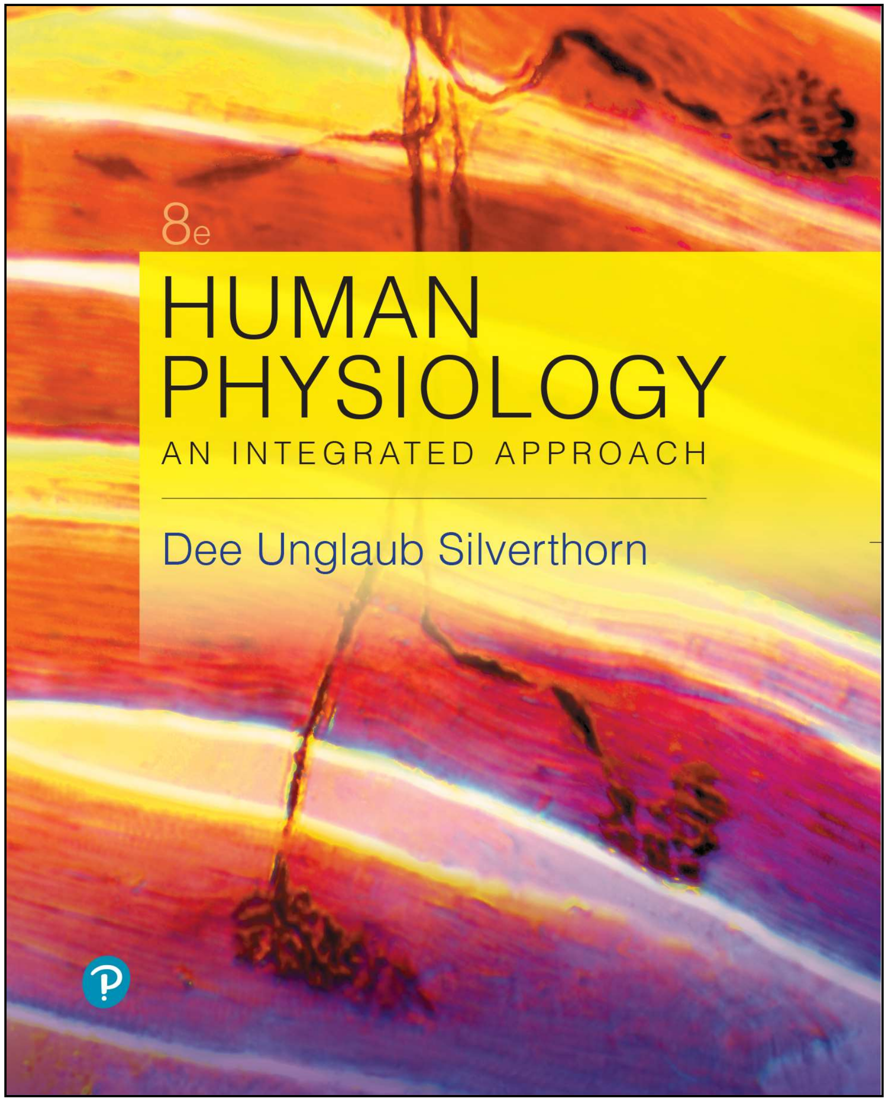
Human Physiology, An Integrated Approach

Eighth Edition



Chapter 1

Introduction to Physiology

About This Chapter

Learning Objectives

1.1 Physiology is an Integrative Science

LO 1.1.1 Define physiology.

LO 1.1.2 List the levels of organization from atoms to the biosphere.

LO 1.1.3 Name the 10 physiological organ systems of the body and give their functions.

1.2 Function and Mechanism

LO 1.2.1 Distinguish between mechanistic explanations and teleological explanations.

1.3 Themes in Physiology

LO 1.3.1 List and give examples of the four major themes in physiology.

1.4 Homeostasis

LO 1.4.1 Define homeostasis. What happens when homeostasis fails?

LO 1.4.2 Name and describe the two major compartments of the human body.

LO 1.4.3 Explain the law of mass balance and how it applies to the body's load of a substance.

LO 1.4.4 Define mass flow using mathematical units and explain how it relates to mass balance.

LO 1.4.5 Define clearance and give an example.

LO 1.4.6 Distinguish between equilibrium and steady state.

Learning Objectives

1.5 Control Systems and Homeostasis

LO 1.5.1 List the three components of a control system and give an example.

LO 1.5.2 Explain the relationship between a regulated variable and its setpoint.

LO 1.5.3 Compare local control, long-distance control, and reflex control.

LO 1.5.4 Explain the relationship between a response loop and a feedback loop.

LO 1.5.5 Compare negative feedback, positive feedback, and feedforward control. Give an example of each.

LO 1.5.6 Explain what happens to setpoints in biological rhythms and give some examples.

1.6 The Science of Physiology

LO 1.6.1 Explain and give examples of the following components of scientific research: independent and dependent variables, experimental control, data, replication, variability.

LO 1.6.2 Compare and contrast the following types of experimental study designs: blind study, double-blind study, crossover study, prospective and retrospective studies, cross-sectional study, longitudinal study, meta-analysis.

LO 1.6.3 Define placebo and nocebo effects and explain how they may influence the outcome of experimental studies.

1.1 Physiology Is an Integrative Science

Physiology: Study of the normal functioning of a living organism and its component parts, includes all its chemical and physical processes

- Linked to anatomy

Emergent properties: properties that "emerge" but can't be predicted based on the parts

- eg- emotion and intelligence are emergent properties of the millions of cells in the nervous system

1.1 Levels of Organization

Levels of Organization:

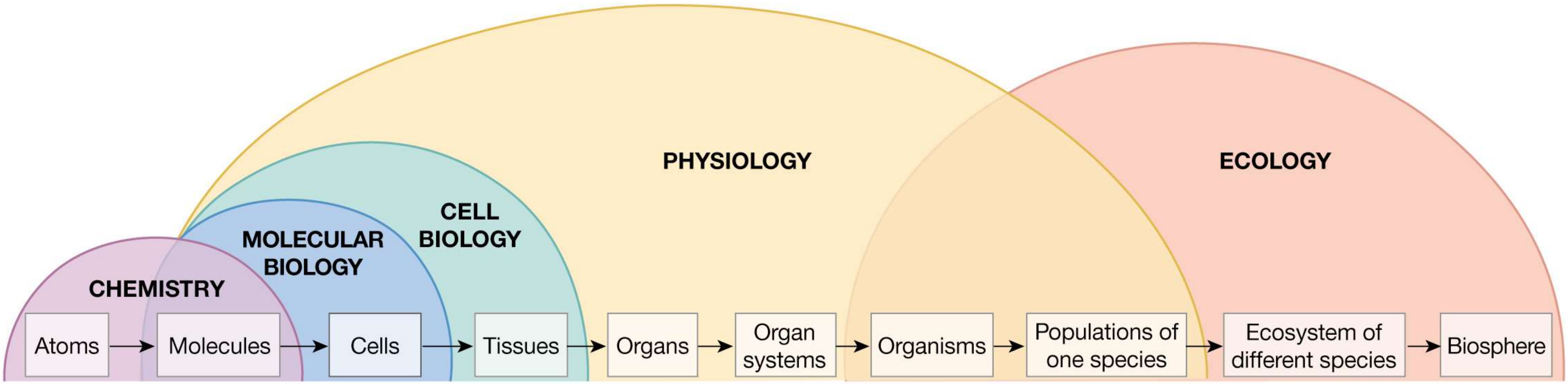


Figure 1.1 Levels of organization and the related fields of study

Organization of life: The cell is the smallest unit of structure capable of carrying out all life processes

There is a link between anatomy (form) and physiology (function)

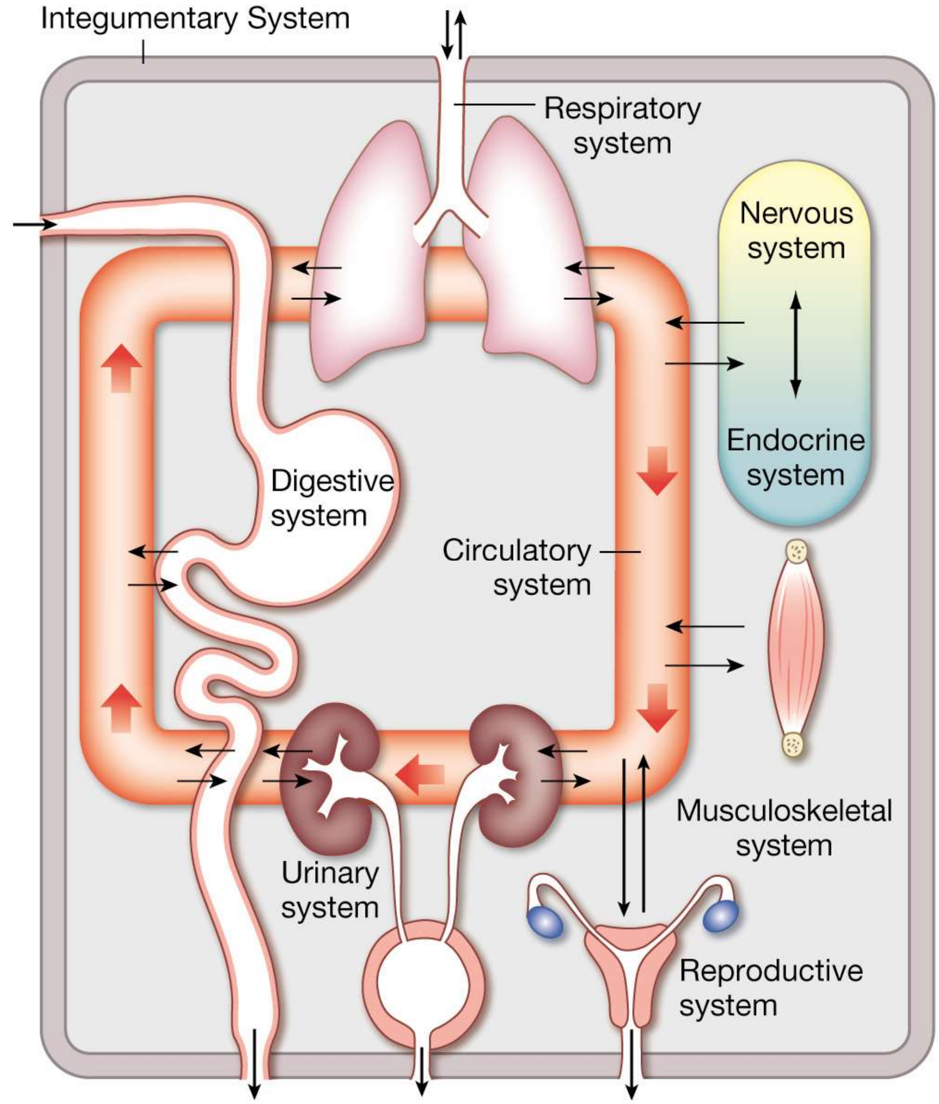
1.1 Organ Systems in Review

Organ System	Primary Function
Integumentary	Protective boundary
Musculoskeletal	Support and body movement
Respiratory (pulmonary)	Exchange gases
Digestive (Gastrointestinal)	Takes up nutrients and removes wastes
Urinary (Renal)	Removes water and waste material
Reproductive	Produces eggs and sperm
Circulatory (Cardiovascular)	Distributes materials by pumping blood through vessels
Nervous	Coordinates body functions
Endocrine	Coordinates body functions
Immune	Protects from foreign substances

FIG. 1.2 Organ Systems of the Human Body and their Integration

System Name	Includes	Representative Functions
Circulatory	Heart, blood vessels, blood	Transport of materials between all cells of the body
Digestive	Stomach, intestine, liver, pancreas	Conversion of food into particles that can be transported into the body; elimination of some wastes
Endocrine	Thyroid gland, adrenal gland	Coordination of body function through synthesis and release of regulatory molecules
Immune	Thymus, spleen, lymph nodes	Defense against foreign invaders
Integumentary	Skin	Protection from external environment
Musculoskeletal	Skeletal muscles, bone	Support and movement
Nervous	Brain, spinal cord	Coordination of body function through electrical signals and release of regulatory molecules
Reproductive	Ovaries and uterus, testes	Perpetuation of the species
Respiratory	Lungs, airways	Exchange of oxygen and carbon dioxide between the internal and external environments
Urinary	Kidneys, bladder	Maintenance of water and solutes in the internal environment; waste removal

The Integration between Systems of the Body



This schematic figure indicates relationships between systems of the human body. The interiors of some hollow organs (shown in white) are part of the external environment.

