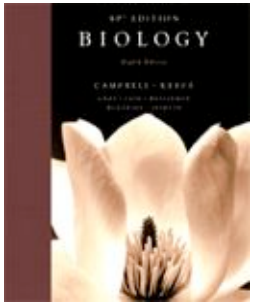
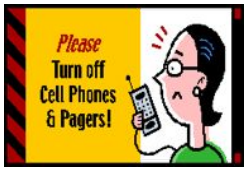


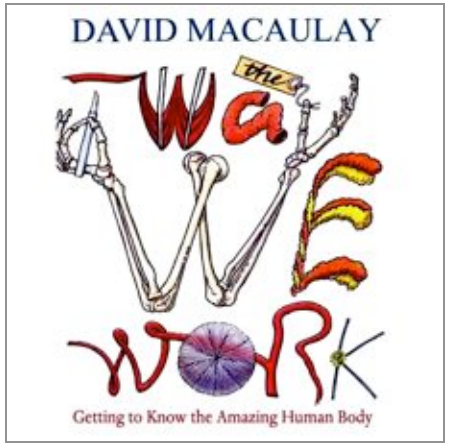


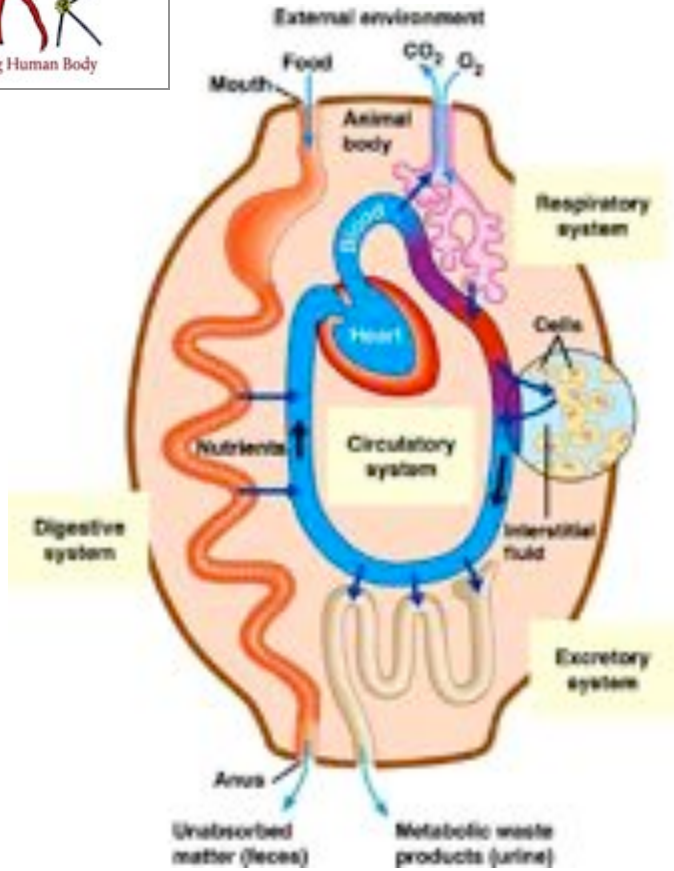
Overview of Lecture: Animal Form & Function; Nutrition

Read: Text pgs 850-851, ch 40 & 41

Bullet Points:

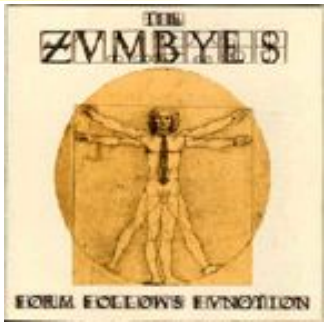
- form & function
- tubes: bulk flow & diffusion
- germ Layers
- tissues
- epithelium
- connective
- muscle & nerve
- skeletal muscle
- Eat Food!
- teeth & guts
- glucose regulation; negative feedback
- fat regulation





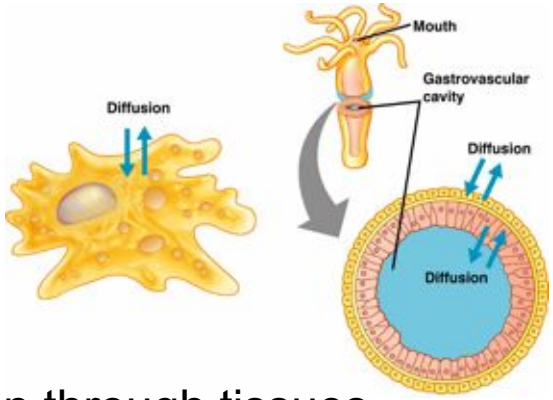
(**F**orm **F**ollows **F**unction) - constrained by physical laws in particular environments.

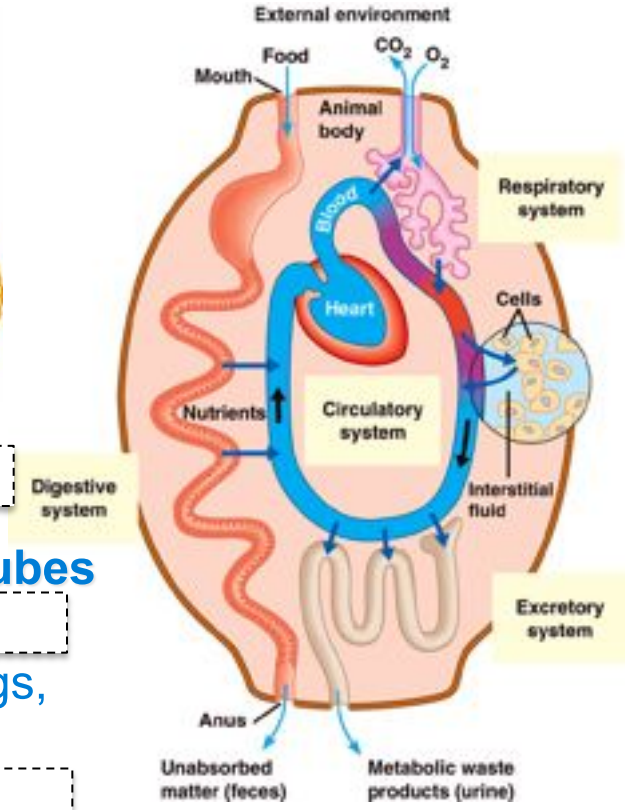
F^3



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

Each cell is plasma-membrane bound aqueous system, with **homeostatic mechanisms** to maintain stasis (or growth) by regulating exchange: energy, nutrients 'raw materials' etc IN & wastes, hormones, 'products' etc OUT





