Overview of Lecture: Animal Form & Function; Nutrition
see the schedule for reading
and watching assignments

Bullet Points:
• tissues, organs & organ systems
• form & function: tubes, bulk flow & diffusion
• body: tubes and cavities
• embryonic germ Layers - 3
• adult tissue types - 4
• epithelium
glands and secretion
breast cancer
• connective tissues
cartilage, aging, injury, arthritis
• skeletal muscle
• Eat Food! Teeth, guts and nutrients
• blood & nerves - later
Learning Goals:

1. Be able to name and briefly describe: The 4 “hierarchical levels of organization” in a vertebrate body. The 3 embryonic germ layers. The 4 primary tissue types in adult vertebrates. For each of the 3 embryonic germ layers, name 1 of the adult tissue types derived from that germ layer. What germ layer(s) does the adrenal gland derive from?

2. Be able to describe and explain the role(s) of epithelial tissue. What roles do tight junctions and basement membranes play in epithelial tissue structure? Give examples of secretory and ciliated epithelial tissues.

3. Be able to name and describe an example of each of these types of connective tissue: cartilage, fibrous and lose connective tissue. Explain why it is futile to wait for a torn knee meniscus cartilage to heal. What is rheumatiod-arthritis and how is it related to connective tissue?

4. Be able to name and describe the three types of muscle tissue. Be able to describe the sliding-filament mechanism of contraction for striated skeletal muscle.
The vertebrate body has four hierarchical levels of organization: (1) **cells**, (2) **tissues**, (3) **organs**, and (4) **organ systems**.

(2) **Tissues are groups of cells**

Each germ layer differentiates into scores of different cell types and tissues.

In **adult** vertebrates, there are four kinds of **primary tissues**:

(3) **Organs** are structures composed of several different types of tissues that form a structural and functional unit.

[ex: heart: muscle, nerve, epithelium, connective tissue]

(4) **An organ system** is a group of organs that are integrated to perform major activities. For example, the circulatory system … [distinctions between organ systems are melting as we learn how integrated they are; for instance, the neural, endocrine and immune systems are functionally integrated]
(Form Follows Function) - constrained by physical laws in particular environments.

Multicellular organisms are big, integrated lineages of cells (clones) (plus various symbionts, parasites, mutants etc.).

Diffusion through tissues is very slow & inefficient but small, thin things can get by if they wiggle about or the medium is moving around.
In mammals **the coelom** is divided by the diaphragm into the

The **endoderm gut tube** passes through the **mesoderm-lined coelom**

The vertebrate body is a tube within a tube

http://www.madsci.org/~lynn/VH/transverse.html
The cells of the embryo differentiate into 3 germ layers plus the germ-stem cells.

{note: in placental mammals the hollow sphere is a flat disk}

Skin, Neural tissue
Adrenal medulla, Pituitary gland
Some connective tissue of the head

Bone marrow (blood), Adrenal cortex, Lymphatic tissue
Skeletal, smooth, & cardiac muscle, neural crest
Connective tissues (including bone, cartilage)
Urogenital system, Heart & blood vessels

Thymus, Thyroid, parathyroid glands,
Larynx, trachea, lung
Urinary bladder, vagina, urethra
Gastrointestinal (GI) organs (liver, pancreas)
Lining of the GI tract & the respiratory tract
Animals are multicellular organisms with their specialized cells grouped into **tissues**. **Tissues** are integrated groups of cells with a common structure and function. Combinations of various tissues make up functional units called **organs**, and groups of organs that work together form **organ systems**. **All organs are made of the four basic tissue types.** {from various germ layers}
Epithelial tissue is derived from all three germ layers; functions to

... the mouth, esophagus, uterus and vagina, ducts of the pancreas and liver, urethra and ureters, blood vessels (where it is called endothelium), tubules of the kidney, air sacs (alveoli) of the lungs ...

Epithelial tissue is classified according to

(1) the shape of the outermost cell layer
   - squamous [flat]: linings - diffusion
   - cuboidal: glands & tubules - transport
   - columnar: linings – secretion & absorption or transitional, \{discrete categorization is an ‘ideal’\}

(2) whether or not the tissue is
   - one layer thick (simple): lungs & capillaries or
   - multiple layers (stratified): skin, mouth or ‘pseudostratified’: glands & mucous membranes and

(3) whether or not the cells are
   - ciliated
   - secrete (glandular, ex: goblet cell) ...
Characteristics of epithelial cells:

A major cytoskeletal component of skin epithelia is the filament called **keratin** {the main component of: mammal hair, reptile scales, bird feathers, claws (including nails and hooves), horn (but not antlers), & the enamel of the teeth}. … rest on an **extracellular matrix** which they produce … the **basement membrane**. … **basement membrane** … is a thin sheet of **collagen** {dense connective tissue}.
Glandular epithelia, absorb or secrete chemical solutions.