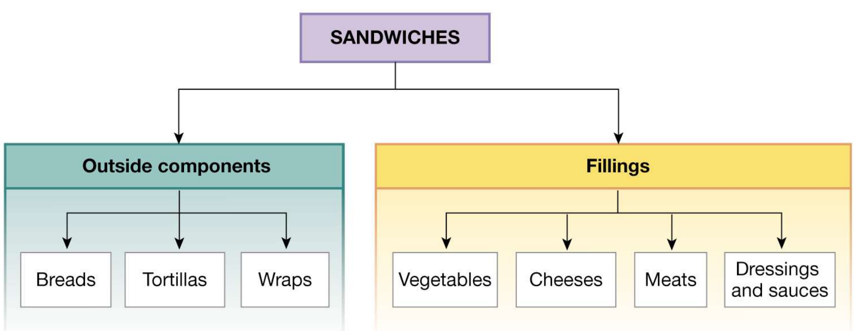
Often studied separately, however their functions are highly integrated.

Mapping

Mapping: Organizational tool for showing relationships and processes and how structure and functions are integrated

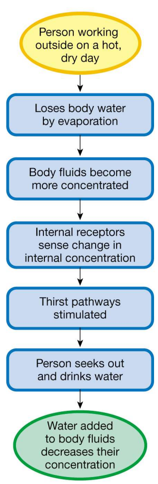
Structure/function maps

- Relationship between anatomical structures and their functions



Process maps or flow charts

- Diagram processes in sequence



Mapping: Structure/Function

Relationship between anatomical structures and their functions (atoms, molecules, cells, tissues, and organs)

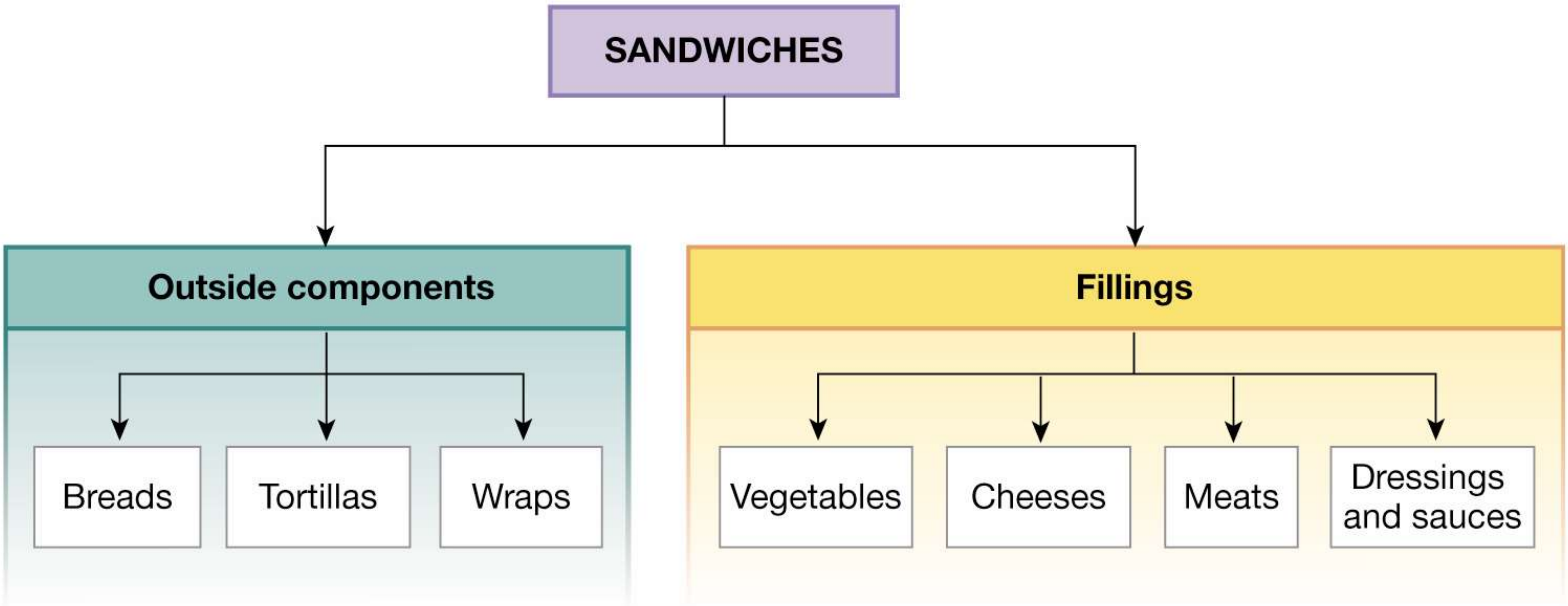
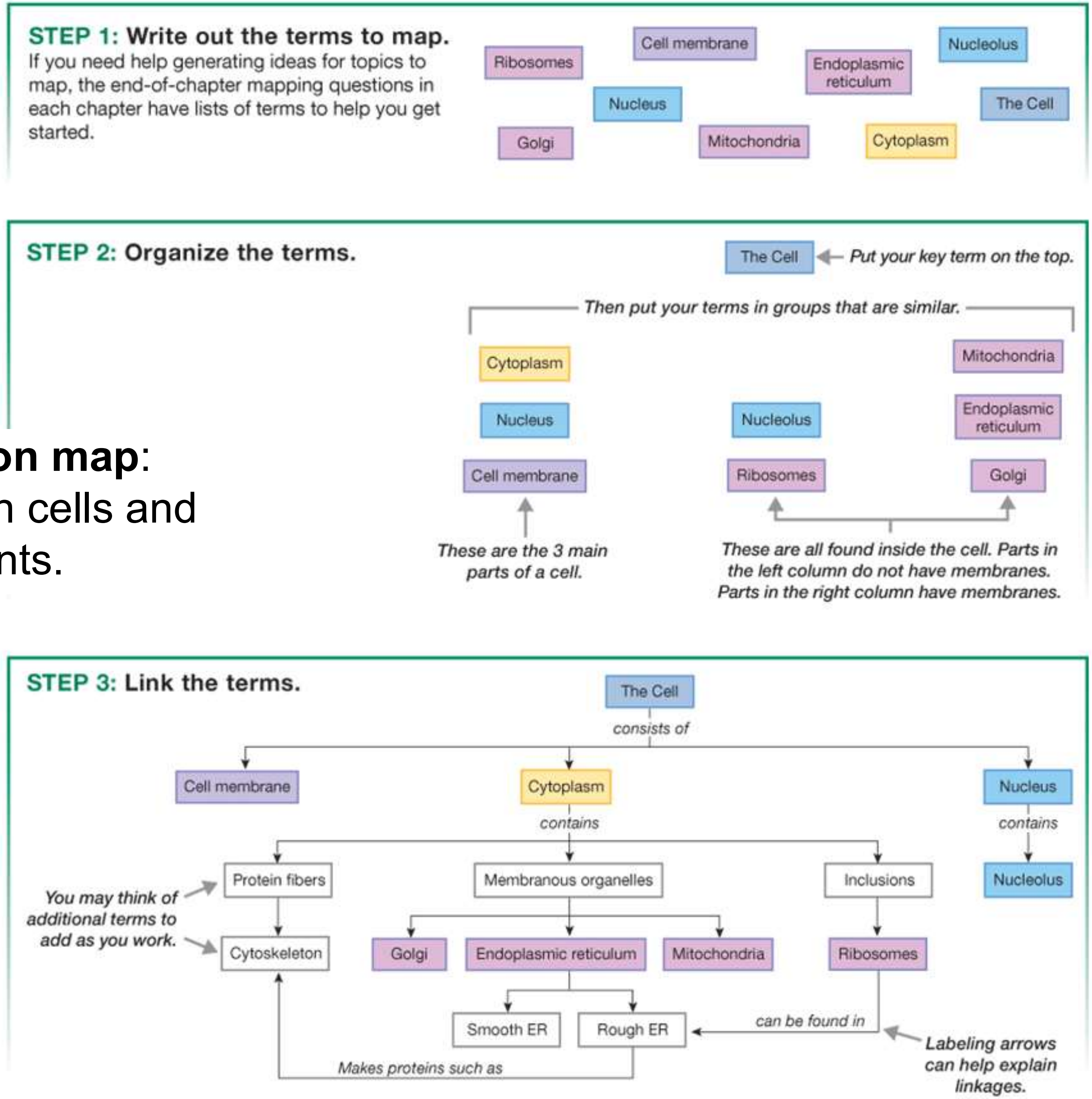


Figure 1.3 Structure/function maps

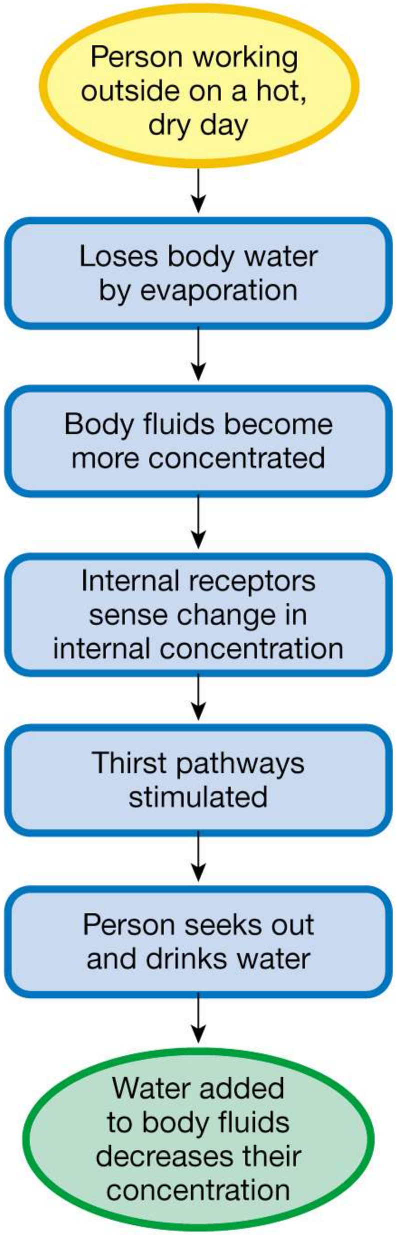
Mapping



Structure/function map: relationship between cells and it's components.

