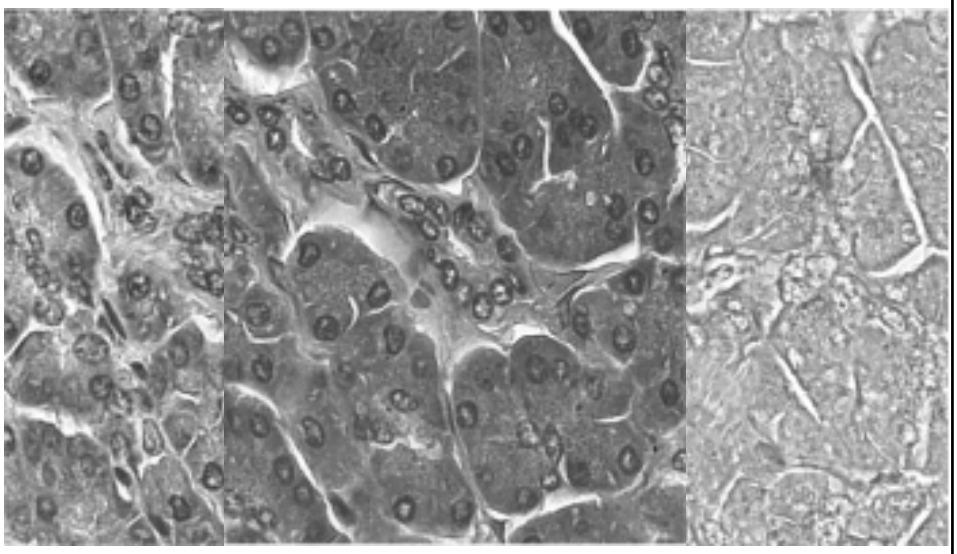
Routine Tissue Preparation

- **Fixation (固定) : the first step**
  - **Chemical fixation (formaldehyde-甲醛)**
  - **Physical fixation (temperature)**
- **Embedding (包埋) :**
  - **Paraffin (石蠟)**
- **Section (切片) : 5~15 μm**
- **Staining (染色) :**
  - **hematoxylin (蘇木紫) and eosin (伊紅)**
- **Examination (觀察) :**
  - **light microscopy**

Fixation

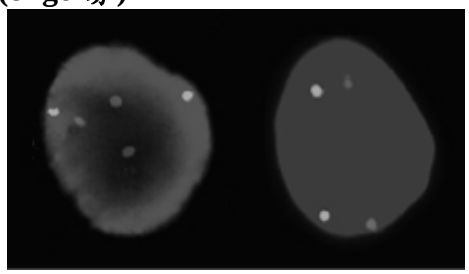
- **The first step**
- **Functions :**
  - **Structural preservation (保存結構)**
  - **Terminate cell metabolism (終止代謝反應)**
  - **Prevent structural degradation (防止構造崩解)**
  - **Kill pathogen (殺死病源)**
  - **Harden tissue (增加硬度)**
- **Methods :**
  - **Chemical fixation (formaldehyde)**
  - **Physical fixation (temperature)**

Hematoxylin and Eosin Staining



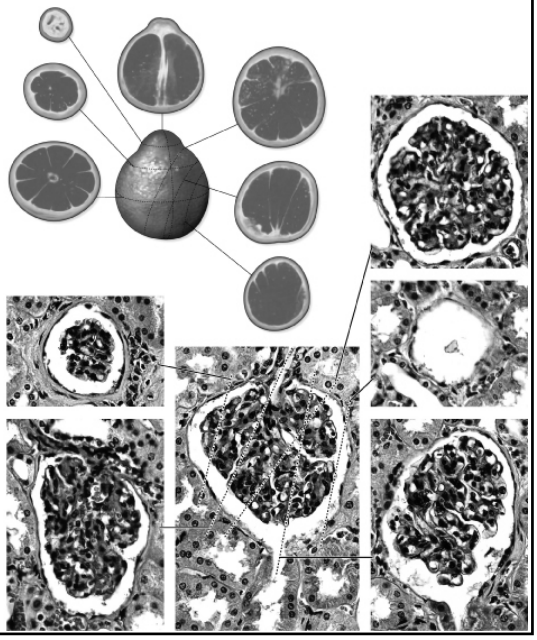
In situ Hybridization Techniques

- **Detection for DNA or RNA**
- **In situ hybridization :**
  - **Complementary (互補) probe (探針) :**
    - **oligonucleotide probes (oligo-寡)**
  - **Single amplification :**
    - **PCR**
    - **RT-PCR**
  - **Label :**
    - **Isotope (同位素) :**
    - **Fluorescence (螢光) dyes :**
      - **FISH (fluorescence in situ hybridization) procedure**

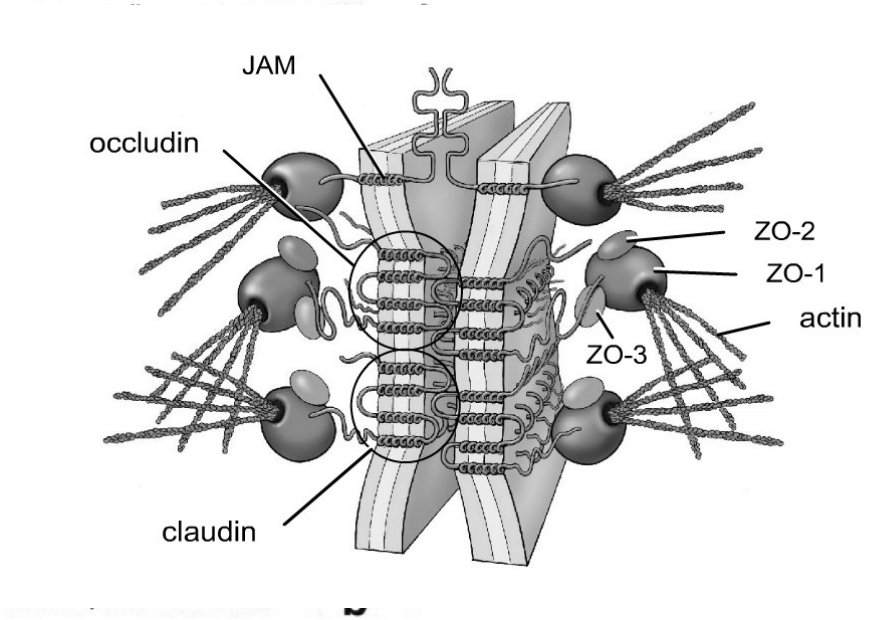


Examination a Tissue Slide

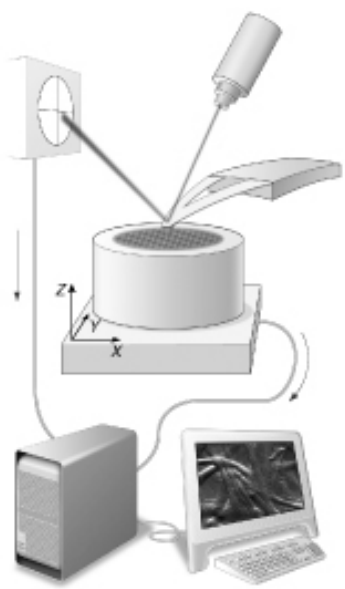
- **Tissues are three-dimensional structures**
  - **From two-dimensional images to three-dimensional structures**
- **Artifacts (人為失誤) :**
  - **Fixation**
  - **Dehydration (脫水)**
  - **Embedding**
  - **Section**
  - **Staining**
  - **Mounting (載片)**

