Exam 3 study guide

Lecture 1 Animal Structure and Function

Most important keywords: scaling

What are the objectives of the second half of the course?

Learn how animals, plants, and bacteria work.

Understanding of relationship between organism function and physical principles

Linkages between biochemistry/cell biology and whole organism function/ ecology

What are the overall themes we will come back to throughout the second half?

1) Organisms have similar functional needs

2) Organisms must obey physical laws

3) Understanding how an organism works involves consideration of biochemistry, cell biology, physiology, ecology and evolution

2. Organisms must obey physical laws

physical principles are evident from structure and function at organismal, cellular, and biochemical levels

Example: Size Does Matter (scaling effects)

Is it hard for a mayfly to hatch out of a stream? Why?

E. coli swimming in water -- is like a human swimming in hot asphalt

How do insects cling to vertical surfaces?

Example: scaling of skeletons

Is it possible to have 12 foot tall humans?

What happens if you double the linear dimension of an animal? Muscle mass? Skeletal mass?

To avoid weaker skeletons on large animals, the skeleton size increases disproportionately
The relationship between skeleton size and body mass for a variety of mammals

***A mouse-sized elephant would have a skeleton around 5 times heavier than a mouse***

Animal Diversity

Body symmetry- What are the types?

Burgess Shale fossils- what do these fossils tell us? i.e., “Wonderful Life”

Review of animal phylogeny- memorize this figure

What are the animals in the Phylum Porifera and what are their characteristics

- Sponges
- "colony" of flagellated cells
- individual cells can potentially regenerate into a new individual

What type of symmetry do sponges have?

Phylum Cnidaria – animals in this phylum? Characteristics?

- Hydras, jellyfish, sea anemones, corals
- ***gastrovascular cavity***
- stinging cells
- ***Radial symmetry***
Phylum Ctenophora - animals in this phylum? Characteristics?

- Comb jellies
- Comblike ciliary plates
- **Gastrovascular cavity**
- **Radiata (radial symmetry)**

Bilateral symmetry

Body plans of the bilateria – I may ask some hard questions on this figure

Phylum Platyhelminthes

- Flatworms
- Dorsoventrally flattened
- No segmentation
- **Gastrovascular cavity**
- **Bilateral, no coelom, protostome**

Phylum Rotifera

- Ciliated crown
- No digestive system
- Bilateral, pseudocoelomates, protostome

Phylum Nematoda

- Roundworms
- Unsegmented
- No circulatory system
bilateral, pseudocoelomate, protostome

Lophophorates - several phyla
- Bryozoans, lampshells (brachiopods)
- bilateral, coelomate, protostome

Phylum Mollusca
- Clams, snails, squids
  - foot, visceral mass, mantle
  - bilateral, coelomate, protostome

Basic body plan of mollusks – know gill, foot, mantle

Anatomy of a clam – know gill foot mantle

Phylum Annelida
- Segmented worms
  - bilateral, coelomate, protostome

Phylum Arthropoda
- Crustaceans, insects, spiders
  - segmented body, jointed appendages, exoskeleton
  - bilateral, coelomate, protostome

Deuterostomes

*** A comparison of early development in protostomes and deuterostomes – I could ask some hard questions on this figure
Phylum Echinodermata

- Starfish, sea urchins
- bilateral, coelomate, deuterostome

Phylum Chordata

- Lancelets, tunicates, vertebrates
  - notochord, nerve cord
  - bilateral, coelomate, deuterostome

Circulation and Gas Exchange I (Chapter 42)

Keywords

cellular respiration

Diffusion of gases

Speed of diffusion

Effect of size on oxygen supply

Gas exchange structures

Gills, lungs

Gastrovascular cavity
Surface area

Cellular respiration

A type of controlled combustion:

Reduced carbon (e.g., glucose) + O₂

------> CO₂ + H₂O

Organismal respiration -- a simple view (understand the cartoon picture in lecture notes)

Rate of diffusion of gases (e.g., oxygen)

How fast is diffusion of oxygen?

1 micron (µm) in 10⁻⁴ seconds

One millionth of a meter in one tenth of a millisecond

How does diffusion work?