Figure 1.x xxxx

Mapping: Process Maps or Flow Charts



get hit with hammer

activate sensory receptor

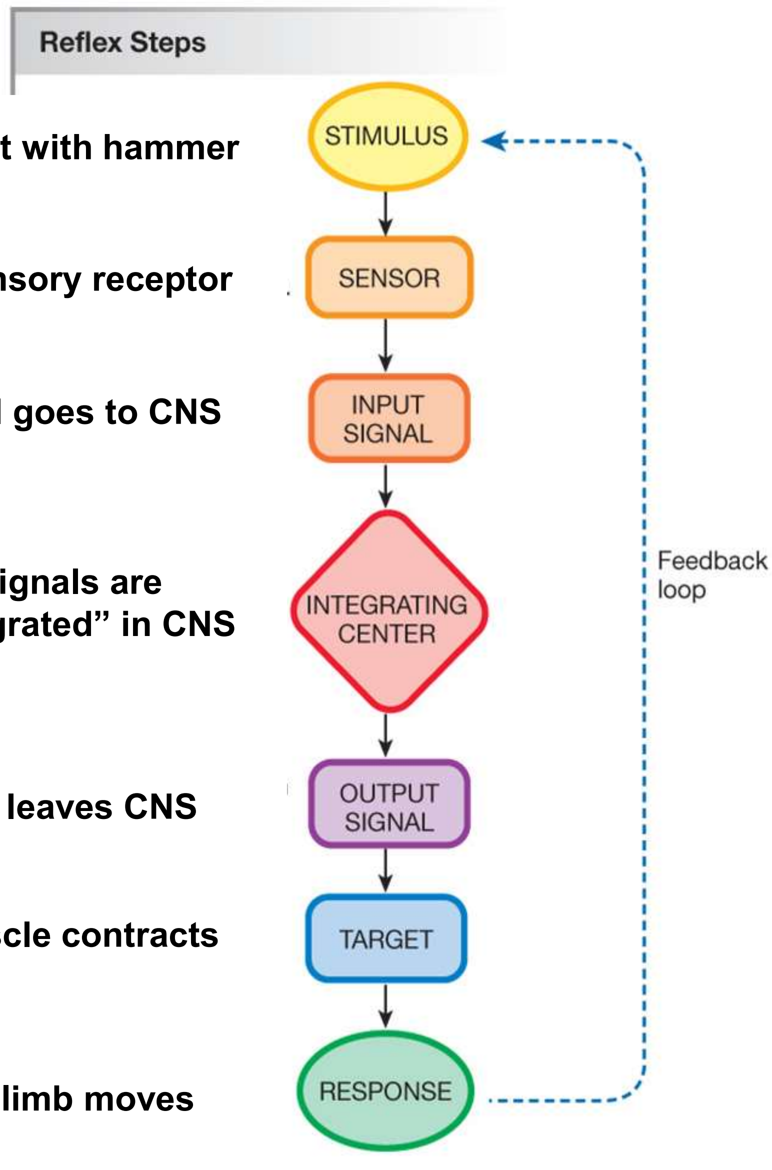
signal goes to CNS

signals are "integrated" in CNS

signal leaves CNS

muscle contracts

limb moves



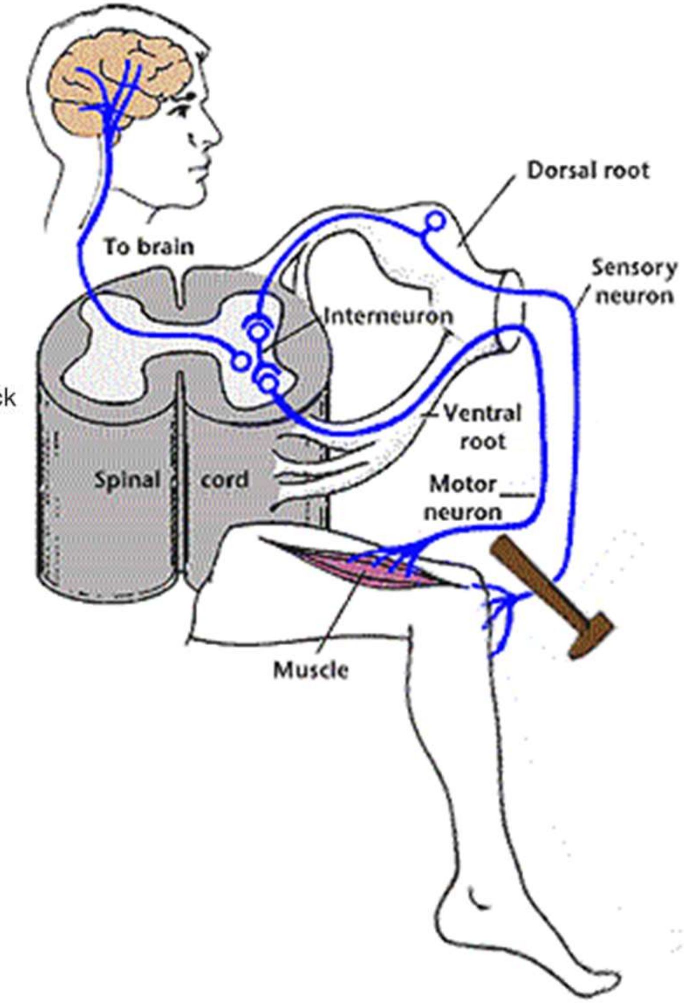


Figure 1.3 Process maps or flow charts

1.2 Function and Mechanism

Physiology

Function

Teleological: Why?

Why do red blood cells transport oxygen?

Because cells need oxygen and red blood cells bring it to them.

Mechanism

Mechanistic: How?

How do red blood cells transport oxygen?

Oxygen binds to hemoglobin molecules in the red blood cells.

Translational Research

1.3 Themes in Physiology

1. Structure and function are closely related
   - Molecular interactions
   - Compartmentation

2. Living organisms need energy

3. Information flow coordinates body functions

4. Homeostasis maintains internal stability

1.3 Structure and function are closely related

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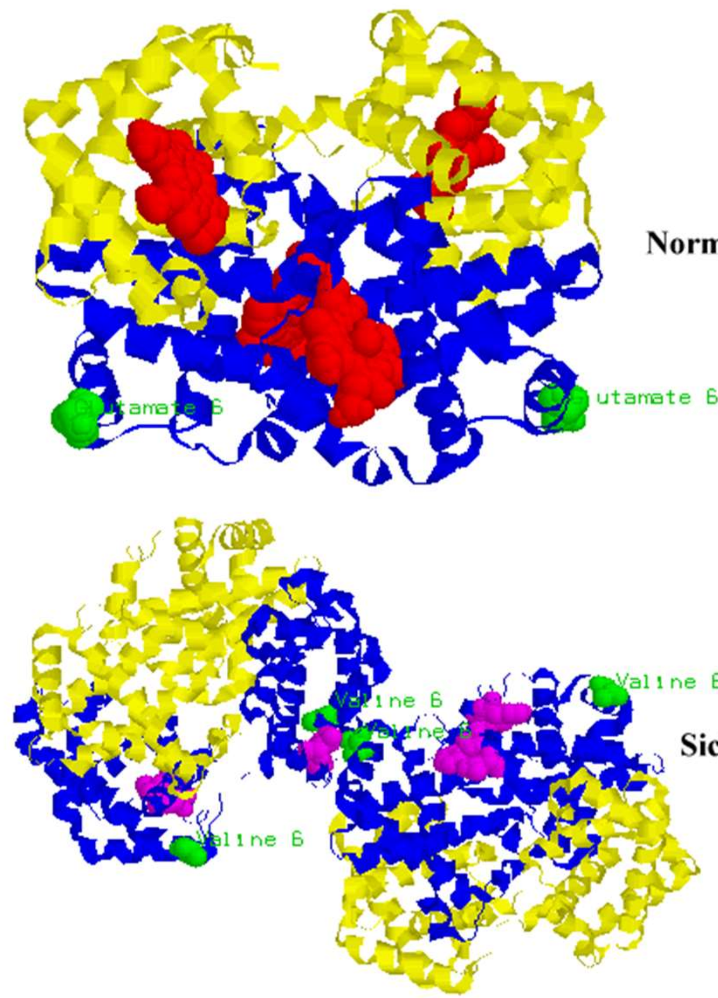
- The link between *form* and *function*



Normal Hemoglobin

Sickle Hemoglobin

Note: The Sickle hemoglobin image is drawn at 50% of the size of the Normal hemoglobin

Molecular interactions: a molecule’s function depends on it’s structure and shape (Chp 2).

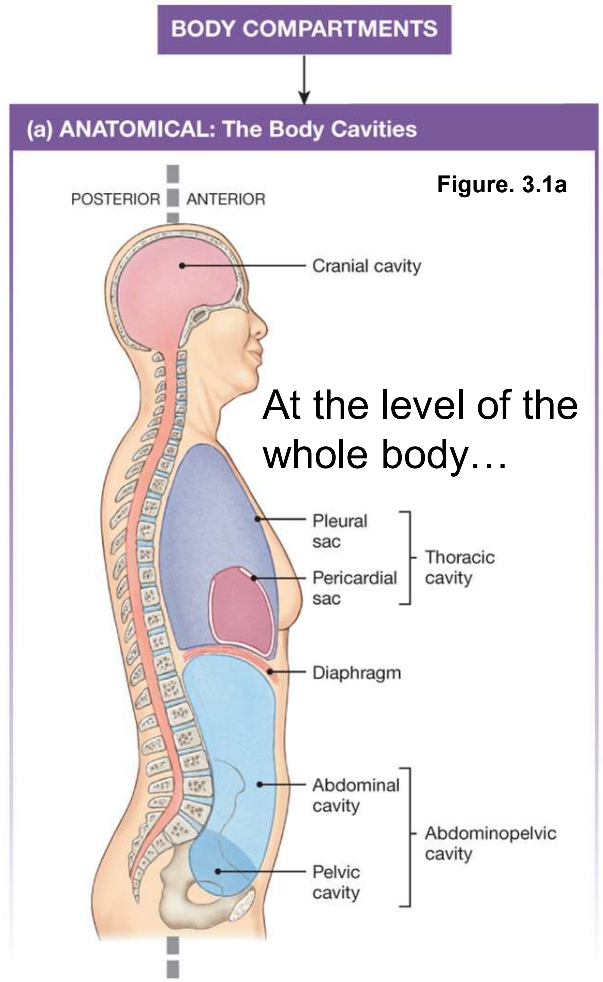
https://bloodchemistryblog.wordpress.com/2016/04/22/blood-disorders-sickle-cell-anemia/

1.3 Structure and function are closely related

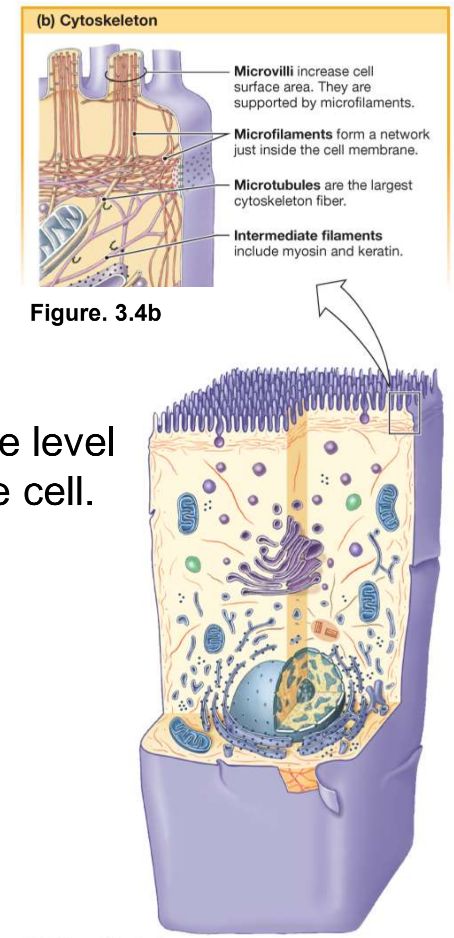
1. Structure and function are closely related

- The link between *form* and *function*

Compartmentation: division of space into compartments. Allows a cell, tissue or organ to specialize and isolate functions (Chapter 3).