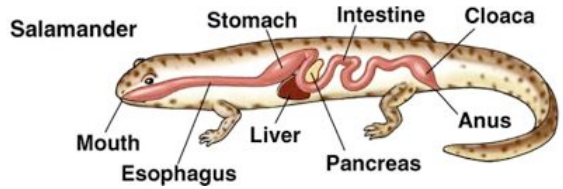
Diffusion through tissues

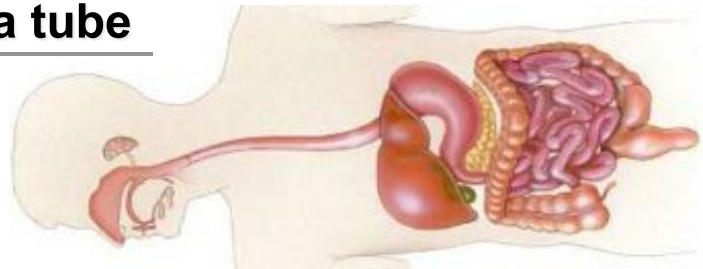
Large animals are masses of tubes

Bulk flow through tubes (gut, lungs, arteries & veins, lymph etc)

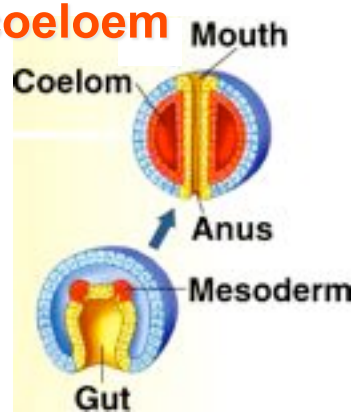
YouTube™ are a tube

The vertebrate body is a tube within a tube





The endoderm **gut tube** passes through the mesoderm **coeloem**



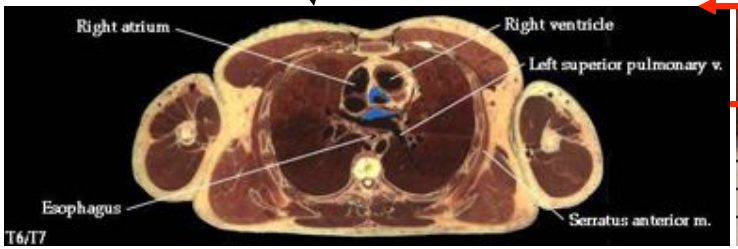
In mammals **the coelom** is divided by the diaphragm into the

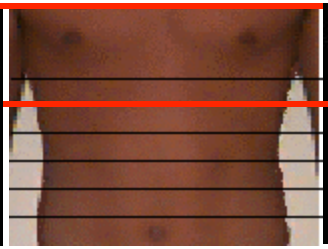
peritoneal cavity –

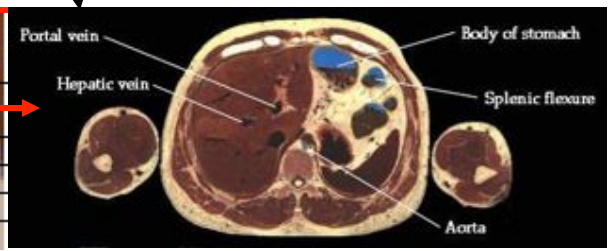
thoracic cavity – subdivided into

pleural cavities –

pericardial cavity







http://www.madsci.org/~lynn/VH/transverse.html

The cells of the embryo differentiate into **3 germ layers**

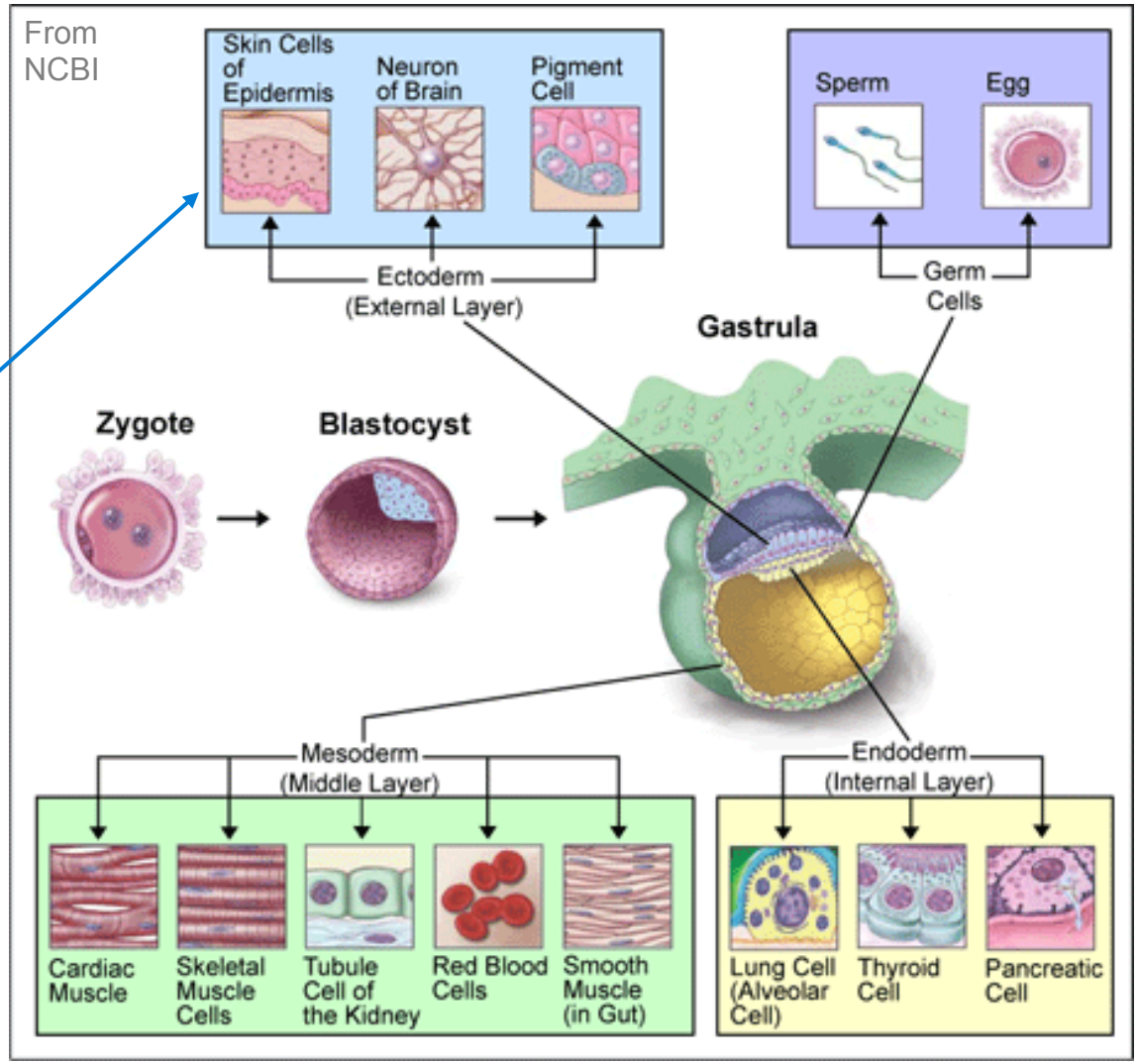
{see ch 47; note: in many vert's the hollow sphere becomes a flat disk}