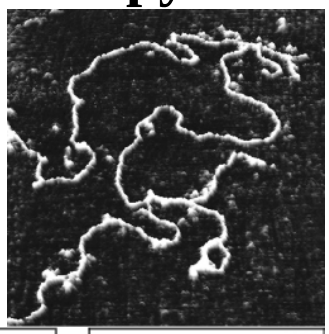


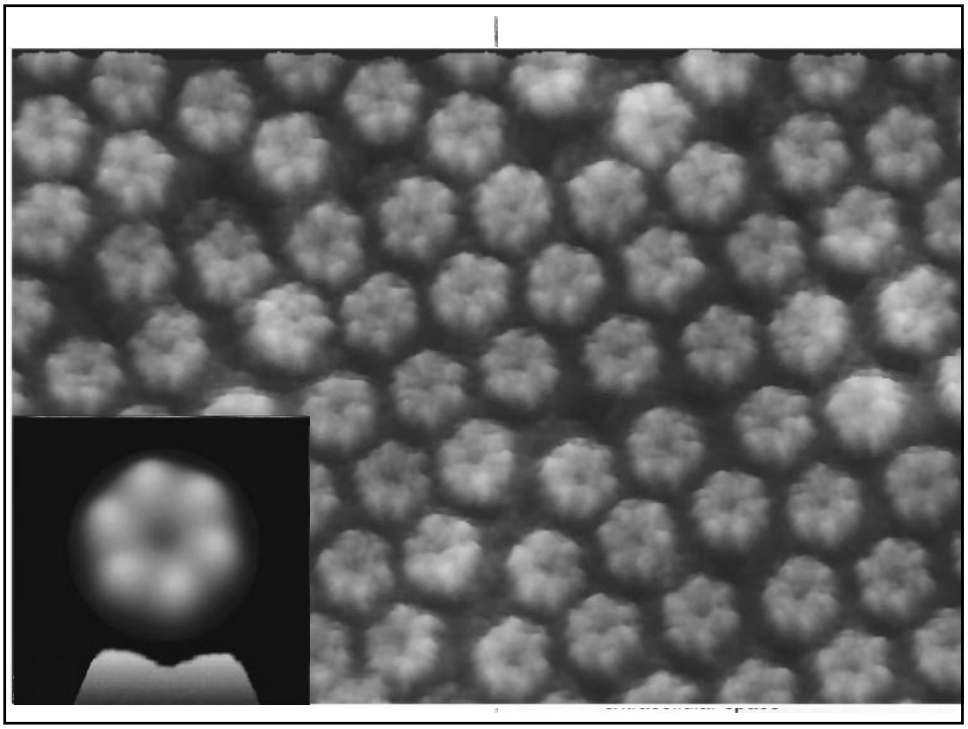
Tight Junction (緊密結合)



Atomic Force Microscopy







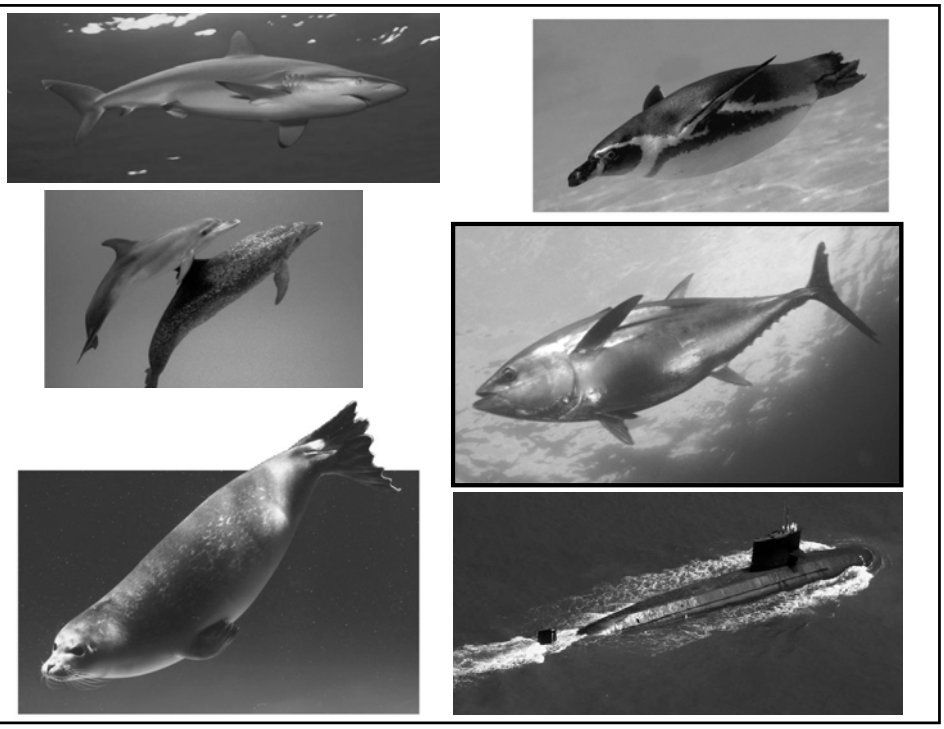
Diverse Form, Common Challenges

Campbell & Reece (2011) Biology 9thed, fig 40.1

- **Evolution (演化) :**
  - **Diversity (多樣性)**
    - **habitat, form, function**
- **Adaptation (適應) :**
  - **Anatomical adaptation**
  - **Physiological adaptation**
  - **Behavior adaptation**

How Physical Laws Constrain Animal Form

- **Physical laws limit :**
  - **Materials exchange (物質交換) :**
  - **Energy exchange (能量交換) :**
  - **Force interaction (力交互作用) :**
    - **Size and shape affect the way an animal interacts with its environment**
- **Physical requirements constrain what natural selection (天擇) can "invent"**
  - **Convergent evolution (趨同演化)**
  - **Many different animal body plans have evolved and are determined by the genome (基因)**

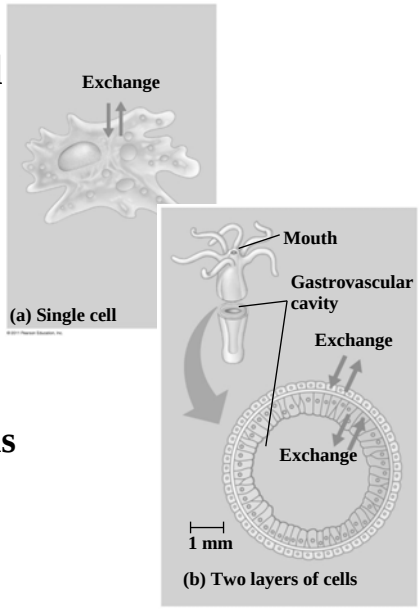


Exchanges with the External Environment

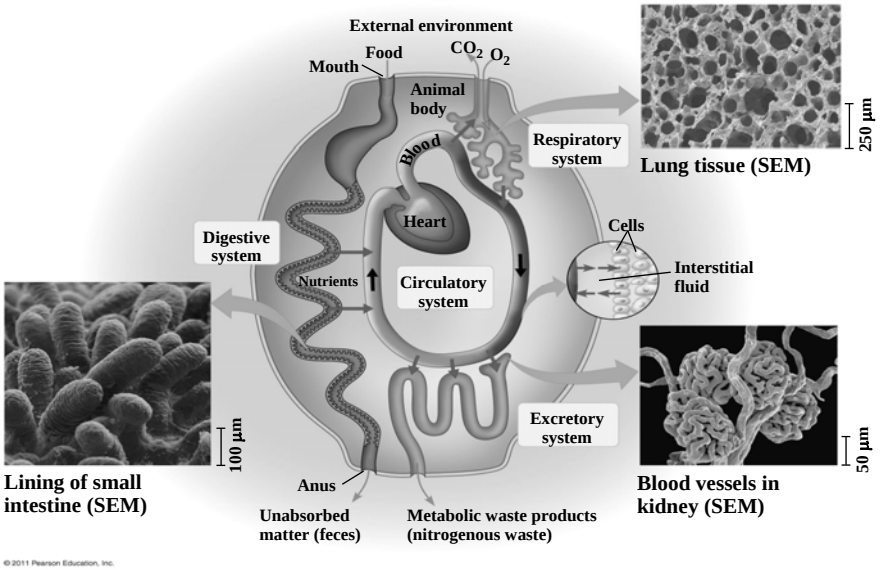
- **Diffusion (擴散) :**
  - **External environment**
  - **Epithelium (上皮組織)**
  - **Interstitial (組織間) environment**
    - **Cells**
    - **Interstitial fluid**
- **Passive transport (被動運輸) :**
- **Active transport (主動運輸) :**