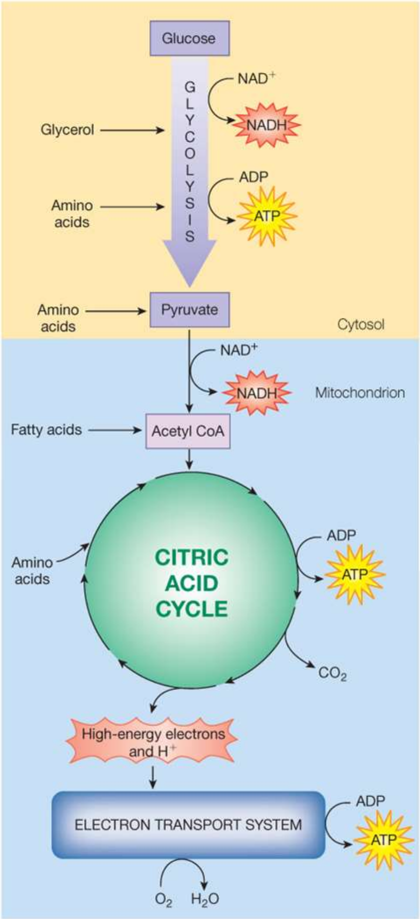
...and at the level of a single cell.

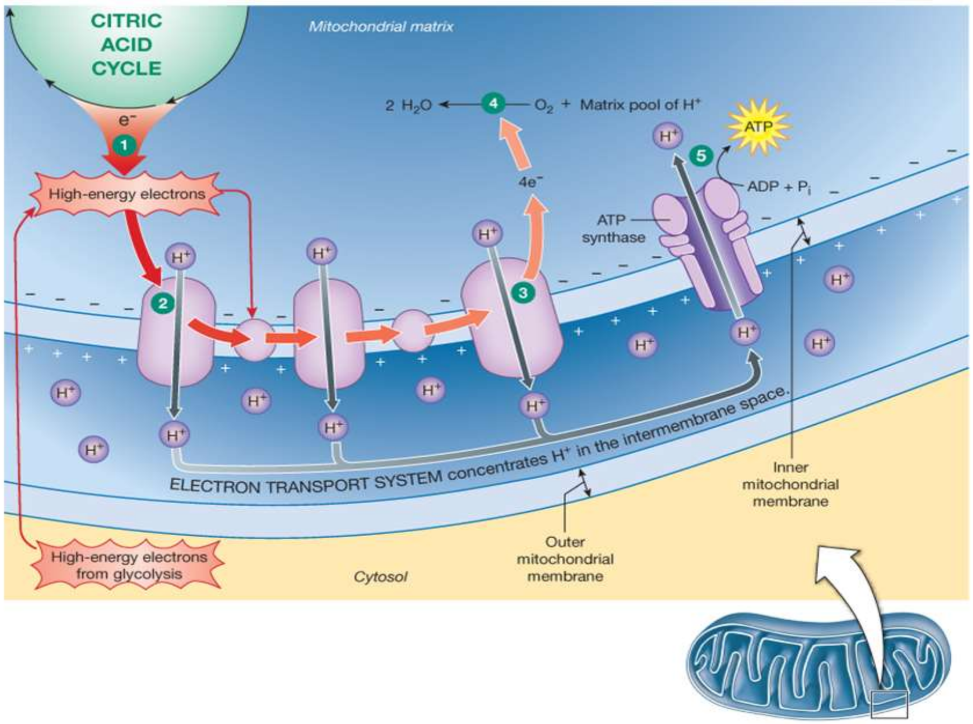


1.3 Themes in Physiology

2. Living organisms need energy

- All processes that take place in an organism require energy (Chp 4).

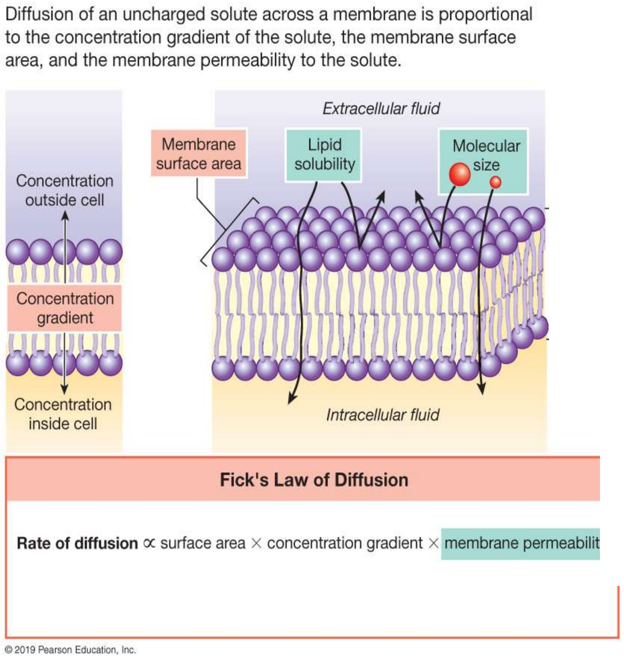


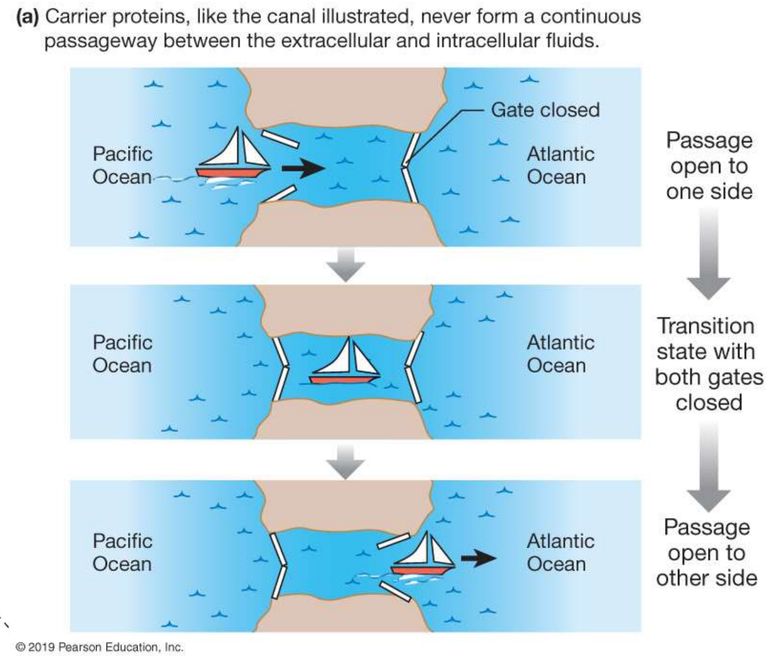


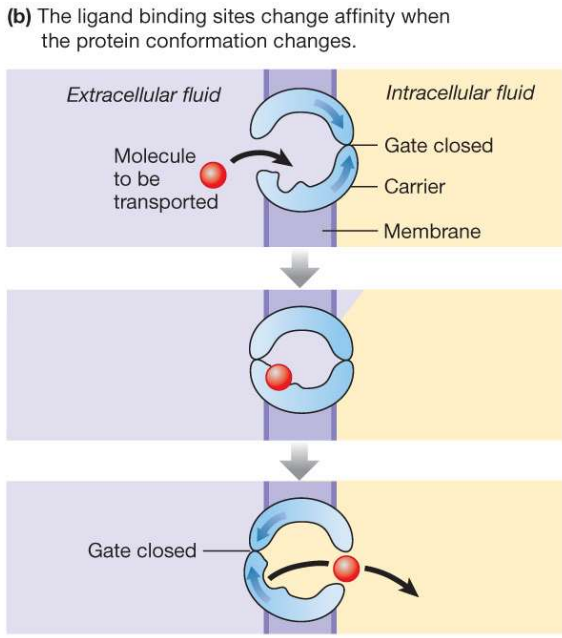
1.3 Themes in Physiology

3. Information flow coordinates body functions (Chp 5 & 6)

- Local to long-distance communication (Chp 6) and how the message is presented (Chp 5)



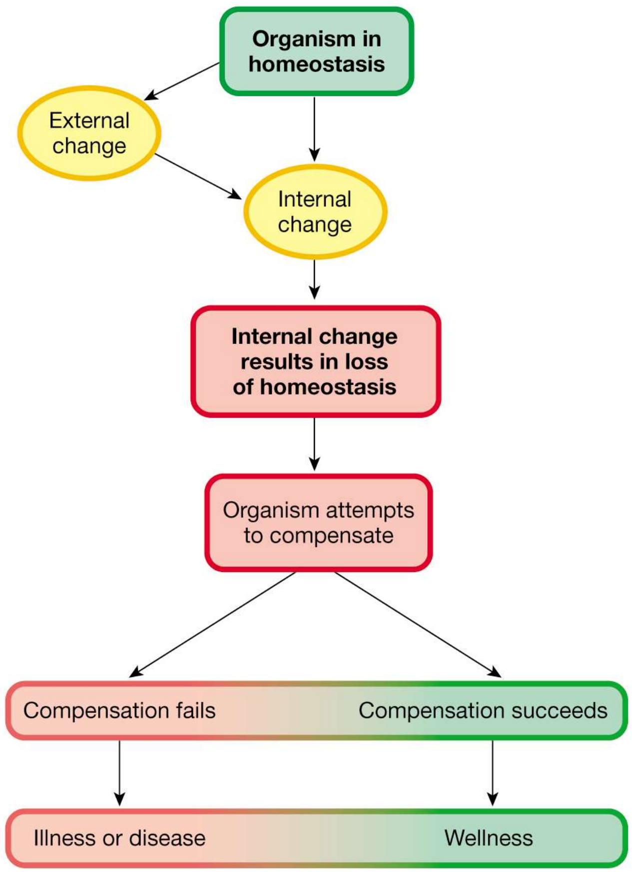




1.3 Themes in Physiology

4. Homeostasis maintains internal stability

- Maintenance of a dynamic equilibrium (Chp 1+)



1.4 Homeostasis

"Maintenance of a relatively stable internal environment"

Homeostasis = dynamic steady state ≠ equilibrium

- Materials are constantly moving between two compartments, but there is no net movement between compartments.
- The goal of homeostasis is to maintain a relatively stable state of **disequilibrium.**