Consider a point source of a diffusing substance

Each molecule will travel randomly (brownian motion)

Over time particles will become separated

But particles don’t just move away from the original point source. They are travelling randomlyThus it takes a long time for molecules to diffuse over long distances

"Speed" of oxygen diffusion in liquid

1 µm in 10⁻⁴ seconds

1000 µm (1 mm) in 100 seconds

Thus diffusion can supply oxygen only over very short distances

Examples where oxygen diffuses only short distances

Vertebrate lung
Very small organisms

How small does an organism have to be to rely on diffusion alone?

Consider a spherical sea creature 1 mm wide

oxygen concentration in normal seawater is sufficient to support low rates of respiration

Predicted that oxygen concentration only needs to be 71% of normal levels

How about a spherical sea creature 1 cm wide?

The oxygen concentration in the water would need to be 71 times normal levels to support a low metabolic rate

Relationship between surface area and volume changes as a function of size

Another example of scaling

Example of organism relying solely on surface: the Protist Paramecium

Paramecium is a freshwater ciliate

Other small organisms that use their surfaces only include: bacteria, microalgae, yeasts

What do you do if you want to be bigger than 1 mm?

Adaptations to enhance gas exchange:

Circulatory systems and/or increased surface area

Example of increased surface area: Green Hydra (several mm long)

The jelly fish Aurelia

Complex gastrovascular cavity that circulates fluid

What are all the possible gas exchange structures?

Surface only (very small organisms 2 1 mm)

Gastrovascular cavity (hydra, jellyfish, also flatworms)

Gills, tracheal systems, lungs
Mixture of the above

Gills (definition)

Appendages around which the medium (usually water) passes.

often richly supplied with blood vessels

Found in many types of invertebrates and vertebrates

Circulation and gas exchange II (Chapter 42)

Keywords

Fish gill

Filaments

Lamellae

Tracheal system

Tracheoles

Gastrovascular cavity

Lung

Tidal ventilation

Ventilation in birds

Fish Gill

Rather than being a solid structure, the fish gill is finely subdivided to enhance gas exchange area
Definitely know these structures and terms: filaments, Lamellae, Countercurrent flow

**How does countercurrent flow enable more complete removal of oxygen from the water**

Are gills effective in increasing surface area?

In mackerel 20 fold increase due to gills

How do gill surface areas compare among different fishes?

Tracheal systems in insects, what are the parts? Can you identify them in the diagram. What is the tracheal system full of air? Liquid?

Know how Tracheoles supply tissues- how close is tracheole to individual mitochondria in cells

Lungs

Internal sacs

Unlike insect tracheal system lungs do not contact entire body

Circulatory system draws oxygen from lungs to tissues

Found in snails, a few fishes, spiders, vertebrates

Structure of the mammalian lung - main structure need to know is alveoli and that alveoli are surrounded by capillaries

Tidal ventilation of mammalian lung

Negative pressure breathing

Tidal volume - volume inhaled and exhaled (around 500 ml in humans)

Tidal volume is much less than total volume of lungs (several liters in humans)

Thus residual volume remains after exhaling

Why is tidal ventilation inefficient?

Birds have a more "sophisticated" type of lung ventilation
Birds have high metabolic rates
Can be exposed to lower oxygen concentrations in high altitude flight
Ventilation is not tidal
Air flows through the lungs

The avian respiratory system - know the structure and the direction of airflow. Know positions of mouth, anterior and posterior airsaes, lung.

The control of breathing- is it regulated by oxygen or carbon dioxide

    Human brain monitors carbon dioxide level (detected as a drop in blood pH)

    Hyperventilation in divers How does it help them to dive?

    Diving mammals can tolerate high blood carbon dioxide. What is the name of the seal discussed in lecture?

    In blood decreased oxygen corresponds to increased carbon dioxide

    Increased carbon dioxide results in acidification which can readily be detected

Lecture 4: Circulation and Gas Exchange III
Circulatory System

keywords
Open vs. closed circulatory systems
Hemolymph vs. blood
Artery, capillary, vein
2-, 3-, 4- chambered heart
Pathway of circulation
Atrium
ventricle

Circulatory Systems

Two types: open and closed

Used to transport oxygen to cells and waste carbon dioxide away.

Also transport of other substances such as hormones, glucose, nitrogenous wastes

Open circulatory system

Found in invertebrates such as clams and insects

Heart pumps fluid to through vessels out to body into spaces called sinuses.

Fluid in sinuses bathes cells and organs

This fluid is called hemolymph not blood

Hemolymph collecting in sinuses can be drawn back into the heart.

Body movements can aid circulation by squeezing sinuses and pushing blood back into the heart.