Exchange with External Environment

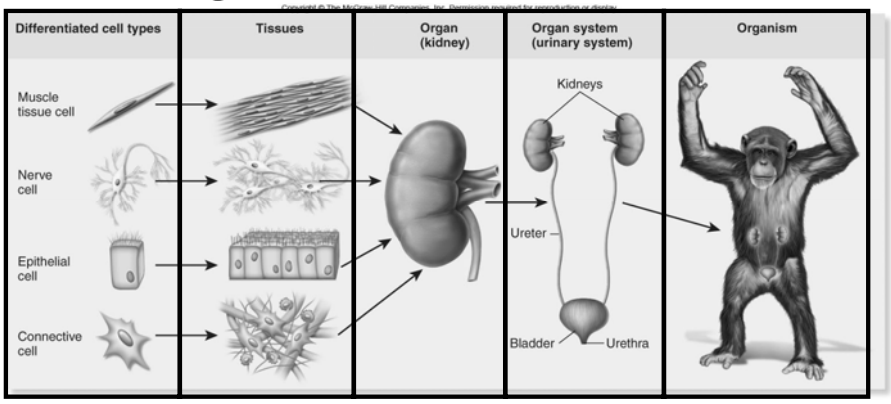
- **Organism (生物個體) and environment interaction**
  - **Aqueous (水) environment**
  - **body size**
    - **material exchange**
    - **energy exchange**
- **Physical laws**
  - **Surface-to-volume relations**
  - **evolution**
  - **adaptation**



Internal Exchange Surfaces And Homeostasis (恆定狀態)



Hierarchical Level (階層) of Structural Organization in an Animal



- **Cells with similar properties group to form tissues**
- **Tissues combine with other types of tissues to form organs**
- **Organs are anatomically or functionally linked to form organ systems**

Tissues

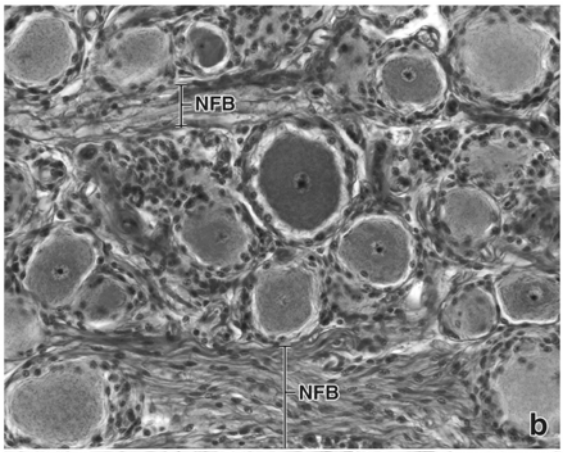
- **An organized aggregation of cells that function in a collective manner.**
  - **Cellular communication**
  - **Cellular cooperation**
  - **Cell interaction**

Tissues (組織)

- **Define :**
  - **groups cells with a common structure and function**
- **Four main categories (類別) :**
  - **epithelial tissue (表皮組織)**
  - **connective tissue (結締組織)**
  - **muscle tissue (肌肉組織)**
  - **nervous tissue (神經組織)**

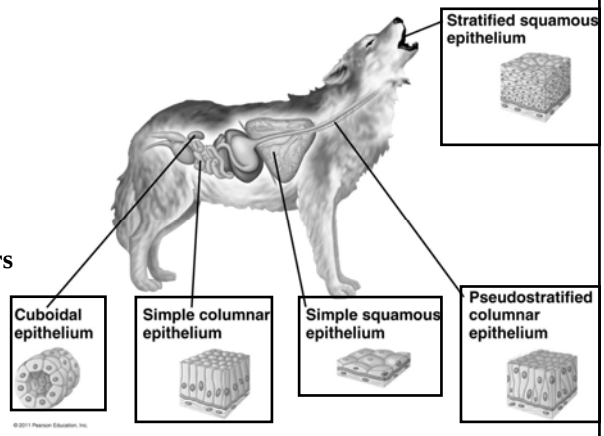
Tissues Classification :

- **Epithelial tissue :**
  - **cell layers**
  - **shape of cells**
- **Connective tissue :**
  - **Structures :**
    - **Cells**
    - **Extracellular matrix**
  - **Classification :**
    - **Connective tissue proper**
      - **loose**
      - **dense**
        - » **regular**
        - » **Irregular**
    - **Specialized connective tissue**
- **Muscle tissue :**
- **Nervous tissue :**



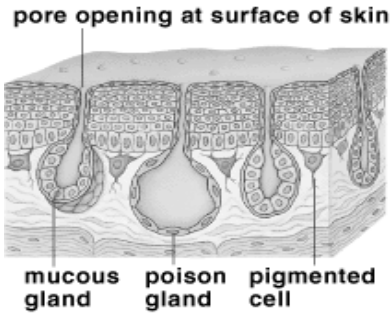
Epithelium

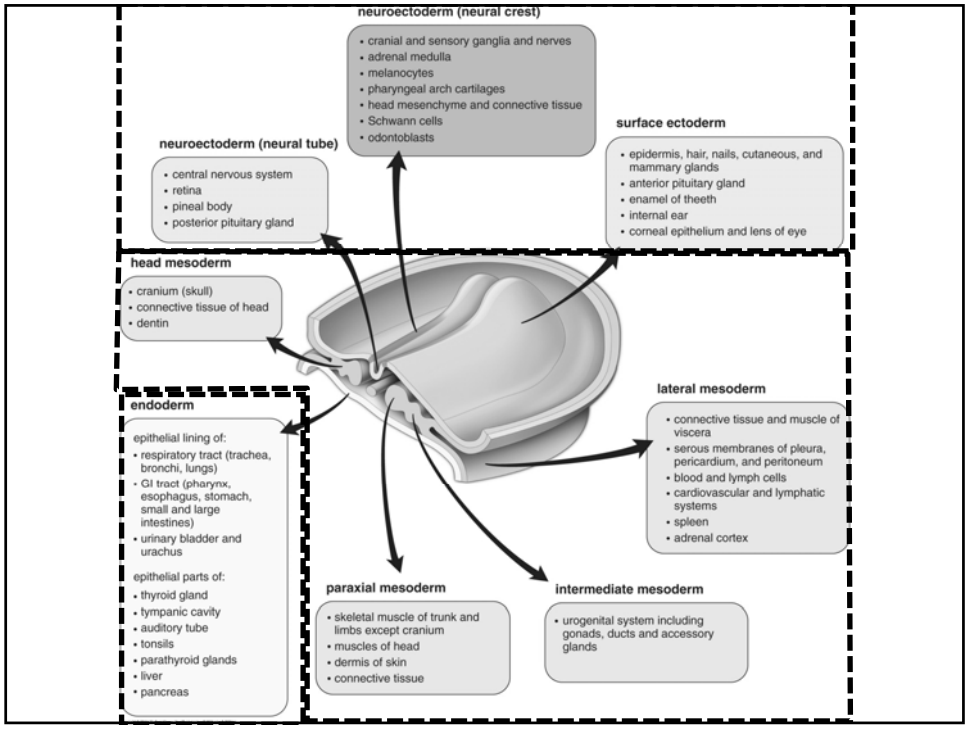
- **Structure :**
  - **cover inner and outer surface of body and organs**
  - **attached to basement membrane (基底膜)**
- **Function :**
  - **barrier**
  - **absorption**
  - **Secretion :**
    - **glandular epithelium**
      - **exocrine**
      - **endocrine**
- **Classification :**
  - **the number of cell layers**
    - **Simple (單層)**
    - **Stratified (複層)**
  - **the shape of the cells**
    - **Squamous (鱗狀)**
    - **Cuboidal (立方)**
    - **Columnar (柱狀)**