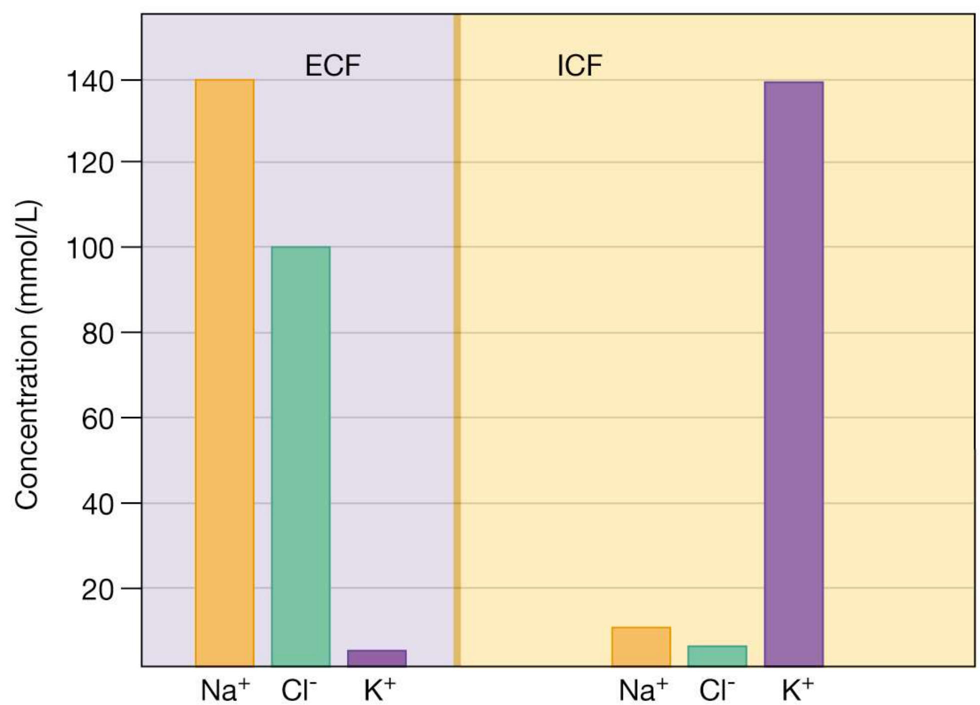
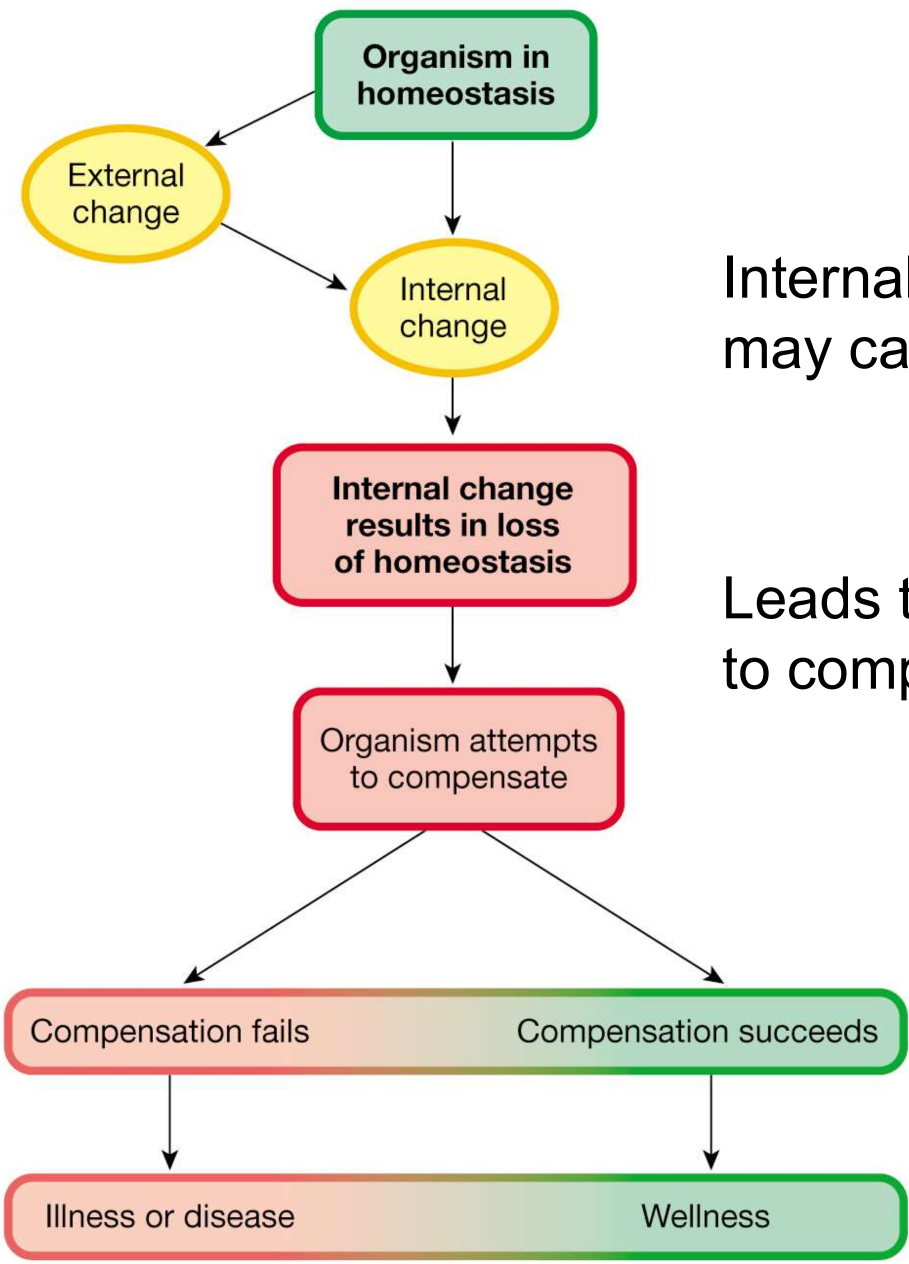


Figure 1.7 Steady-state disequilibrium

Pearson

Figure 1.4 Homeostasis



Internal (cancer) or external (COVID-19) agents may cause a disruption to homeostasis

Leads to an internal change that the body attempts to compensate.

Failure to maintain homeostasis may result in a disease or pathology.

The Body's Internal Environment

Extracellular fluid (ECF): the watery environment that <u>surrounds</u> cells

Intracellular fluid (ICF): fluid <u>within</u> cells

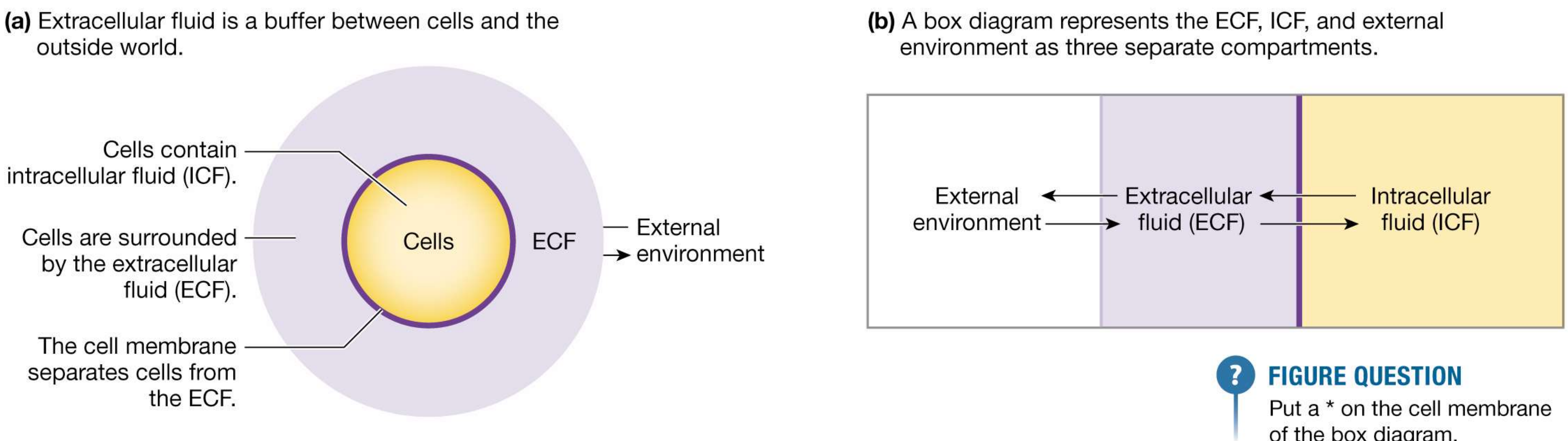


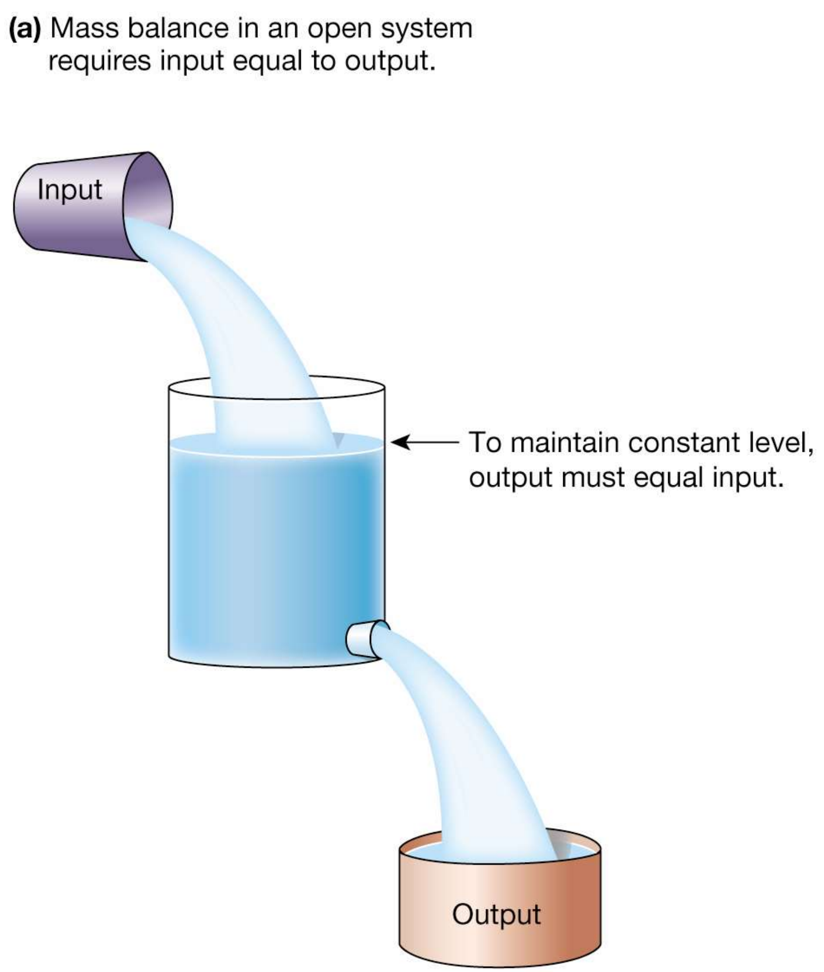
Figure 1.5 The body's internal and external environments

Homeostasis Depends on Mass Balance

Law of mass balance: if the amount of a substance in the body is to remain constant any gain must be offset by an equal loss

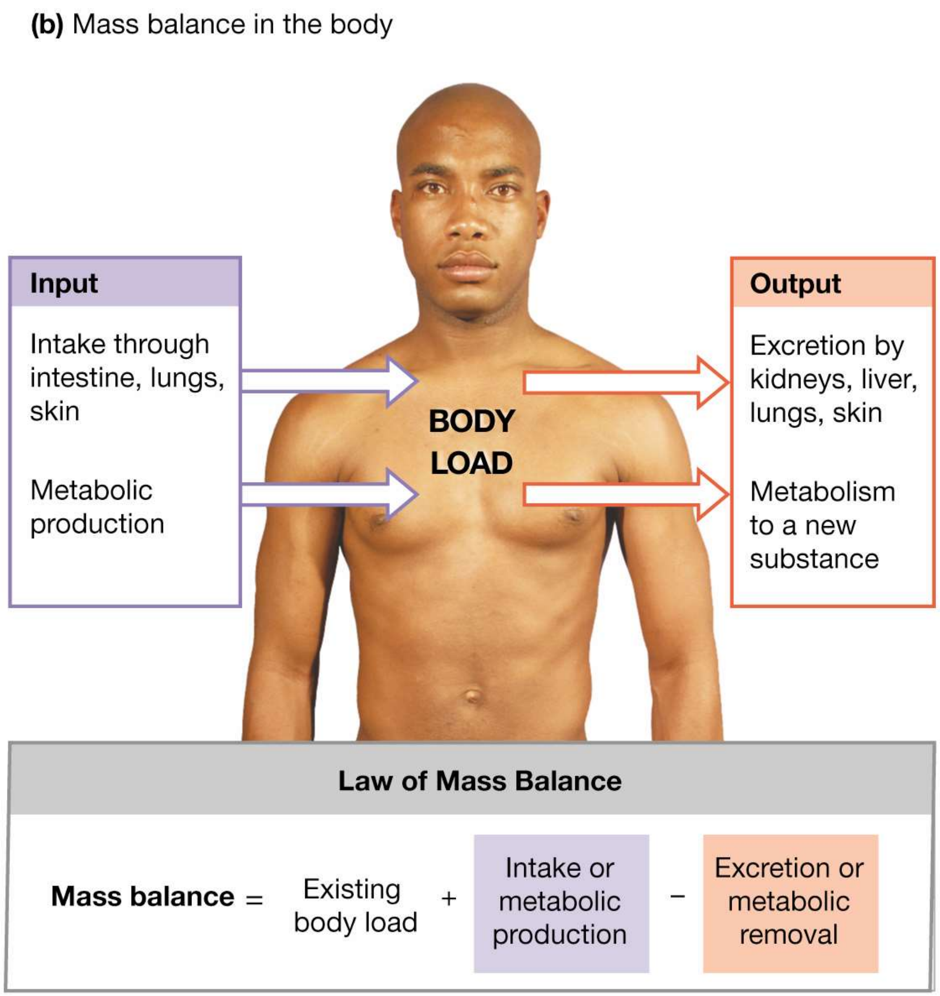
Load: amount of a substance in the body

- Constant when gains = losses
- Gains: intake from outside, metabolic production
- Losses: excretion to outside, metabolic removal