Skin,

Pituitary gland
Connective tissue of the head and face,

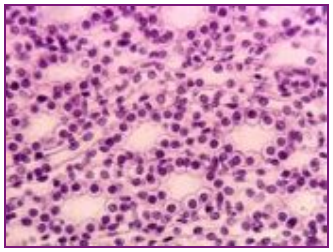
Bone marrow (blood),

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



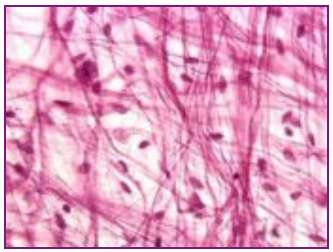
Larynx, trachea, lung
Urinary bladder, vagina, urethra
Gastrointestinal (GI) organs (liver, pancreas)
Lining of the GI tract & the respiratory tract

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** {Table 40.1}
All organs are made of the four basic tissue types. {*from various germ layers*}

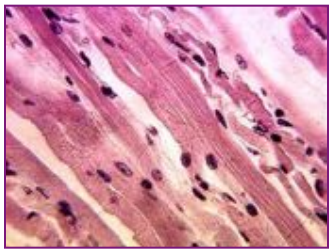


http://mindquest.net/biology/histology/index.html

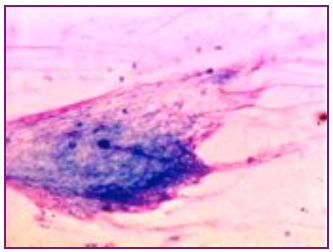
is derived from all 3 germ layers;
- covers the outside of the body; lines internal organs & cavities;
secrete material (e.g. glands), or *absorb* material (e.g. intestine).



(mainly ectoderm & mesoderm)
connects body parts, Many subtypes of connective tissue,
including bone, cartilage, ligaments & tendons, adipose (fat) tissue,
areolar (loose irregular) connective tissue, and
blood (connective tissue because it derives from bone marrow).



(from mesoderm) have the ability to contract/shorten.
This allows muscle tissue to function for providing movement …
There are three subtypes of muscle tissue:
skeletal muscle, smooth muscle, and cardiac (heart) muscle.



known as *neurons*, (from ectoderm)
are specialized for conducting electrical signals in the body.

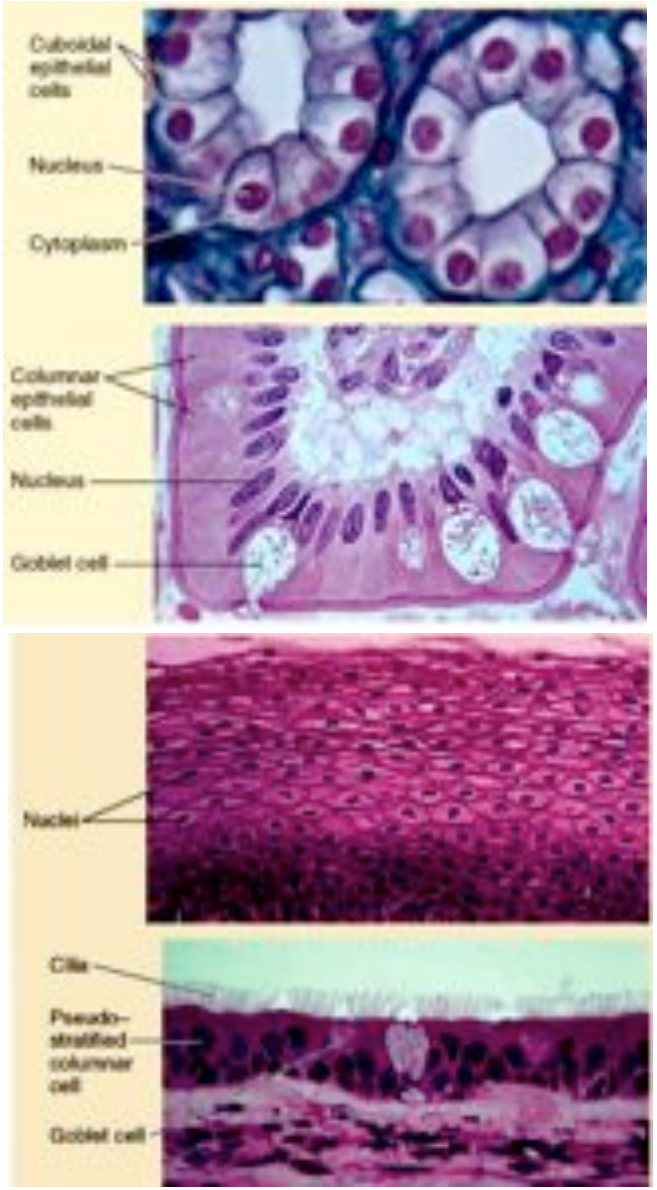
http://mindquest.net/biology/histology/epithelial-tissue.html

Epithelial tissue is derived from all three germ layers; functions to

Epithelial tissue

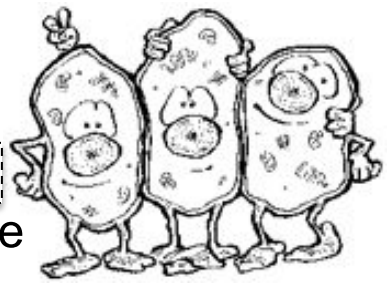
… the mouth, esophagus, uterus and vagina,
ducts of the pancreas and liver, urethra and ureters,
blood vessels (where it is called **endothelium**),
tubules of the kidney, air sacs (alveoli) of the lungs ...