Glandular Epithelium

- **Exocrine :**
  - **Mucus**
  - **Saliva**
  - **Earwax**
  - **Milk**
  - **Oil**
  - **Digestive enzymes**
- **Endocrine :**
  - **Secrete hormones**
- **Mucous Membrane :**
  - **Secrete mucous**
    - **Lubrication**
    - **Moistly**
  - **Digestive tract**
  - **Respiratory tract**

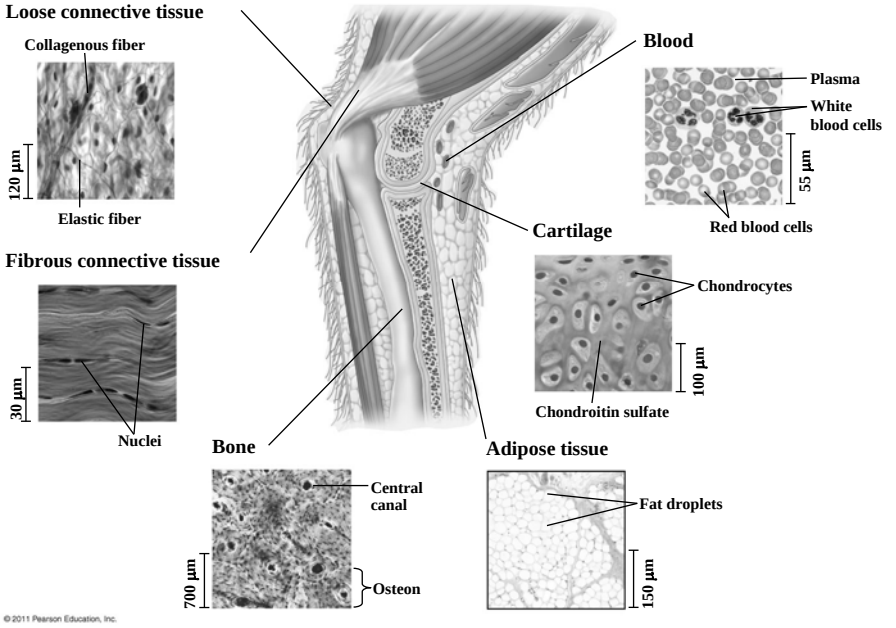




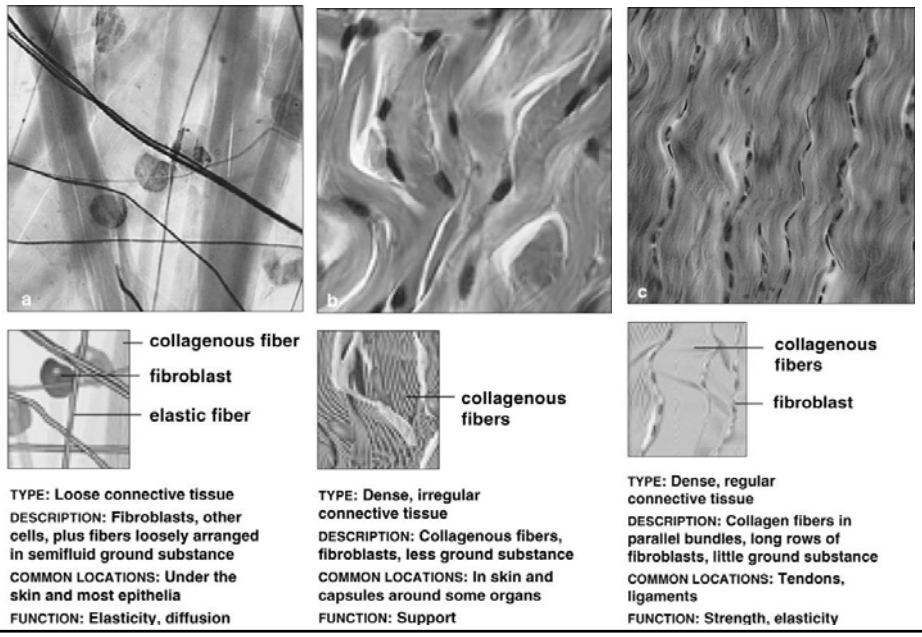
Connective Tissue

- **Common Structure :**
  - **a sparse population of cells scattered through an extracellular (細胞外) matrix (基質)**
- **Function：**
  - **Binding and supporting for other tissues**
- **Extracellular matrix :**
  - **fibers**
  - **ground substance**
- **Cells :**
  - **fibroblast (纖維母細胞), macrophage (巨噬細胞)**
- **Fiber types of connective tissue :**
  - **collagenous fibers (collagen-膠原纖維)**
  - **elastic fibers (彈性纖維)**
  - **reticular fibers (網狀纖維)**

Connective Tissue



Soft Connective Tissue



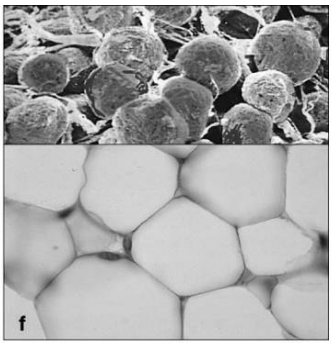
TYPE: Loose connective tissue
DESCRIPTION: Fibroblasts, other cells, plus fibers loosely arranged in semifluid ground substance
COMMON LOCATIONS: Under the skin and most epithelia
FUNCTION: Elasticity, diffusion

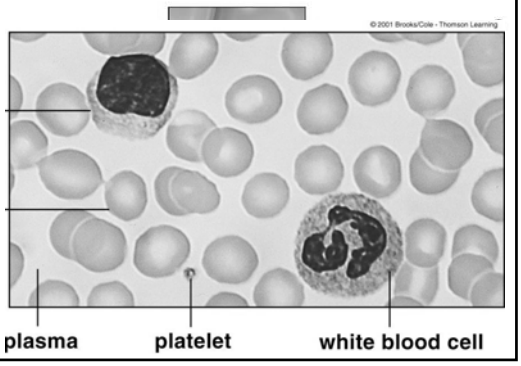
TYPE: Dense, irregular connective tissue
DESCRIPTION: Collagenous fibers, fibroblasts, less ground substance
COMMON LOCATIONS: In skin and capsules around some organs
FUNCTION: Support

TYPE: Dense, regular connective tissue
DESCRIPTION: Collagen fibers in parallel bundles, long rows of fibroblasts, little ground substance
COMMON LOCATIONS: Tendons, ligaments
FUNCTION: Strength, elasticity

Specialized Connective Tissues

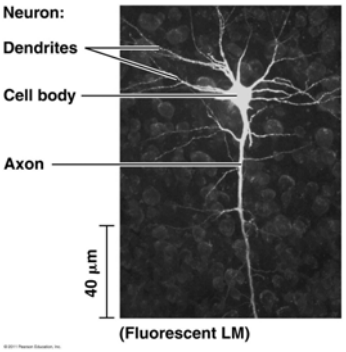
- **Cartilage**
  - **Cushions**
  - **Bone formation**
- **Bone**
  - **Spongy and compact**
- **Adipose tissue**
  - **Fat**
- **Blood**
  - **Transport**