Load of χ in the body = (intake + production) – (excretion + metabolism)

Homeostasis Depends on Mass Balance



Excretion clears substances from the body (urine, feces, lungs, skin)

Mass flow: rate of transport through the body or into or out of the body

Mass flow = concentration of χ * volume flow

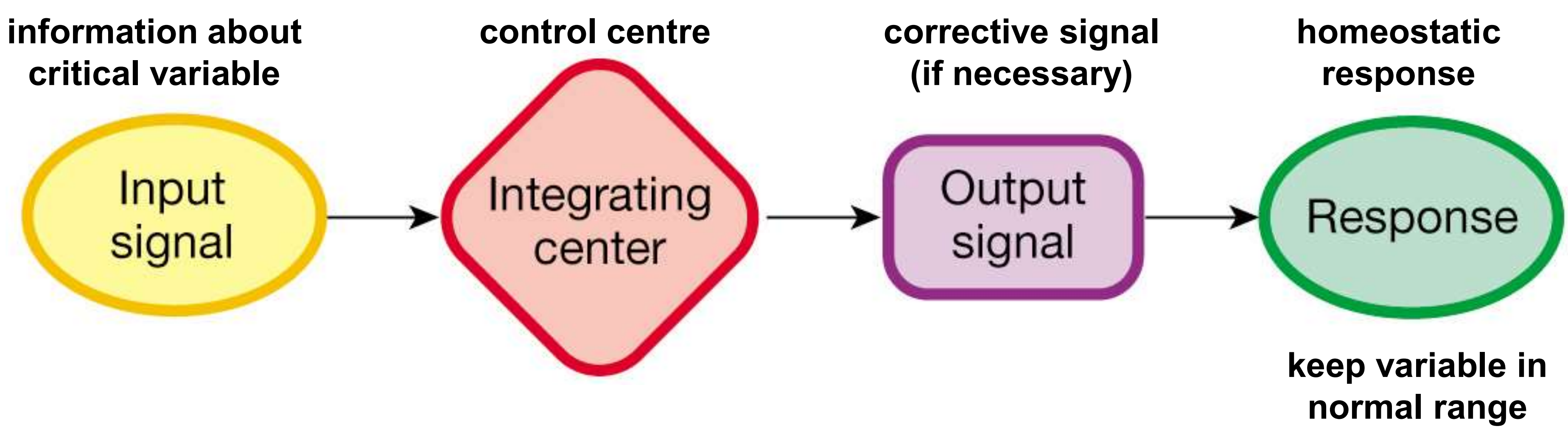
Clearance: the rate of which a substance disappears from the blood

1.5 Control Systems and Homeostasis

Regulated variables: Variables that are kept within normal range by control mechanisms

Homeostasis attempts to keep values near **setpoint**, or optimum value

Figure 1.8 A simple control system



Local versus reflex control

Local control: restricted to a local tissue or cell

1. drop in local tissue oxygenation

2. sensed by cells in blood vessels, release chemical signal

3. smooth muscle relaxes, vessels dilate, oxygen increases

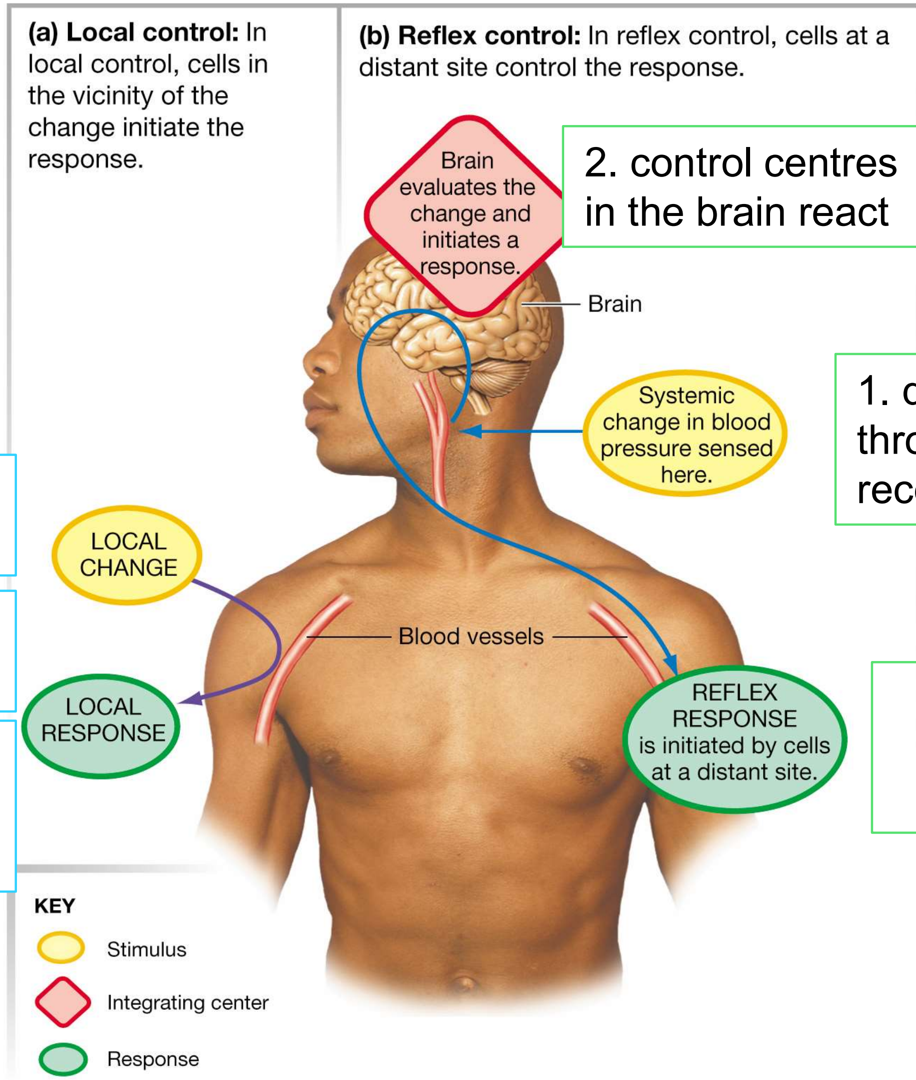


Figure 1.9 A comparison of local control and reflex control

Reflex control: uses long-distance signaling

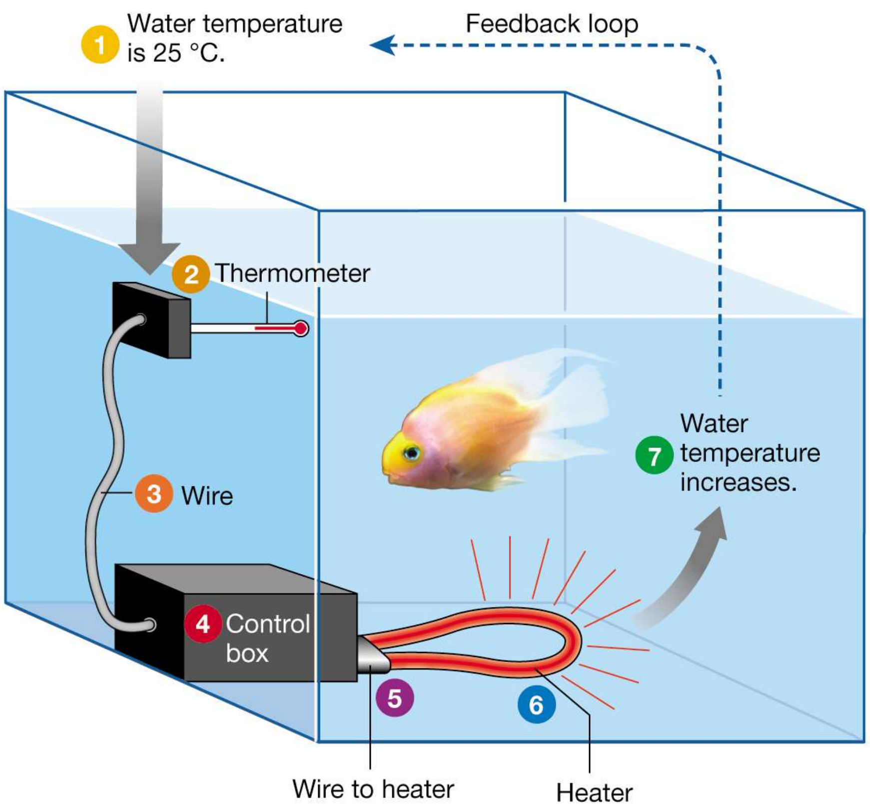
2. control centres in the brain react

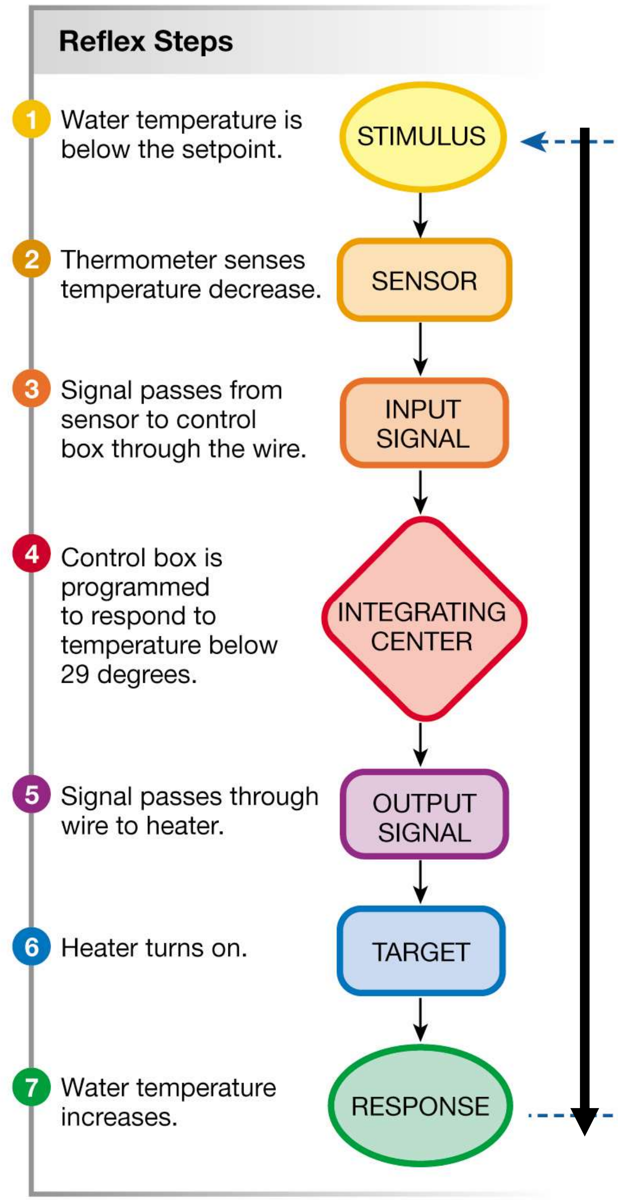
1. drop in blood pressure throughout the body detected by receptors in the neck

3. smooth muscle contracts, vessels constrict, blood pressure increases

Figure 1.10 The steps in a reflex pathway

In the aquarium example shown, the control box is set to maintain a water temperature of 30 ± 1 °C.





response loops begin with a stimulus

feedback loops modulate the response loop

control systems use "negative feedback"

Pearson

Figure 1.11 Oscillation around the setpoint

Most control systems that maintain homeostasis have a **setpoint**, or normal value. The response loop that controls the critical variable activates when the variable moves outside a predetermined **normal range**.