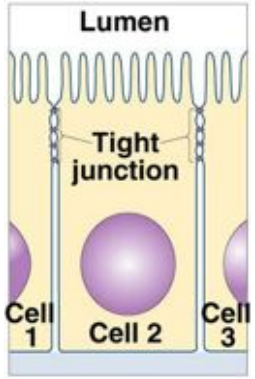
Epithelial tissue is classified
according to
(1) the **shape** of the outermost cell layer
squamous [flat]: linings - diffusion
cuboidal: glands & tubules - transport
columnar: linings – secretion & absorption
or transitional, *{discrete categorization is an 'ideal'}*
(2) whether or not the tissue is
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
or **secrete** (glandular, ex: goblet cell) …



http://www.mc.vanderbilt.edu/histo/BasicTissue/Epith.Definition.html

Characterisitics of **epithelial cells**:





see Fig 6.31

Epithelia are **avascular** … blood vessels do not penetrate up between these cells … *{ex: blood-brain barrier}*

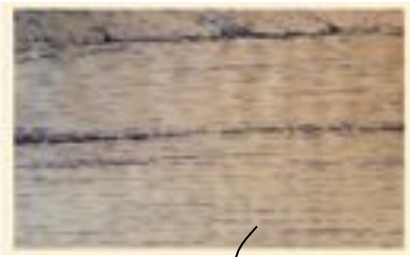
Unlike muscle and connective tissue, they can be derived from any of the three embryologic germ layers (**endoderm, mesoderm, ectoderm**).

Rapid replacement: stomach epithelium replaced ~2-3 days; epidermis ~2 weeks;

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 Fig 40.5}



Cancer biology: Breaking and entering

Genes Dev. doi:10.1101/gad.1451806 (2006)

To spread, or metastasize, cancer cells must escape from their site of origin.
Doing so requires crossing the basement membrane, a barrier of connective tissue.
S Weiss and colleagues have identified three enzymes that allow tumors to degrade proteins in the basement membrane, allowing cancer cells to escape.
Knowing the enzymes ... could enable future cancer therapies to target this process.

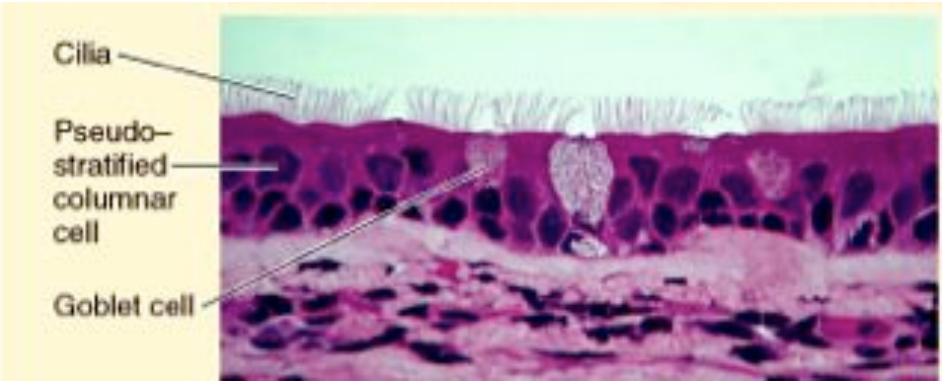
Glandular epithelia, absorb or secrete chemical solutions.

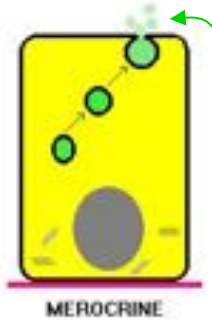
ex: tear, sweat and sebaceous glands to skin; liver to gut.

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

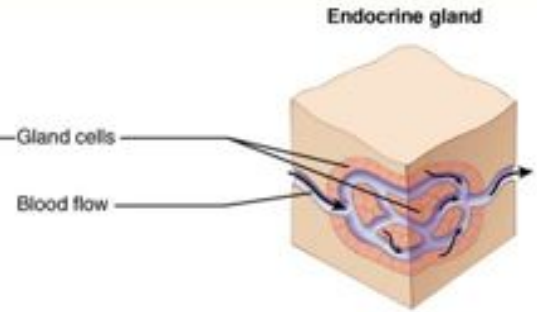
that move the film of mucus along the surface:
helps keep our lungs clean by trapping dust, 'germs' and other particles and sweeping them back up the trachea (windpipe) – to esophagus.





water-soluable: spilled out

Vertebrate glands (ch 45) develop from invaginated epithelium



http://courseweb.edteched.uottawa.ca/medicine-histology/English/Reproduction/Mammary/Mammary_repro.htm

In the inactive **mammary gland**, the glandular elements consist only of ducts:
lined by cuboidal or columnar epithelium ...

Dramatic changes in the mammary gland occur **during pregnancy**.

Ducts proliferate and secretory alveoli sprout from them.

Alveoli are collections of cuboidal or columnar epithelial cells
that become active milk-secreting structures.

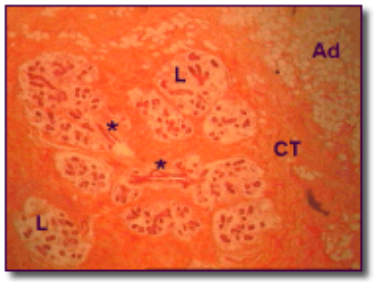


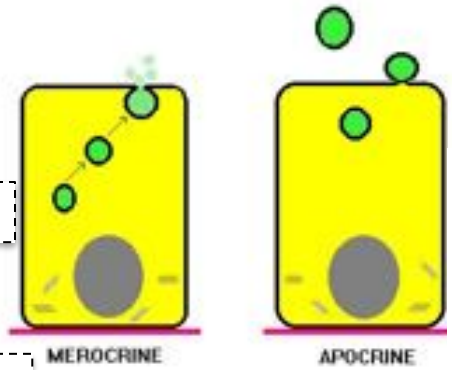
Fig 1 Low power view of inactive mammary gland

The **lipid** *{water insoluable}* component of milk
is released in an envelope

{homogenization breaks up large globules}

The **protein** *{water soluable}* component of milk

.