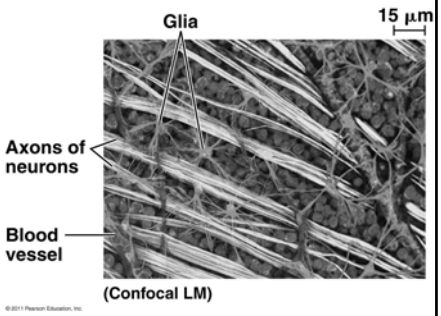




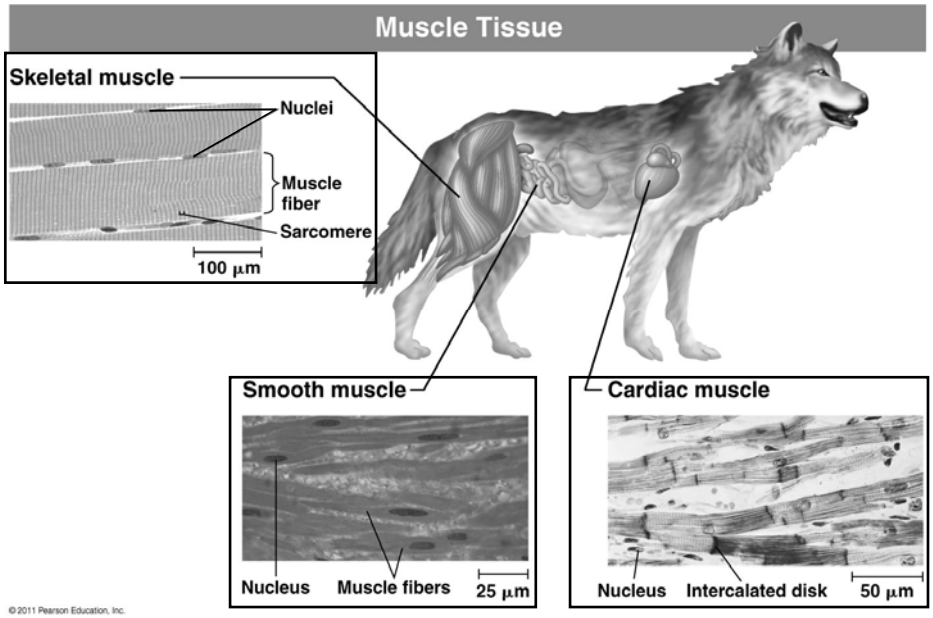
Nervous Tissue

- **Function :**
  - **sensor**
  - **signal transmission**
    - **nerve impulses**
- **Neuron : the functional unit**
  - **cell body**
  - **dendrites (樹突) :**
    - **impulses from ending to cell body**
  - **axon (軸突) :**
    - **impulses from cell body to ending**

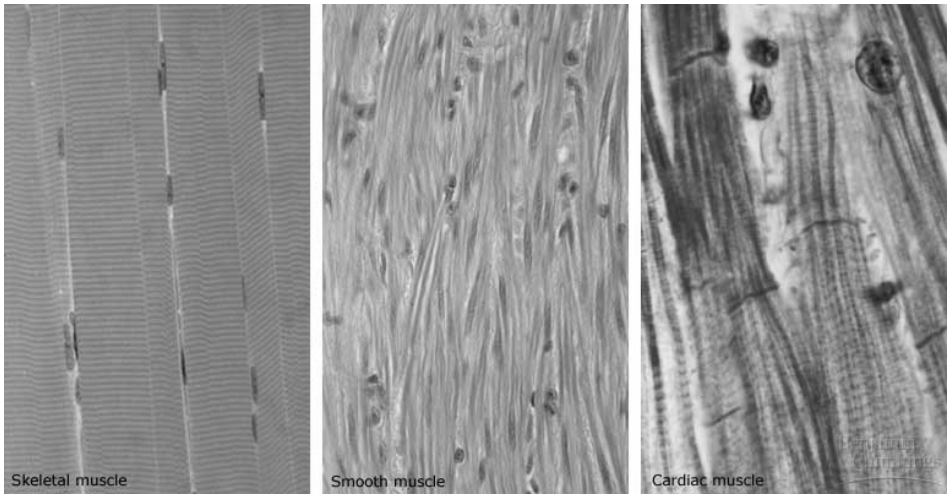


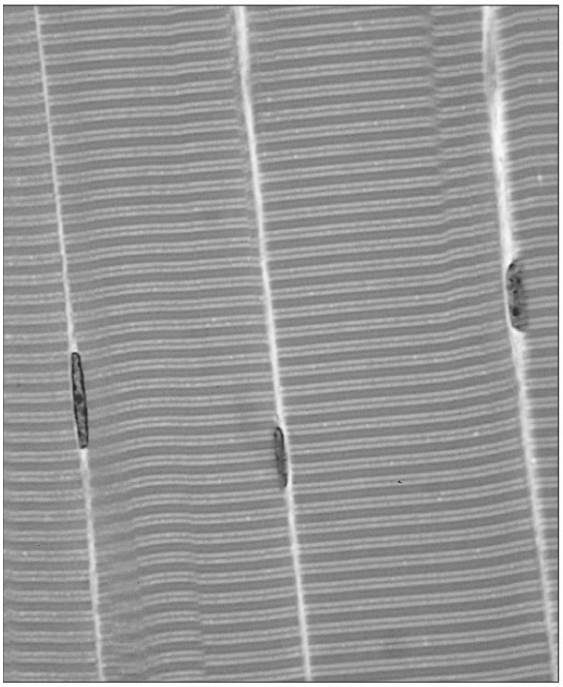


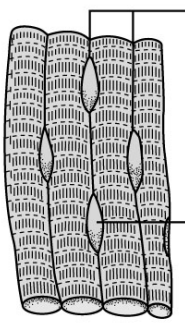
Muscle Tissue



skeletal muscle (striated) | **smooth muscle (non-striated)** | **cardiac muscle (striated)**