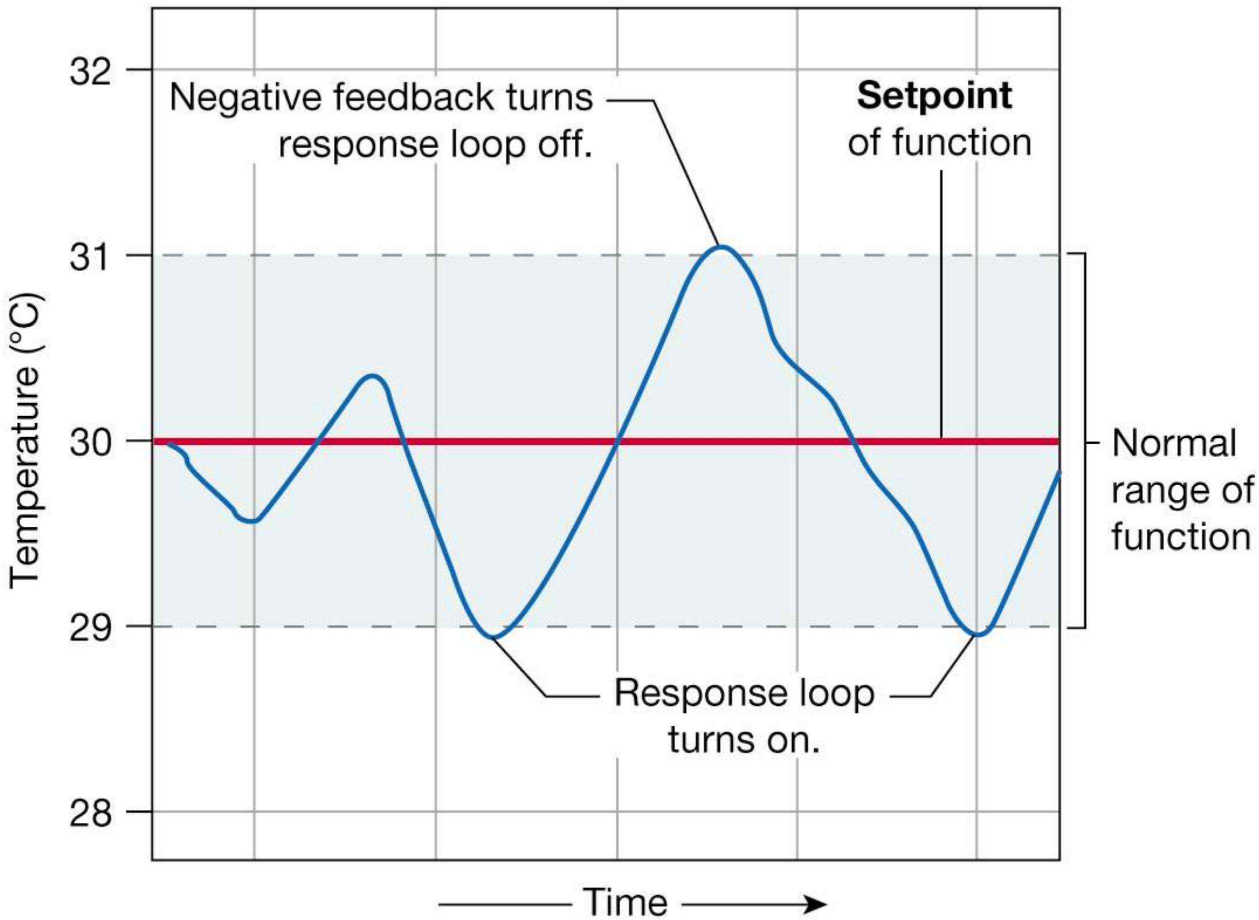
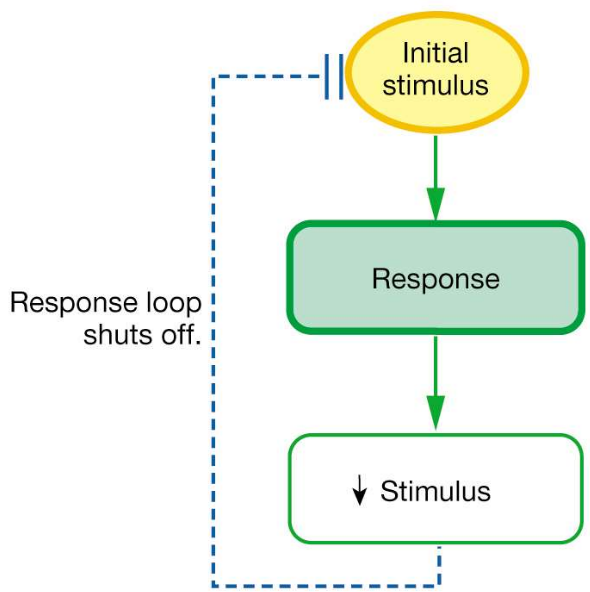


Figure 1.12 Negative and positive feedback

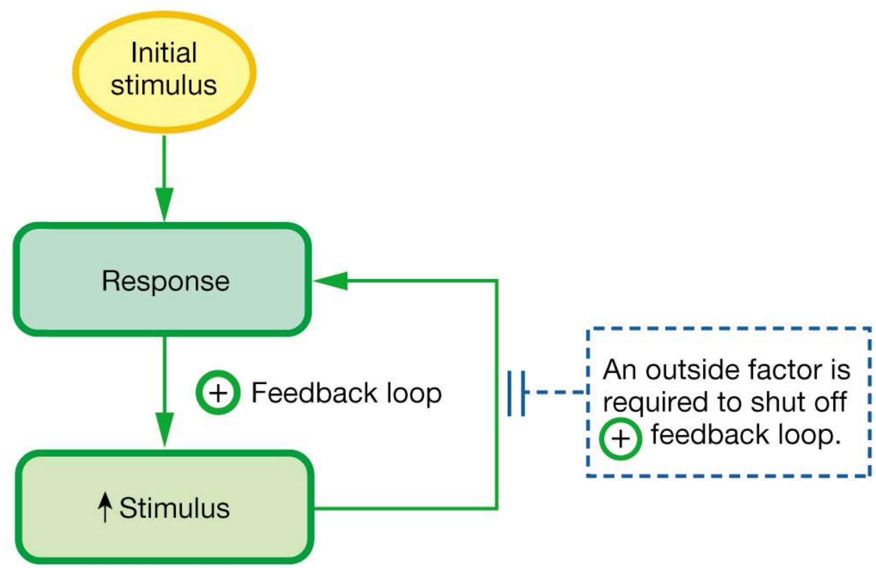
Negative feedback loops are homeostatic - stabilize variable (Fig 1.11, previous slide)

(a) Negative feedback: The response counteracts the stimulus, shutting off the response loop.



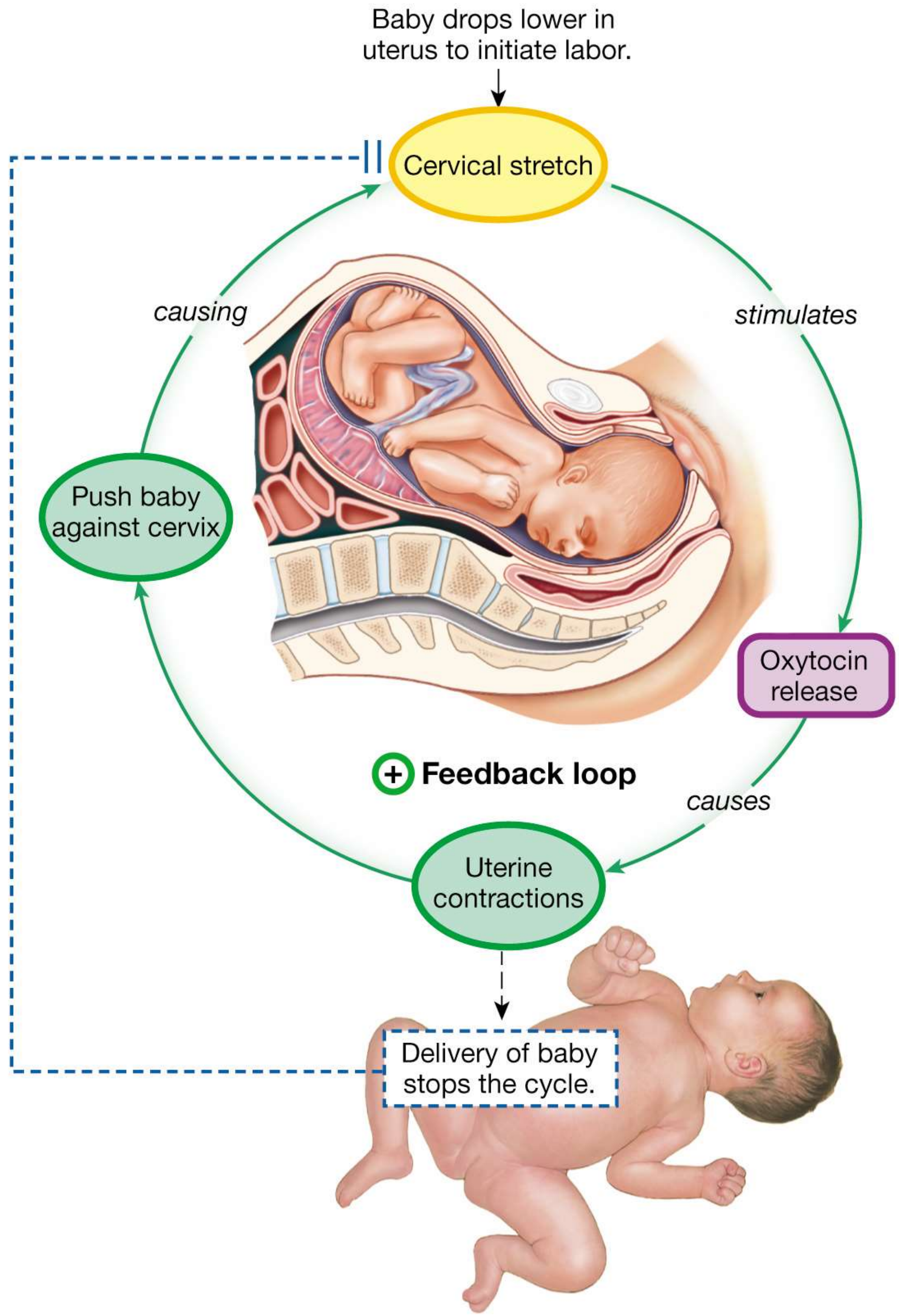
Positive feedback loops are not homeostatic – reinforce (Fig 1.13, next slide)

(b) Positive feedback: The response reinforces the stimulus, sending the variable farther from the setpoint.