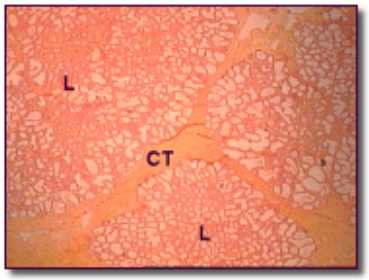


Fig 3 Low power view of mammary gland during pregnancy

During the menstrual cycle
slight development of secretory alveoli may begin ...

... an increasing number of menstrual cycles
{fewer pregnancies} increases the stimulation
of breast ductal epithelial cells

with lifetime exposure to estrogen.

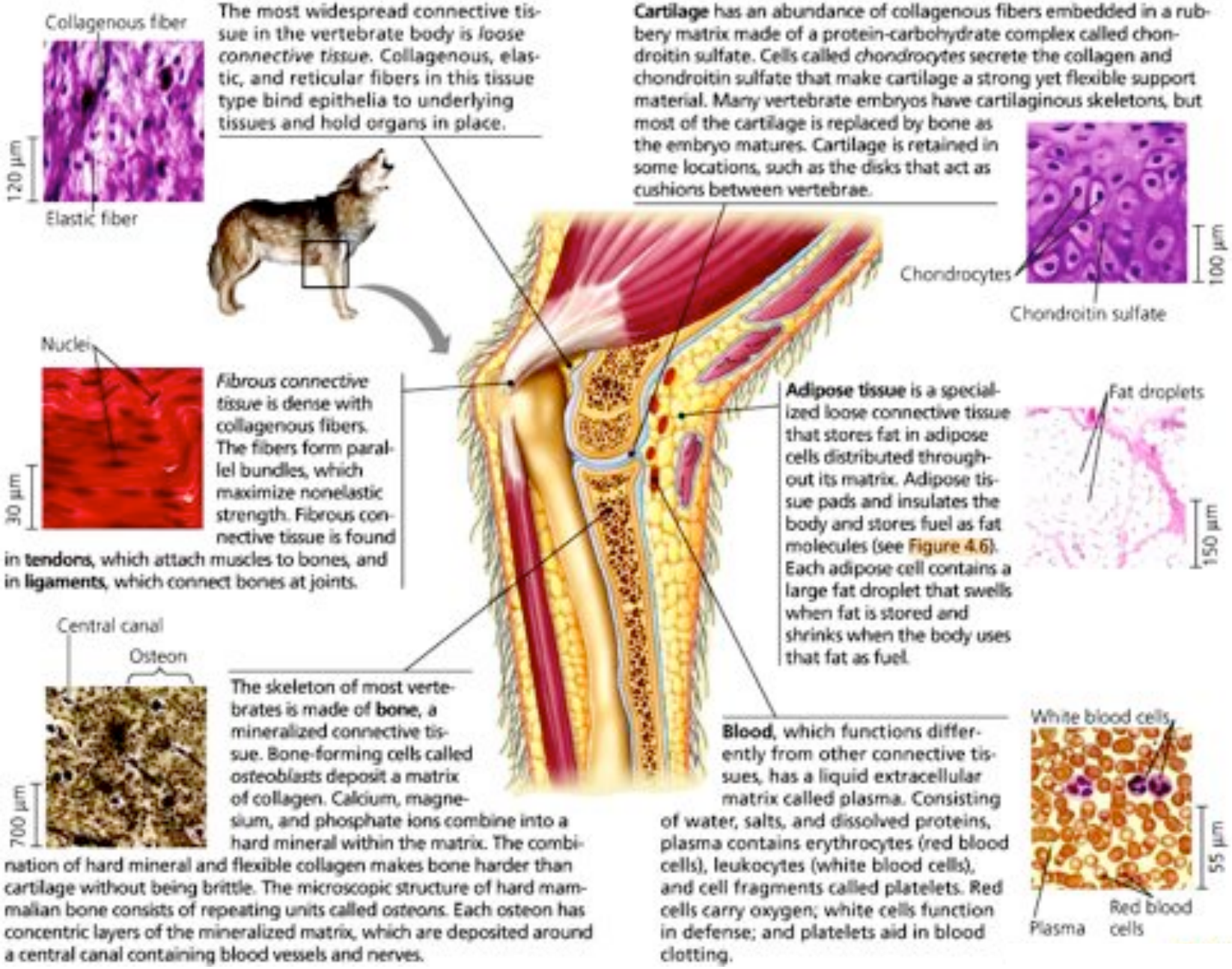
Breast Cancer Risk Factors: Estrogens

National Cancer Institute
U.S. National Institutes of Health | www.cancer.gov

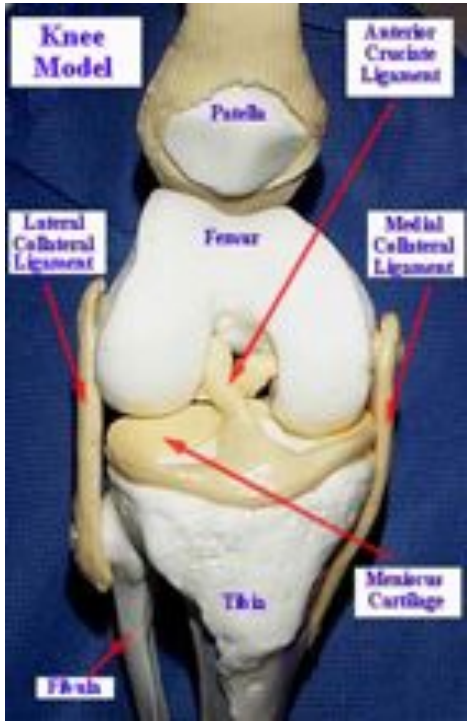
see:
http://www.cancer.gov/cancertopics/factsheet/Risk/oral-contraceptives

Menstrual and reproductive factors and endometrial cancer risk ...
Xu et al. 2004. Int J Cancer 108(4):613-9.

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

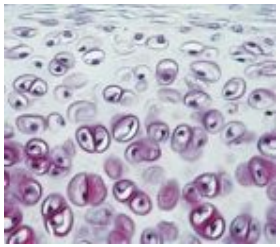


Fibrous connective tissue is dense, due to its large numbers of **collagenous fibers**.