Glandular epithelia that line the digestive & respiratory tracts form **mucous membrane**; they secrete a slimy solution called **mucus** that lubricates the surface.

**The epithelium of our respiratory tract has beating cilia** that move the film of mucus along the surface:
helps keep our lungs clean by trapping dust, ‘germs’ and other particles
and sweeping them back up the trachea (windpipe) – to esophagus.

Vertebrate glands develop from invaginated epithelium

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water-soluable: spilled out
In the **inactive mammary gland**, the glandular elements consist only of ducts lined by epithelium...

Dramatic changes in the mammary gland occur **during pregnancy**. Ducts **proliferate and secretory alveoli sprout** from them. Alveoli are epithelial cells that become milk-secreting structures.

During the menstrual cycle

Slight development of secretory alveoli begins ...

Breast Cancer Risk Factors: Estrogens

Cumulative number of menstrual cycles and breast cancer risk: ...

**Connective Tissue** derives from embryonic **mesoderm**, ... has a sparse population of cells scattered through an extracellular matrix.

The most widespread connective tissue in the vertebrate body is **loose connective tissue**. Collagenous, elastic, and reticular fibers in this tissue type bind epithelia to underlying tissues and hold organs in place.

**Cartilage** has an abundance of collagenous fibers embedded in a rubbery matrix made of a protein-carbohydrate complex called chondroitin sulfate. Cells called **chondrocytes** secrete the collagen and chondroitin sulfate that make cartilage a strong yet flexible support material. Many vertebrate embryos have cartilaginous skeletons, but most of the cartilage is replaced by bone as the embryo matures. Cartilage is retained in some locations, such as the disks that act as cushions between vertebrae.

**Fibrous connective tissue** is dense with collagenous fibers. The fibers form parallel bundles, which maximize nonelastic strength. Fibrous connective tissue is found in **tendons**, which attach muscles to bones, and in **ligaments**, which connect bones at joints.

**Adipose tissue** is a specialized loose connective tissue that stores fat in adipose cells distributed throughout its matrix. Adipose tissue pads and insulates the body and stores fuel as fat molecules (see Figure 4.6). Each adipose cell contains a large fat droplet that swells when fat is stored and shrinks when the body uses that fat as fuel.

The skeleton of most vertebrates is made of **bone**, a mineralized connective tissue. Bone-forming cells called **osteoblasts** deposit a matrix of collagen. Calcium, magnesium, and phosphate ions combine into a hard mineral within the matrix. The combination of hard mineral and flexible collagen makes bone harder than cartilage without being brittle. The microscopic structure of hard mammalian bone consists of repeating units called **osteons**. Each osteon has concentric layers of the mineralized matrix, which are deposited around a central canal containing blood vessels and nerves.

**Blood**, which functions differently from other connective tissues, has a liquid extracellular matrix called plasma. Consisting of water, salts, and dissolved proteins, plasma contains erythrocytes (red blood cells), leukocytes (white blood cells), and cell fragments called platelets. Red cells carry oxygen; white cells function in defense; and platelets aid in blood clotting.
It is unclear whether certain tissues in our bodies are permanent or refreshed over time. Nuclear bomb testing more than 50 years ago released the carbon-14 isotope into the atmosphere, which allows researchers to determine the turnover of human tissues in people over 50 years old. Heinemeier et al. used this “14C bomb pulse” method to determine the regenerative potential of cartilage. They examined human knee joints … taking cartilage …

Fibrous connective tissue is dense, due to its large numbers of collagenous fibers.

The “unhappy triad” is where the ACL is torn at the same time as the MCL and the meniscus (shock absorbing cartilages in the knee).
Rheumatoid arthritis occurs when your immune system attacks the synovium - the lining of the membranes that surround your joints. [Rheumatoid arthritis is an autoimmune disease]

The resulting inflammation thickens the synovium, which can eventually destroy the cartilage and bone within the joint. The tendons and ligaments that hold the joint together weaken and stretch. Gradually, the joint loses its shape and alignment.

Doctors don't know what starts this process, although a genetic component appears likely.

Mechanisms of Disease: The Pathogenesis of Rheumatoid Arthritis
McInnes IB & Schett G.
2011 N Engl J Med
365:2205-2219
Does the microbiota play a role in the pathogenesis of autoimmune diseases?
MH McLean et al. 2015 Gut 64:332-341.

The microbiota of the human metaorganism is not a mere bystander. These microbes have coevolved with us and are pivotal to normal development and homoeostasis. Dysbiosis of the GI microbiota is associated with many disease susceptibilities, including … rheumatoid arthritis (RA).