Example of open circulation

Closed circulatory system

Found in earthworms (annelids), squids & octopus (cephalopods), vertebrates

Fluid (called blood) stays in the vessels

Smaller branching vessels supply tissues

Example of closed circulatory system: Earthworm
Compare and contrast open vs. closed

Open less effective at circulating all the fluid

Doesn’t matter if metabolism is slow, e.g., clams

Insects use trachael system to supply oxygen and get rid of carbon dioxide

Closer look at closed circulatory system

Also called cardiovascular system: heart, blood vessels, blood

Three main types of blood vessels

Arteries, capillaries, veins

Arteries are thicker walled, veins have valves

Arteries transport blood AWAY from heart, veins TOWARDS heart

Doesn’t necessarily correlate with oxygenated vs. deoxygenated blood

Hemoglobin – respiratory protein, 4 globins, 4 hemes, hemes bind to oxygen

Hemoglobin oxygen dissociation curve - what happens to hemoglobin oxygen saturation as the oxygen concentration increases?

Bohr effect – At high pH hemoglobin has high affinity for oxygen; at lower pH hemoglobin has a lower affinity for oxygen (will tend to release oxygen)

The vertebrate circulatory system - types of hearts

Two chamber - fish

Three chamber - amphibians

Four chamber - mammals, crocodiles

2-chamber - know the pathway of blood and the names of the structures it passes through (i.e., systemic capillaries, ventricle, atrium), where is it oxygenated, where is it deoxygenated, where is blood pressure the highest, where is blood pressure the lowest, where is blood pH low, where is blood pH high

3-chamber - know the pathway of blood - - know the pathway of blood and the names of the structures it passes through (i.e., systemic capillaries,
ventricle, left atrium), where is it oxygenated, where is it deoxygenated, where is blood pressure the highest, where is blood pressure the lowest, where is blood pH low, where is blood pH high

4 chamber- know the pathway of blood --- know the pathway of blood and the names of the structures it passes through (i.e., systemic capillaries, pulmonary vein and artery, left and right ventricle, left and right atrium), where is it oxygenated, where is it deoxygenated, where is blood pressure the highest, where is blood pressure the lowest, where is blood pH low, where is blood pH high

What are the advantages of 3 chamber over 2 chamber? 4 chamber over 3 chamber?

Arterial switch operation – transposition of the major blood vessels – Why doesn’t the baby’s blood become oxygenated when there is this heart defect?

Chemical signals in animals

Keywords
Reading Ch. 45

- Endocrine system
- Hormone
- Neurosecretory cell
- Steroid
- Action of steroids
- Glucose homeostasis
- Insulin
- Glucagon
- Epinephrine
- Norepinephrine
- ACTH

Endocrine system definition

- The internal chemical communication system involving hormones

Hormone

- Chemical signal secreted into body fluids (usually blood)
- Effective in minute amounts
Types of hormones

- Steroid
  - Amino acid derived

Steroid hormones

- Made from cholesterol
- Include sex hormones

Amino acid derived

- Single amino acids
- Peptides
- Proteins
- Glycoproteins

Hormones act on specific target cells in two ways

- Surface receptors
- Within target cells (internal receptor)

Surface receptor—how does it work?

Internal receptor—steps in how it works? Used with steroid hormones

Two examples of hormone action

- Glucose homeostasis
- Stress and the adrenal gland

Glucose homeostasis

- **Homeostasis** = The steady-state physiological condition of the body
- Glucose = major fuel of cellular respiration
- **Normal blood glucose level** = 900 mg/L
- How is this regulated?
  - First look at when glucose levels are too high

- High blood glucose causes beta cells to release insulin

What happens if you need to increase blood glucose?
- Low blood glucose causes alpha cells to release the hormone glucagon
- Glucagon stimulates the liver to break down glycogen releasing glucose

Diabetes mellitus
- Greek = copious urine, honey
- Type I - autoimmune disorder - cells of pancreas are targeted - no ability to produce insulin - usually occurs during childhood
- Type II (90%) - reduced responsiveness of target cells or insulin deficiency-usually occurs after age 40

Stress and the adrenal gland
- Short-term response - Epinephrine (adrenaline) and norepinephrine
- Long-term response - ACTH and corticosteroids
- ***Know the figure showing the hypothalamus, adrenal glands etc.***