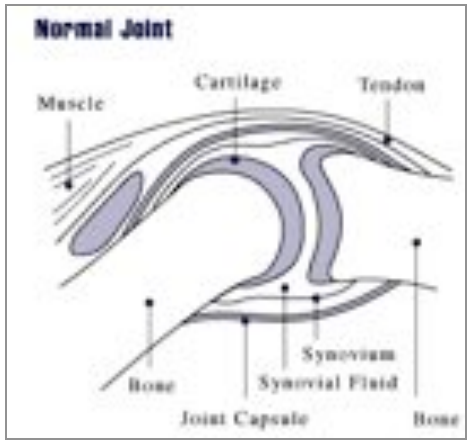


In **tendons**, which attach muscles to bones, and in **ligaments**, which join bones together at joints. the fibers are organized into parallel bundles …

The "unhappy triad" is where the ACL is torn
at the same time as the MCL
and the lateral meniscus (one of the
shock absorbing **cartilages** in the knee).

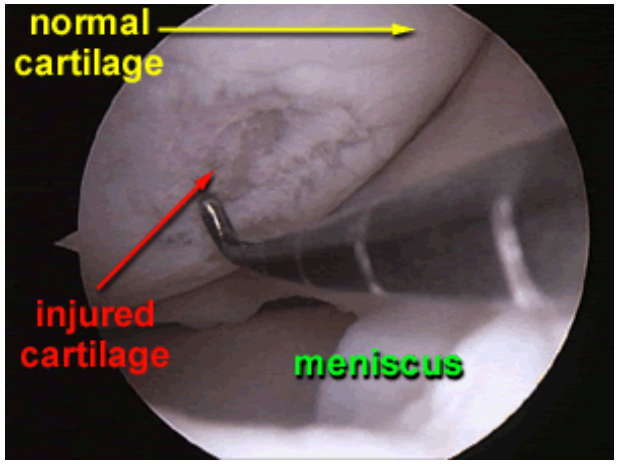


Cartilage has **collagenous fibers**
embedded in a rubbery matrix of
chondroitin sulfate, a protein-carbohydrate complex.
… secreted by cells called **chondrocytes**.



… **articular (meniscus) cartilage**
lining the bones of your knee joint

the **joint capsule**.
{similar to 'the blood-brain barrier'} .
Synovial fluid, secreted by
synovium (membranes),
lubricates the joint and
carries nutrients to the cartilage.



NIAMS
National Institute of Arthritis and Musculoskeletal and Skin Diseases

National Institutes of Health
Department of Health & Human Services

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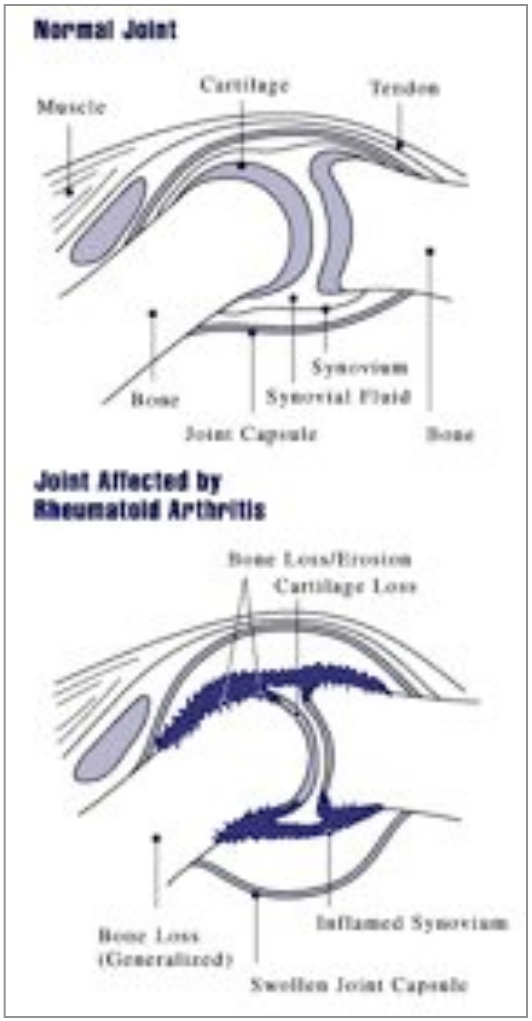
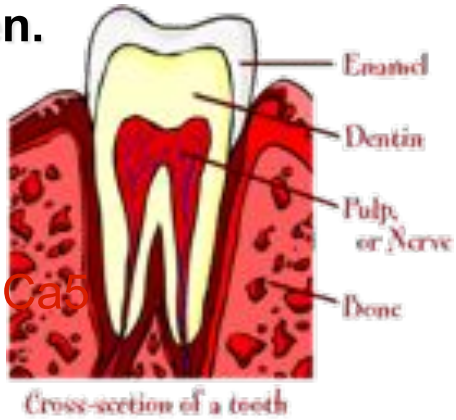
Rheumatic diseases are connective tissue diseases.
Arthritis means joint inflammation.
… arthritis is a kind of rheumatic disease.
Osteoarthritis affects cartilage, the tissue that cushions the ends of the bones within the joints.
Rheumatoid arthritis is
… the immune system attacks a person's own synovium, the tissue inside the joint capsule.
*{**Rheumatoid factor** is an autoantibody against the Fc portion of IgG, which is itself an antibody. ch 43}*



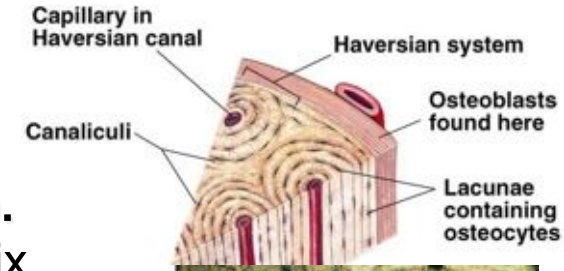
http://en.wikipedia.org/wiki/Rheumatoid_arthritis
In theory, RA requires susceptibility to the disease through genetic endowment with specific markers *and* an infectious event that triggers an autoimmune response.
The "mistaken identity" theory suggests that an infection triggers an immune response; then, there is an auto-immune attack because the host molecule "looks like" the infectious antigen - this phenomenon is called molecular mimicry.
Epidemiological studies have confirmed a potential association between RA and two herpesvirus infections ... *{a GXE interaction}*

Bone is an extracellular mineralized connective tissue (from mesoderm).

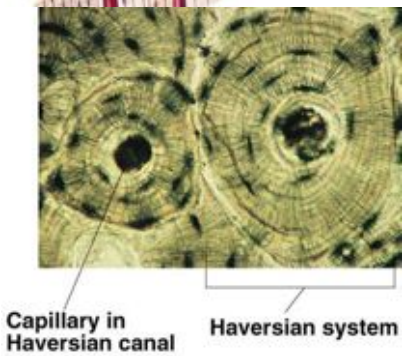
Bone-forming cells called **osteoblasts** deposit a matrix of **collagen.**
Calcium, magnesium, and phosphate ions combine
and harden within the matrix
into the mineral **hydroxyapatite** – rigid but brittle.