Feedforward control provides a response in anticipation of an event

Figure 1.13 A positive feedback loop



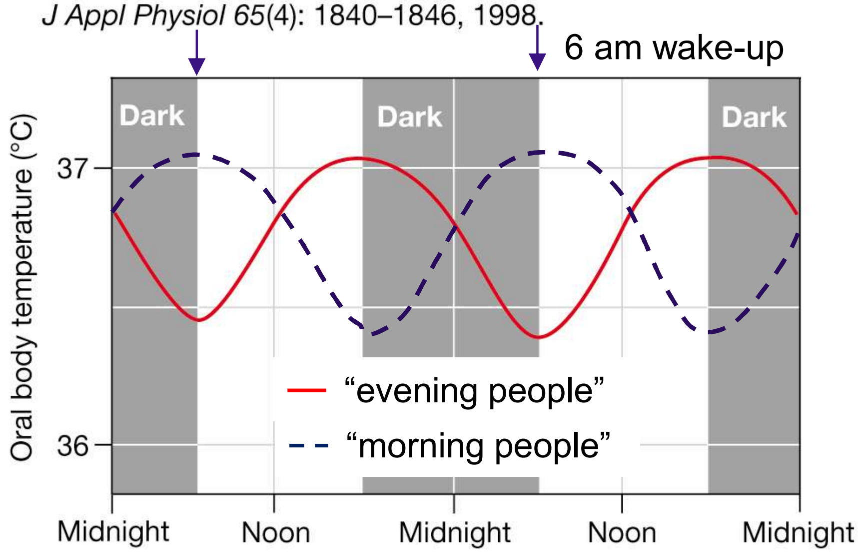
Biological Rhythms Result from Changes in a Setpoint:

Set-points vary between people and over time

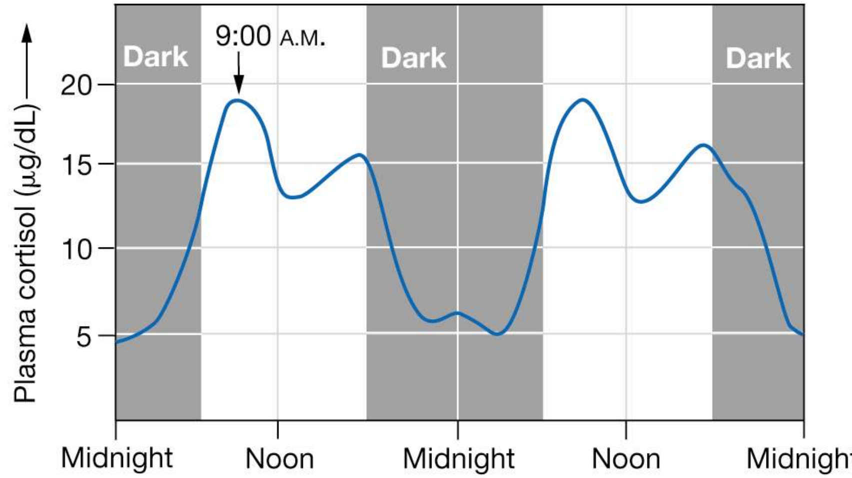
Biorhythms: Some variables follow environmental changes.

Circadian rhythm: Some variables follow a daily (24hr) cycle.

(a) Body temperature is lowest in the early morning and peaks in the late afternoon and early evening. Data from W. E. Scales *et al.*, *J Appl Physiol 65*(4): 1840–1846, 1998.



(b) Plasma cortisol is lowest during sleep and peaks shortly after awakening. Data from L. Weibel *et al.*, *Am J Physiol Endocrinol Metab 270*: E608–E613, 1996.



1.6 The Science of Physiology

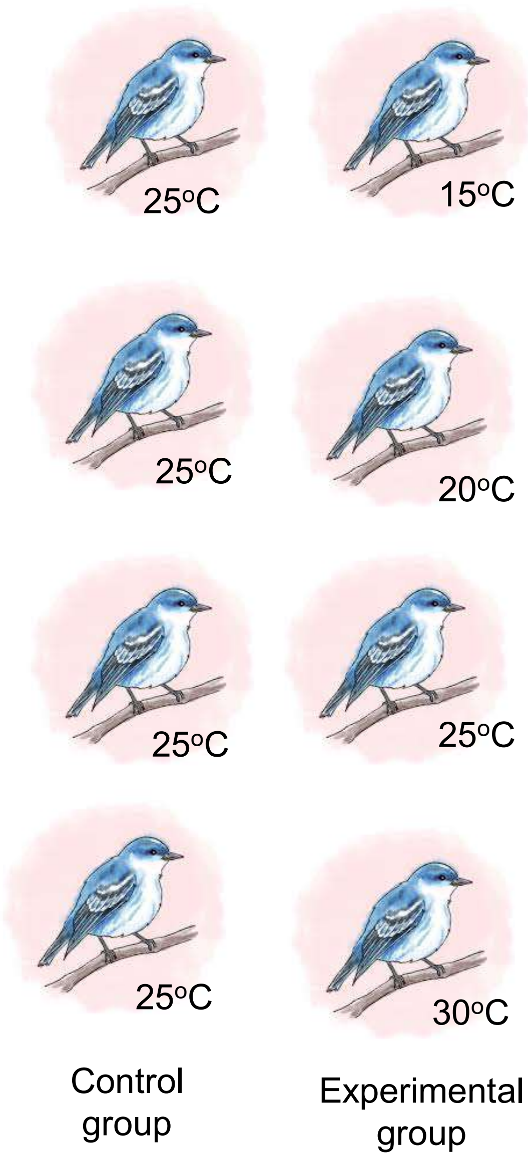
Experimental science

- Hypotheses
- Experimentation
  - Independent variable: manipulated or altered
  - Dependent variable: responds to the independent variable

Groups

- Experimental group: the independent variable is manipulated
- Control group: the independent variable is unchanged

Hypothesis: Birds eat more when it's cold.

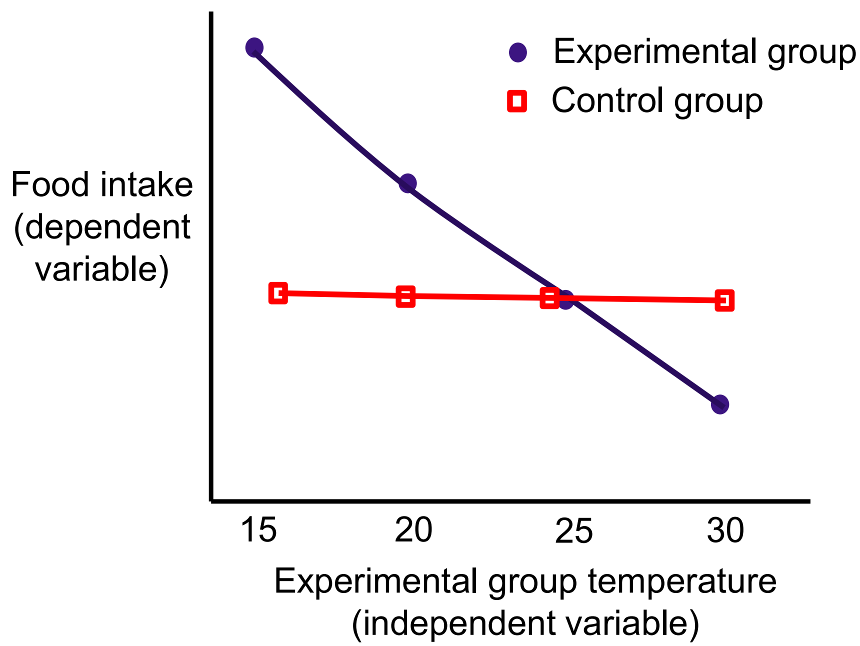


Eight group of birds divided into two groups.

In the experimental group, environmental temperature (independent variable) is altered between 15-30°C.

In the control group, temperature is unchanged.

Food intake (dependent variable) is measured.



Replication, models and theories

Replication: If a result supports a hypothesis it must be replicated to ensure the observation was not a chance or “one-off” event.

When data support a hypothesis after multiple experiments, the hypothesis may become a **working model.**

A working model with substantial evidence from multiple investigators and approaches may become a **scientific theory**.

Graphing

- Independent variable typically on the horizontal X-axis
- Dependent variable typically on the vertical Y-axis
- Bar graphs – independent variables are distinct entities
- Line graphs – independent variable is a continuous phenomenon
- Scatter plots – show relationship between two variables

Review <u>Figure 1.15 Focus on… Graphing</u>

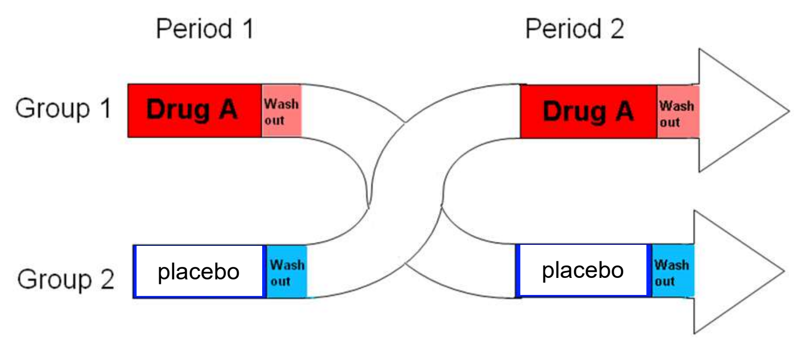
Pearson

The Results of Human Experiments Can Be Difficult to Interpret

Variability

Variability: there is wide genetic and environmental variability between humans. In a **crossover study** each individual gets the experimental treatment and then “crosses over” to also be in the control group.

In this example of a crossover study the control treatment was a **placebo** or inactive substance.



https://en.citizendium.org/wiki/Cross-over_study

In a cross-over study, each individual acts as their own control, enabling researchers to see the effect of the drug in each participant, rather than between two groups, which helps deal with variability between participants.

Psychological Factors

Placebo effect: If you give someone a pill and tell them it will alleviate some problem, that beneficial effect may be observed, even the pill contains sugar or an inert substance.

Nocebo effect: If you give someone a pill and tell them it may have an adverse side effect, that side effect may be observed, even the pill contains sugar or an inert substance.

The simplest way to control for these effects is with a "**blind study**" in which participants don't know if they took the treatment or the placebo.

Sometimes researchers expectations can influence the outcome. Then, a **double-blind study**, in which researchers are also "blinded" until after the experiment, would be most appropriate.

Ethical Considerations

Scientific experiments must adhere to ethical rules and regulations and protocols and procedures must be approved local ethics committees.

Concerns regarding ethics do arise, particularly when involving people experiencing a disease or illness.

Example: When researchers were testing the efficacy of a treatment for dissolving blood clots in heart attack victims, the survival rate among treated patients was much higher than the control group.

Was it ethical to withhold this new and promising treatment from the control group?

Testing was halted so that members of the control group could also be given the experimental drug.

Types of Studies

Longitudinal studies: follow participants over long periods of time.

Prospective studies (now and looking forward): participants are enrolled before they develop the disease or condition in question.

Cross-sectional studies: survey a population for the prevalence of a disease or condition.

Retrospective studies (looking back): compare groups of people who have a particular disease or condition to a similar healthy control group.

Meta-analyses: combines all the data from a group of similar studies and uses statistical techniques to extract trends or findings from the combined data.

Learning Objectives

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LO 1.1.2 List the levels of organization from atoms to the biosphere.

LO 1.1.3 Name the 10 physiological organ systems of the body and give their functions.

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