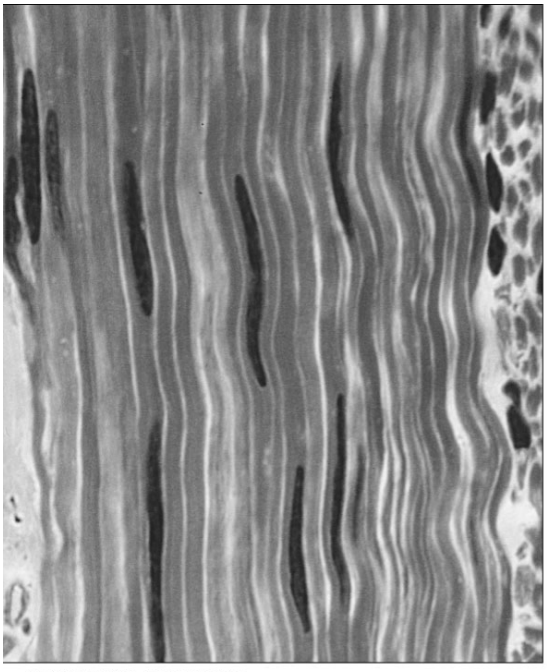


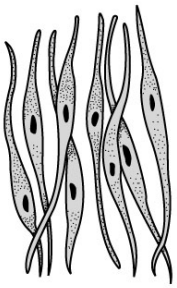
TYPE: Skeletal muscle

DESCRIPTION: Bundles of long, cylindrical, striated, contractile cells

LOCATION: Associated with skeleton

FUNCTION: Locomotion, movement of body parts





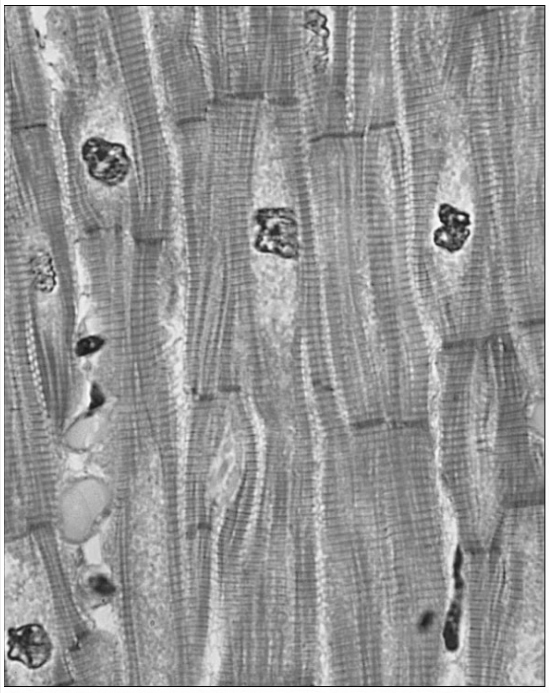
cells teased apart for clarity

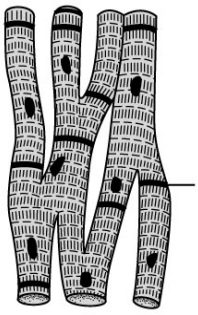
TYPE: Smooth muscle

DESCRIPTION: Contractile cells with tapered ends

LOCATION: Wall of internal organs, such as stomach

FUNCTION: Movement of internal organs





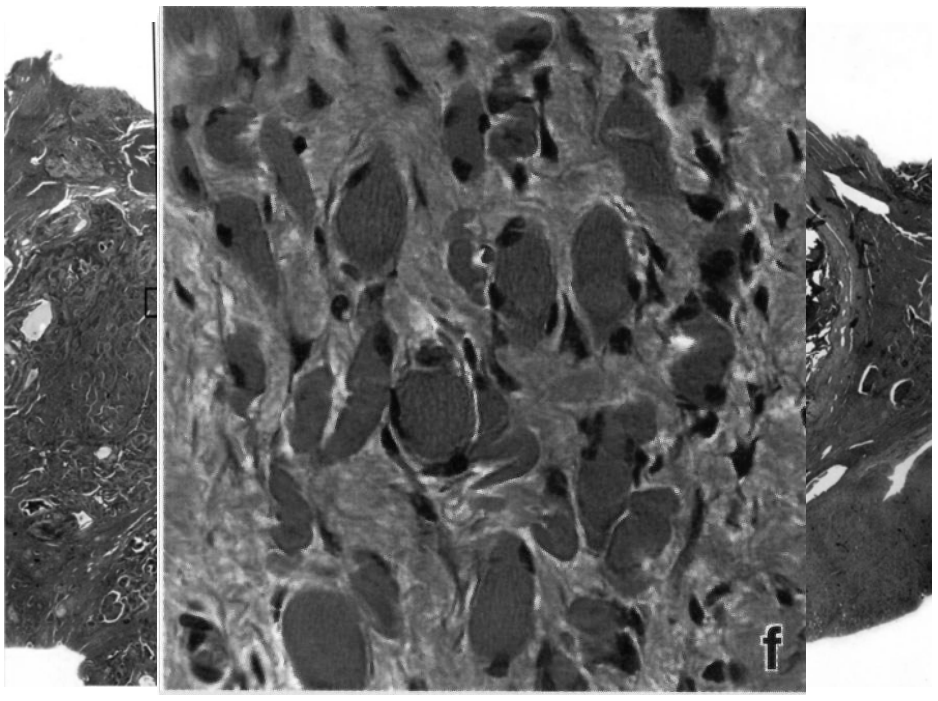
junction between adjacent cells

TYPE: Cardiac muscle

DESCRIPTION: Cylindrical, striated cells that have specialized end junctions

LOCATION: Wall of heart

FUNCTION: Pump blood within circulatory system



Organs and Organ Systems

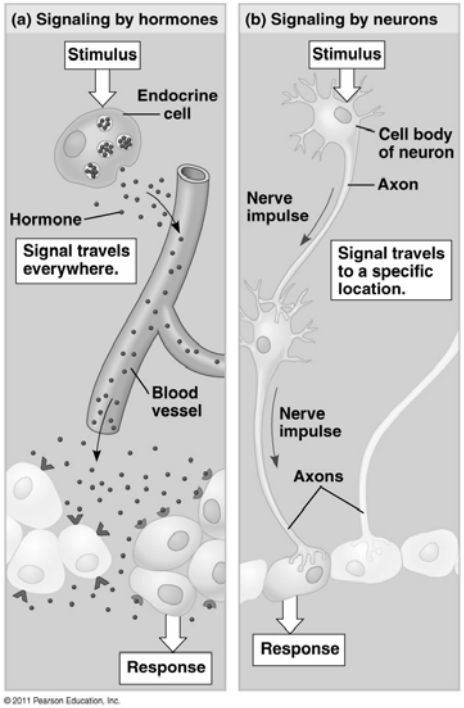
- **Organ (器官) :**
  - **different tissues are organized into the specialized centers of function**
  - **may surround with mesenteries (腸繫膜) in body cavity**
- **Organ system (器官系統) :**
  - **several organs are grouped into carrier out some specific functions**
- **Organism (生物個體) :**
  - **coordinate all organ system for survival**

The Functions of Organ System

Digestive system	**Nutrition and digestion**
Respiratory system	**Gas exchange**
Circulatory system	**Materials transport**
Lymphatic and immune system	**Defense**
Excretory (排泄) system	**Waste excrete**
Endocrine (內分泌) system	**Hormone secretion**
Reproductive system	**Offspring production**
Nervous system	**Control and response**
Muscular system	**Movement**
Skeletal system	**Supporting and protection**
Integumentary (皮膚) system	**protection**

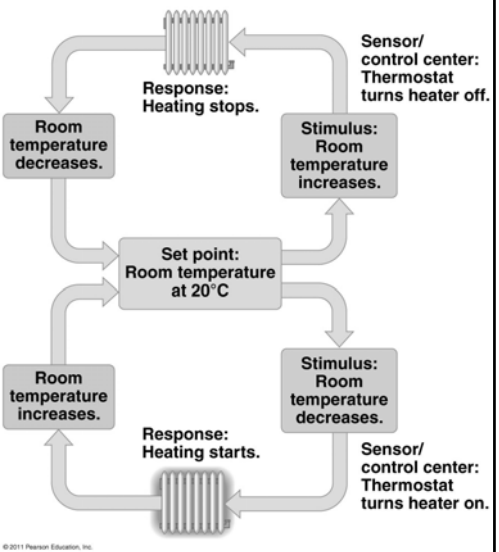
Coordination and Control

- **Control and coordination within a body depend on :**
  - **Endocrine system**
  - **Nervous system**
- **The endocrine system :**
  - **Hormones : chemical signals**
  - **Signal transporter : blood**
  - **Receptive cells : throughout the body**
- **Characteristic features :**
  - **A hormone may affect one or more regions throughout the body**
  - **Hormones are relatively slow acting, but can have long-lasting effects**



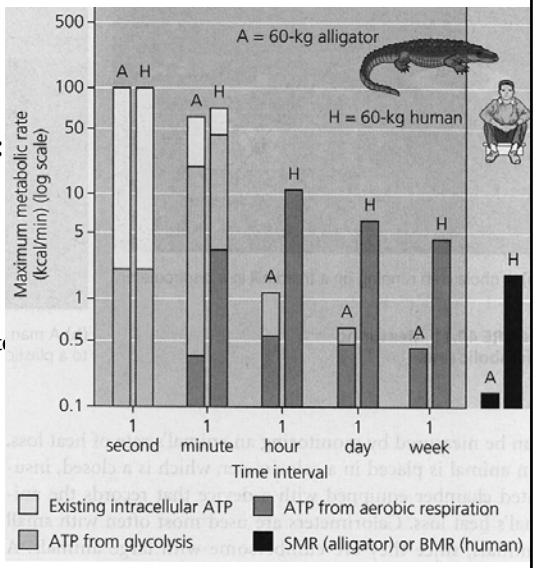
Regulating and Conforming

- **Regulator (調控者) :**
- **Conformer (順應者) :**
- **Homeostasis (恆定狀態) :**
  - **Negative feedback control**
    - **Sensor :**
    - **Control center :**
    - **Effector :**
      - **Response :**