Short-term stress: medulla of the adrenal gland

Some effects of epinephrine and norepinephrine
- Glycogen broken down to glucose
- Increased blood pressure, breathing, metabolic rate

Long-term stress: cortex of the adrenal gland
Corticosteroids (mineral- and gluco-corticoids) released by adrenal cortex

- Some effects: increased blood volume and blood pressure, breakdown of protein and fats

Animal Nutrition I (Ch. 41)

Keywords

Heterotroph
Autotroph
Herbivore
Carnivore
Omnivore
Intracellular digestion
Food vacuole
Extracellular digestion
Gastrovascular cavity
Alimentary canal
Basic parts of alimentary canal
Roles of mouth and stomach in digestion

Categories

I. Autotroph
II. Heterotroph
   A. Herbivore
   B. Carnivore
   C. Omnivore

Why is digestion necessary?

   Macromolecules cannot easily enter cell
   Small molecules such as amino acids can
   Even if macromolecules are taken in…
   They cannot be readily incorporated
   Unless broken down first

Outline of how animals break down food

   I. Intracellular digestion
      A. food vacuoles
   II. Extracellular digestion
      A. outside organism
      B. gastrovascular cavity
      C. alimentary canal

I. Intracellular digestion
   A. food vacuoles

   Intracellular digestion without vacuoles—what problem arises?
   Intracellular digestion with vacuoles — how is this better?

Digestion in Paramecium — know generally what occurs

The difference between Intracellular digestion vs. Extracellular digestion is that extracellular occurs outside the organism’s cells
Gastrovascular cavity: Hydra — recognize this structure know how it is involved in digestion. Same opening serves as mouth and anus

Gastrovascular cavity vs. Alimentary Canal – advantage of alimentary canal?

Alimentary canal: a simple view

Basic parts of alimentary canal

In detail below Alimentary canal: mammalian

Mouth types of digestion

- Mechanical — how?
- Enzymatic—how?

Animal Nutrition II (Ch. 41)

Keywords

Roles of mouth, stomach, sm.&lg. Intestine in digestion

Pepsin, pepsinogen

Villi, microvilli

Cecum

Cellulose

Cellulase

Stomach

- Mechanical
- Mixing and churning

Chemical
pH around 2
Also breaks food down
Enzymatic

Pepsin
Breaks down proteins
Why doesn’t pepsin digest stomach?

***Activation of pepsin-gastric glands, chief and parietal cells, HCl, pepsinogen***

Small intestine

***Most of the enzymatic digestion occurs here
***Why doesn’t the small intestine digest itself? Secretion of inactive enzymes (trypsinogen, procarboxypeptidase, chymotrypsinogen) by pancreas, activation of trypsin (from trypsinogen) by enteropeptidase, activation of other enzymes (to form carboxypeptidase and chymotrypsin) by trypsin.***

***Most nutrient absorption takes place in small intestine

Structure: another example of increasing surface area

***Structure of small intestine

Villi and microvilli

Large intestine (colon)

Major function is to reabsorb water, much bacteria present here

Variations of vertebrate digestive system Herbivorous mammals

Specialized fermentation chambers

**Coyote vs. Koala

Why does herbivory require specializations?

Plant tissue
Harder to break up

Contains cellulose

Nutrients less concentrated than meat

Structure of cellulose

Only bacteria and protozoa can break down cellulose

***Cecum

Pouch at junction between lg and sm intestine

Large cecum in rabbits, some rodents, koala, horses

Full of symbiotic bacteria

***Cecum function

Fermentation chamber

Bacteria breakdown cellulose

Feces must be reingested. Why?

Animal Nutrition III (Ch. 41)

Keywords

Ruminant digestion

Symbiosis

Definition

Algal-invertebrate

Chemoautotroph-invertebrate

Hydrothermal vent
H2S (sulfide)

chemoautotrophy

Ruminant digestion- fermentation where?, re-mechanically digest stomach contents, difference between ruminant digestion and digestion of cellulose with the cecum?

Algal-invertebrate symbiosis

Symbionts are algae

Algae photosynthesize and provide molecules such as sugars to the host

Hydra, anemones, giant clams, corals

Chemoautotroph-invertebrate symbiosis

Symbionts are chemoautotrophic bacteria

***Bacteria use hydrogen sulfide as an energy source and provide molecules such as sugars to host

Tubeworms (also clams, mussels) have these symbionts

***Chemoautotrophy: Bacteria oxidize sulfide and use the energy for carbon fixation