The **surface enamel of teeth** is composed of hydroxyapatite: Ca5 (PO4)3(OH). The OH- ion can be replaced by fluoride. Fluorapatite is "harder" and more resistant to damage caused by acids ... more resistant to tooth decay.



The structure of hard mammalian bone consists of
repeating units called **osteons (**or **Haversian systems).**
Each osteon has concentric layers of the mineralized matrix,
which are deposited around a central canal
containing blood vessels and nerves that service the bone.
Mature **osteocytes** maintain, remodel and repair mineral bone.

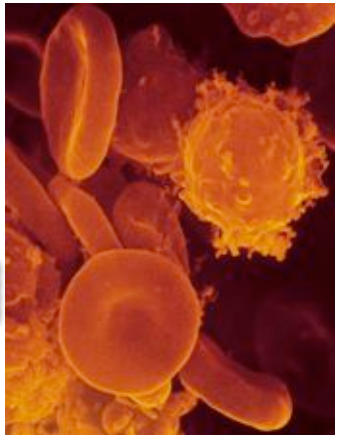


Optimization of **bone growth and remodeling**

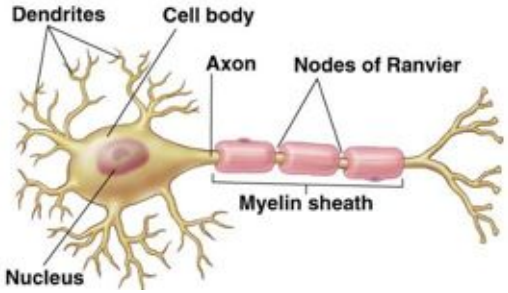
Lieberman et al. 2003 J Exp Biol. 206:3125-38

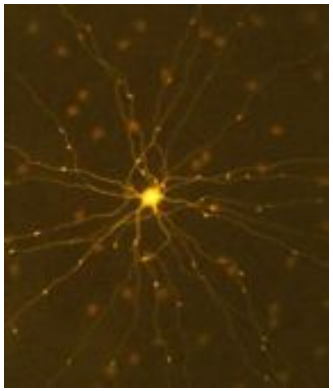
In juveniles, exercise induces higher rates of *{remodeling}* ... *{but less so in adults}*

Blood functions differently from other connective tissues (mesoderm) but it has an extensive extracellular matrix: a liquid called **plasma**, consisting of water, salts, and a variety of dissolved proteins. Suspended in the plasma are two classes of blood cells, and cell fragments called **platelets**.
Blood will be discussed later (Chapters 42, 43 & 44).

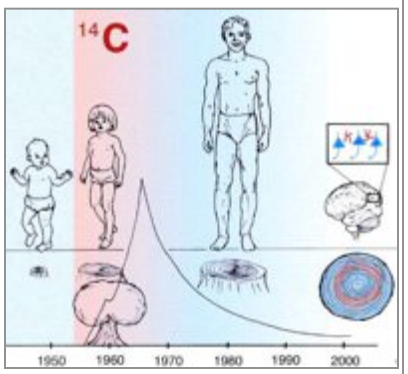


Nervous tissue (from ectoderm) senses stimuli and transmits signals from one part of the animal to another, & stores memories.
The functional unit of nervous tissue is the neuron, or nerve cell,
Discussed later in ch 48

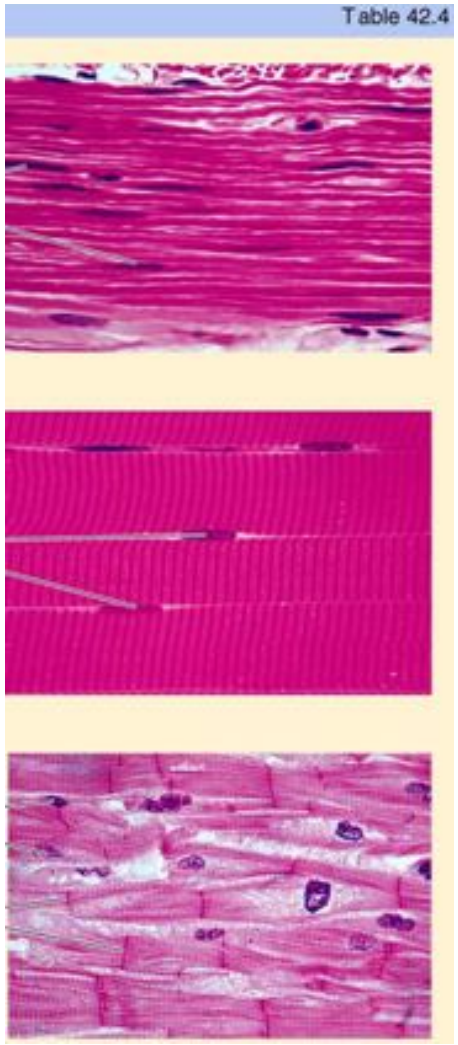




Archeo-Cell Biology: Carbon Dating Is Not Just for Pots and Dinosaurs
P Arlotta & JD Macklis 2005 Cell 122: 4-6.
In this issue of *Cell,* Spalding et al. (2005) describe a clever strategy for birth dating human cells in vivo, based on incorporation of 14C during a peak in atmospheric levels resulting from above-ground nuclear arms testing in the 1950s.
The amount of 14C in neurons of the human cerebral cortex corresponds to the amount in the atmosphere at the time of birth ...