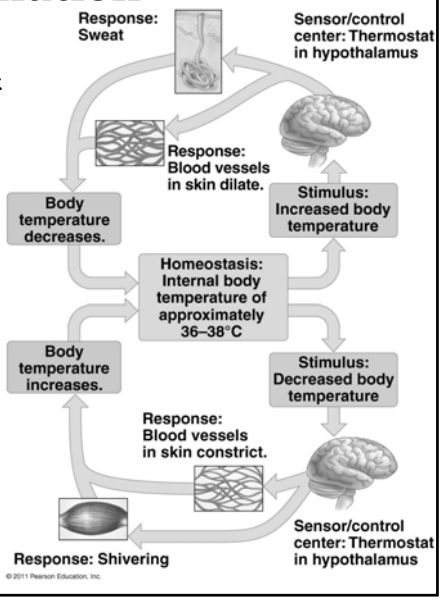
Maximum and Minimum Metabolic Rate

- **Minimum metabolic rate (最低代謝速率) :**
  - **Endotherm (內溫動物) :**
    - **BMR (基礎代謝速率) :**
      - **Basal Metabolic Rate**
  - **Ectotherm (外溫動物) :**
    - **SMR (標準代謝速率) :**
      - **Standard Metabolic Rat**
- **Maximum metabolic rate (最高代謝速率) :**



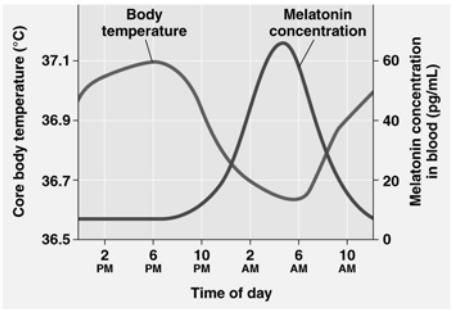
Feed back Mechanism in Thermoregulation

- **Thermostat center : 體溫中樞**
  - **Hypothalamus (下視丘)**
  - **36-38 ℃**
- **Skin :**
  - **blood vessels**
  - **Sweat glands (汗腺)**
- **Muscles :**
  - **Shivering (顫抖) contraction**

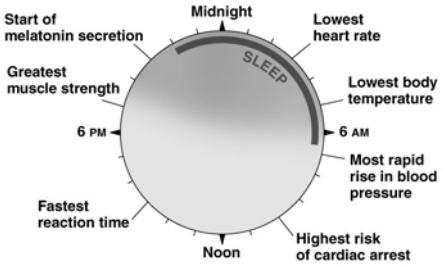


Regulating the Internal Environment

- **Internal environment :**
  - **interstitial fluid :**
- **Homeostasis :**
  - **dynamic (動態) state**
  - **feed-back control (回饋控制)**
    - **negative (負) feedback :**
    - **positive (正) feedback :**
- **Circadian rhythm (周期)**
  - **Set points and normal ranges can change with age or show cyclic variation**
  - **every 24 hours**



(a) Variation in core body temperature and melatonin concentration in blood



(b) The human circadian clock

Thermoregulation (體溫調控)

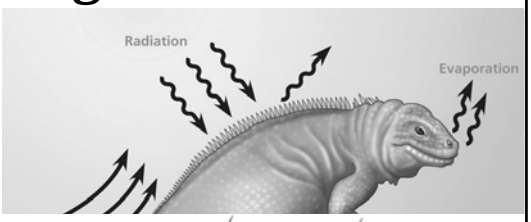
- **Maintain internal body temperature within defined limits**
- **Ectotherms :**
  - **obtain body heat primarily by absorbing it from their surroundings**
- **Endotherms :**
  - **derive the majority of their body heat from their metabolism (代謝)**

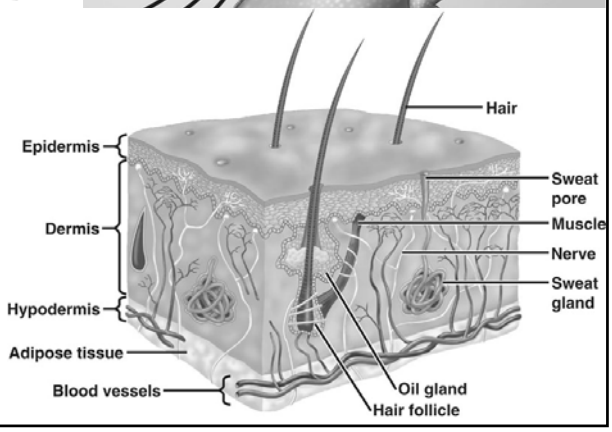

(a) A walrus, an endotherm


(b) A lizard, an ectotherm

Thermoregulation

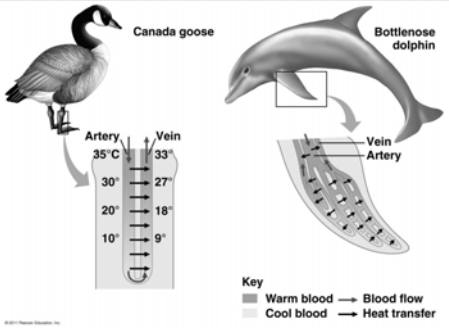
- **Ectotherms**
  - **Lower metabolic rate-SMR**
  - **Cold blooded**
- **Endotherms**
  - **Higher metabolic rate-BMR**
  - **Warm blooded**
- **Heat exchange :**
  - **Conduction (傳導)**
  - **Convection (對流)**
  - **Radiation (輻射)**
  - **Evaporation (蒸散)**
- **Insulation (絕緣) :**
  - **Skin**
  - **Adipose tissue**
  - **hypodermis**

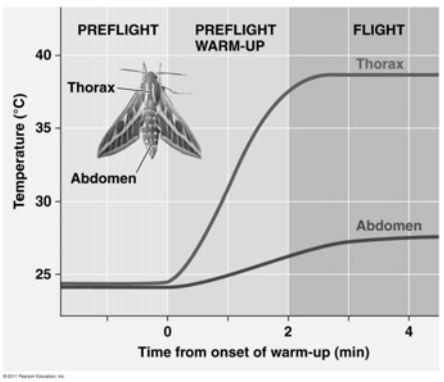




Circulatory Adaptation

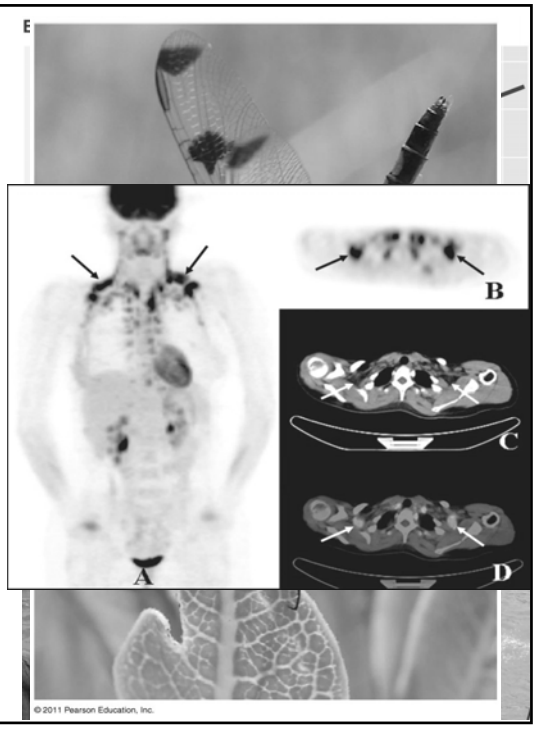
- **Blood flow control :**
  - **Vaso-dilation (舒張)**
  - **Vaso-constriction (收縮)**
- **Countercurrent (對流) exchange :**
  - **Vertebrate :**
    - **Blood**
  - **Insect :**
    - **Flight muscle**