RA is characterised by synovial inflammation and erosion of bone and cartilage. Genetic factors are important but account for only a proportion of susceptibility.

There is ongoing debate on whether RA is initiated by an infectious microorganism. This idea of ‘molecular mimicry’ has existed for at least a century, but has never been definitively proven. [a microbe with foreign antigens that are similar to some of our self-antigens confuses the immune system see https://en.wikipedia.org/wiki/Molecular_mimicry].

It has been hypothesised that individuals who possess a genetic predisposition together with P. gingivalis within their oral microbiota are more likely to develop [auto]immune responses to self.

Could intestinal microbiota play a pivotal role in the pathogenesis of RA? Don’t know!
Adipose tissue has longed been viewed as a harmless tissue in the pathogenesis of chronic inflammatory connective tissue and joint diseases … However, three discoveries have completely changed this point of view …

Adipocytes [fat cells] can actively secrete proinflammatory factors operative in the pathophysiology of inflamed joints …

These adipokines target well-known immune system effector cells operative in the pathophysiology of chronic rheumatic diseases. The key prototype molecule in this scenario is adiponectin, … a central mediator of inflammation with well-known deleterious effects in arthritis.

Fat cells use immune signal Nature 495, 413 (28 March 2013)
In obese individuals, fat cells may act like inflammatory white blood cells by using communication machinery once considered to be exclusive to immune cells.
Muscle tissue (from mesoderm) is composed of long cells called muscle fibers that are capable of contracting when stimulated by nerve impulses. Arranged in parallel within the cytoplasm of muscle fibers are large numbers of myofibrils made of the proteins actin and myosin.

Smooth muscle is found throughout animals. In vertebrates – ‘visceral’ muscle, sheets surround larger blood vessels and bronchia, gut, iris of eye. Not striated (not lined up) Not ‘voluntary;’ ex: pupil dilation, spontaneous waves in gut;

Skeletal muscle is usually attached to tendons & bones. Antagonistic pairs of muscles flex & extend. Lined up in orderly, multinucleate myofibrils – ‘striated.’ ‘Voluntary;’ excited Ach signal at neuromuscular junctions

Cardiac (heart) muscle ‘striated’ but single cells (& nuclei) linked by gap junctions into single functioning myocardium. Specialized ‘autogenic’ cells maintain rhythmic contractions; modified by sympathetic (+) and parasympathetic (-) nerves [and circulating hormones]
**Sliding filament mechanism**

Each **skeletal muscle** is a nested hierarchy of filaments.

**Contraction:**
Somatic motor neurons release **acetylcholine Ach** *(blocked by Botox)*

Ach depolarizes muscle ... starting the power cycle

**Power cycle:**

(a) myosin splits ATP

(b) cross-bridges w/ actin,

(c) myosin head bends
   (power stroke - rowing)

(d) new ATP releases bridge,
   straightens →(a)

**Rigor mortis** – no ATP to break bridges

actin Z bands get closer, Sarcomeres shorten

muscle contracts *[by increasing the overlap of actin and myosin – molecules do not shorten]*
Teeth and Guts are great indicators of diet

The vestigiality of the human vermiform appendix from cecum

... as is the number of copies of the gene coding for the salivary enzyme amlayse, which digests complex starches into simple sugars ...

news@nature  Ewen Callaway, Published online: 9 September 2007; 
Ability to digest starch could have spurred human evolution. 
Compared with chimpanzees, humans boast many more copies of the gene that makes salivary amylase – a saliva enzyme that breaks down starch into digestible sugars. And carbohydrate-loving societies carry more copies of the gene than those that follow low-carbohydrate diets, says a new study....

Dog's dinner was key to domestication - dogs possess genes for digesting starches, setting them apart from their carnivore cousins — wolves.

All animals eat other organisms, dead or alive, whole or by the patty

An adequate diet must satisfy three nutritional needs:

1 **fuel** (chemical energy) for all cellular work of the body;
   {empty calories in junk food serve this purpose OK}

2 the **organic raw materials** animals use in **biosynthesis**;
   Given a source of **organic carbon** (such as sugar) & **organic nitrogen** (usually amino acids in protein), animals can fabricate a great variety of organic molecules - carbohydrates, proteins, and lipids;

3 **essential nutrients** - substances that the animal cannot make for itself:
   vitamins, and minerals

**complementary foods** {not complimentary} balance essential nutrients across plant foods

**Glyphosate Roundup herbicide** inhibits the synthesis of three essential {to animals} aromatic amino acids synthesized only in plants, therefore ... only toxic to plants ...
Later lectures -

**Blood** functions differently from other connective tissues (mesoderm)

**Nervous tissue** (from ectoderm) senses stimuli and transmits signals from one part of the animal to another, & stores memories.