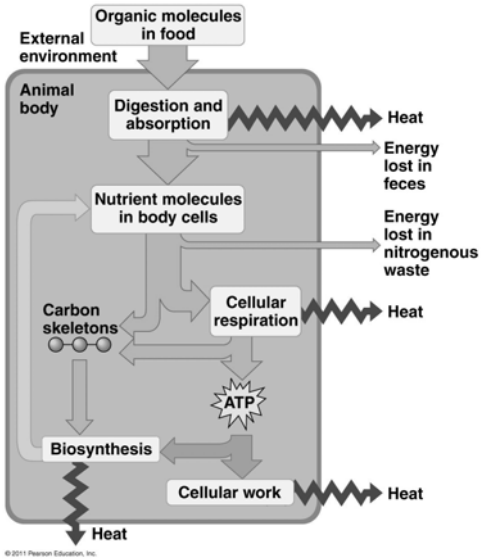
Other regulations of heat exchange

- **Muscle contraction :**
- **Evaporation (蒸散)**
- **Behavioral responses**
- **Physiological adjusting**
  - **Shiver**
  - **Brown fat :** 棕脂肪
    - **nonshivering thermogenesis**



Chemical Energy Utility

- **Energy Harvest :**
  - **Autotrophs**
  - **heterotrophs**
- **Energy require for :**
  - **Growth**
  - **Repair**
  - **Physiological processes**
  - **Regulation**
  - **Reproduction**
- **Bioenergetics :**
  - **the overall flow and transformation of energy in an animal**
- **Quantifying energy utilization**
  - **Metabolic rate :**

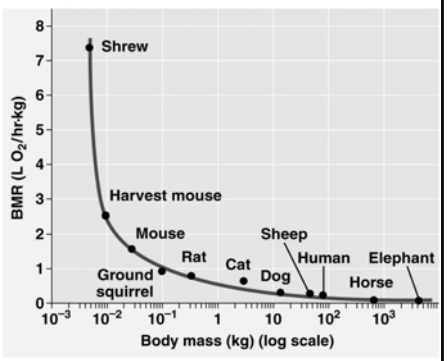


Quantifying energy use : Metabolic rate

- **Define :**
  - **the total amount of energy for an animal that used in a unit time**
- **Energy unit :**
  - **calories (cal)**
  - **kilocalories (kcal)**
- **Metabolic rate measure :**
  - **heat lose**
  - **O_2 consumed (利用)**
  - **CO_2 produced**
  - **Energy content of the food**

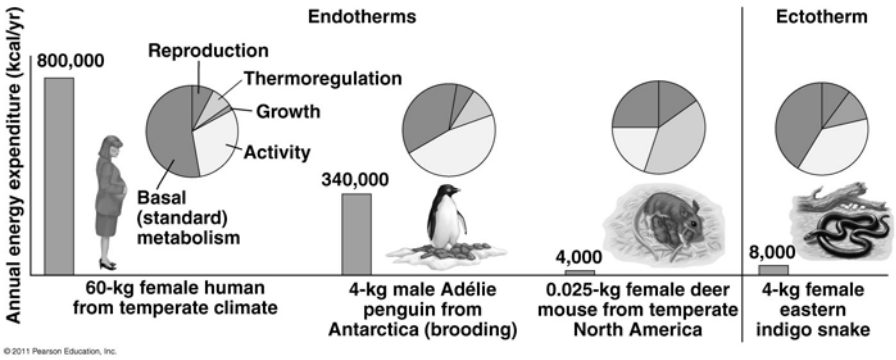
Metabolic Rate and Body Size

- **Smaller animals comparing with the larger animals :**
  - **higher metabolic rate :**
  - **higher breathing rate**
  - **higher heart rate**
  - **higher relative blood volume**
  - **larger surface volume ratio :**
    - **Endotherm :**
      - **greater heat loss to surroundings**
    - **Ectotherm :**
      - **greater heat gain from surrounding**
- **Physical support :**
- **Body size and shape affect interaction with environment :**



(b) Relationship of BMR per kilogram of body mass to body size

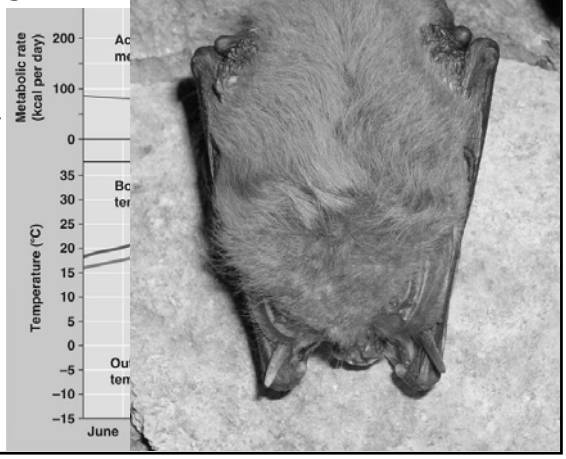
Energy budgets (預算) of different animals species and sizes



- **Different species use energy and materials in food in different ways, depending on their environment**
- **Use of energy is partitioned to BMR (or SMR), activity, thermoregulation, growth, and reproduction**

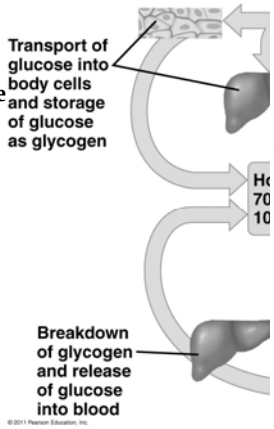
Adjustment to changing temperatures

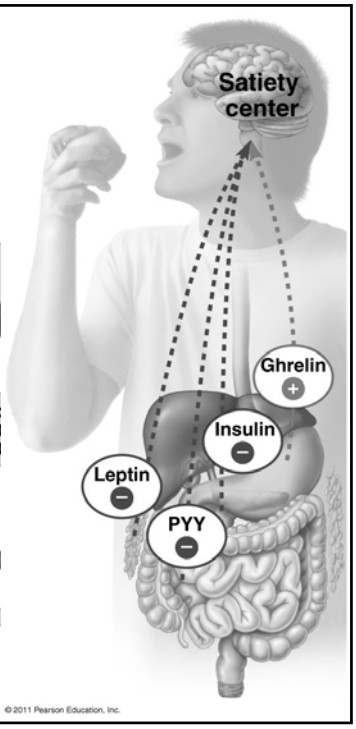
- **Acclimatization : 馴化**
  - **Stress-induced proteins :**
  - **Heat-shock proteins**
- **Torpor (休眠) :**
  - **Hibernation : 冬眠**
  - **Estivation : 夏眠**
    - **Summer torpor**
  - **Daily torpor :**
    - **Small endotherms**



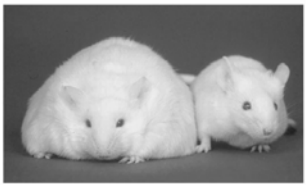
Feedback circuits regulate digestion, energy storage, and appetite

- **Energy budgets :**
  - **ATP producing and using**
- **Homeostasis :**
  - **Nutrient (營養)**
    - **intake and consume**
  - **Caloric utility**
- **Caloric imbalance :**
  - **Undernourishment**
  - **Overnourishment**
- **Appetite : 食慾**
  - **Leptin (suppression)**
  - **PYY (suppression)**
  - **Insulin (suppression)**
  - **Ghrelin (activation)**





EXPERIMENT



Obese mouse with mutant *ob* gene (left) next to wild-type mouse

RESULTS

Genotype pairing (red type indicates mutant genes)		Average change in body mass (g) of subject
Subject	Paired with	
ob^+ob^+, db^+db^+	ob^+ob^+, db^+db^+	8.3
ob ob, db^+db^+	*ob ob*, db^+db^+	38.7
ob ob, db^+db^+	ob^+ob^+, db^+db^+	8.2
ob ob, db^+db^+	ob^+ob^+, *db db*	−14.9*

*Due to pronounced weight loss and weakening, subjects in this pairing were reweighed after less than eight weeks.

Obesity (肥胖) and Evolution

- **Nutrient requirement :**
- **Evolutionary past :**
  - **fat hoarding : to survive famines (飢荒)**

下課~起床囉~！