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 contractile proteins **actin** and **myosin**.
Recall actin in eukaryotic cytoskeleton (see ch 6)



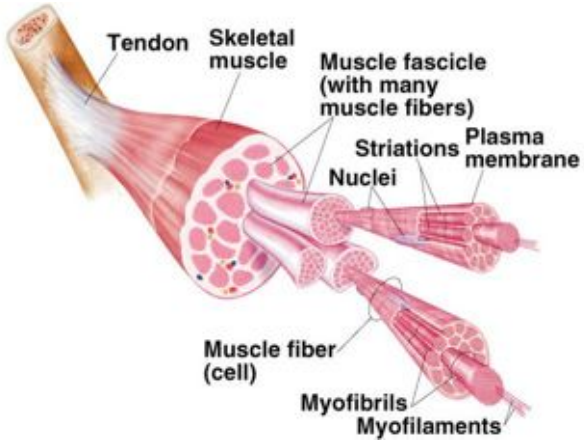
is found throughout animals.
In vert's – 'visceral' muscle, sheets surround
larger blood vessels and bronchia,
gut, iris of eye. Not striated (lined up)
Not 'voluntary;' spontaneous waves in gut;

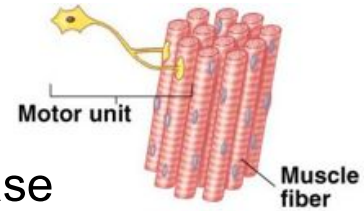
is usually attached to tendons & bones
at origin & insertion; antagonists flex & extend.
Lined up in orderly, multinucleate myofibrils – 'striated.'
'Voluntary;' excited at neuromuscular synaptic junctions

'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

Sliding filament mechanism (see text ch 50.5)

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

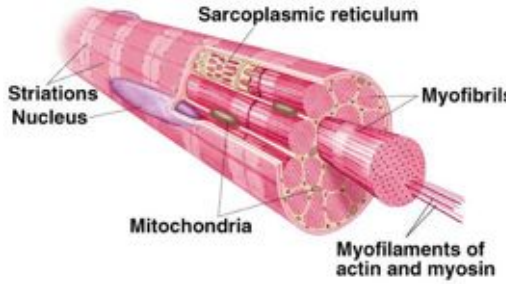




Contraction:

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

Ach depolarizes muscle ... starting the power cycle



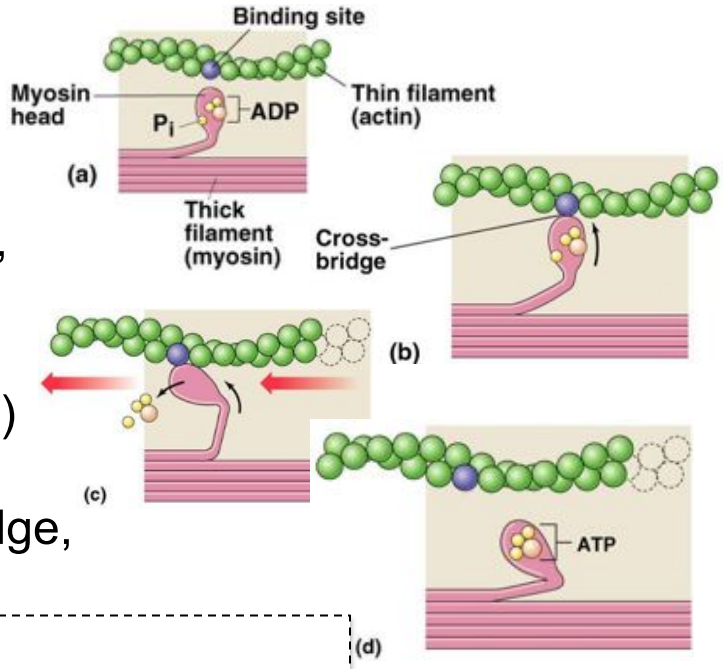
Power cycle:

(a) myosin splits ATP

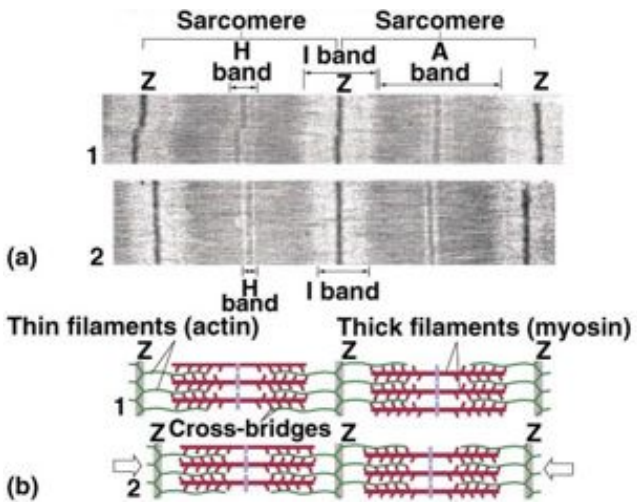
(b) cross-bridges w/ actin,

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

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



Rigor mortis –



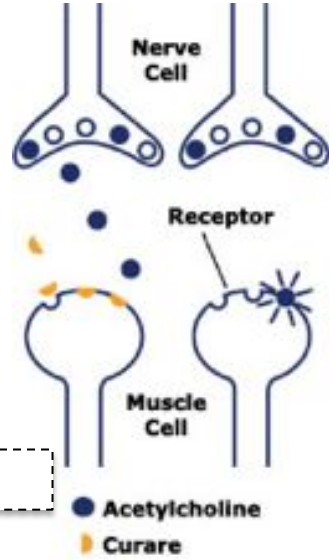
actin Z bands get closer, Sarcomeres shorten
muscle contracts

http://ci.mond.org/9522/952214.html

From venoms to toxins to drugs:

Toxins have been used to elucidate physiological mechanisms;

the pure alkaloid, **tubocurarine**, isolated from the arrow poison **curare**, has been used as a muscle relaxant to accompany general anaesthetic.



Subject frowning prior to botulinum toxin injections

Subject attempting to frown after botulinum toxin injections

Another toxin used for its muscle relaxant properties is **botulinum toxin**, from bacteria Clostridium botulinum

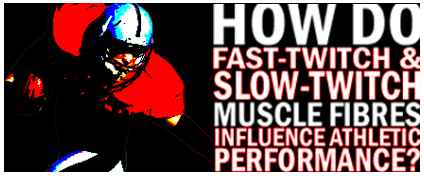
The toxin gets into motor nerve terminals and

{presynaptic vesicle can't fuse w/ membrane}

… botulinum toxin is often regarded as one of the most toxic substances known …

However, its specificity and irreversibility have been useful …

*When **Botox** is injected into a muscle, it blocks the release of acetylcholine; the lack of stimulation & activity weakens the muscle. … the skin overlying the muscle relaxes and the wrinkles in the skin often disappear.*



Essentially We Have Two Fibre Types:

Fast-twitch (Type 2) & **Slow-twitch (Type 1)**

High intensity, anaerobic, short-burst activity, engages the **fast-twitch** fibres, which are lighter in coloring than slow-twitch fibres due to the low levels of myoglobin (stores oxygen for use in cell respiration) and mitochondria they possess – **quickly fatigue**.

Slow-twitch fibres, on the other hand, possess more mitochondria and myoglobin, and are red in coloring as a result. **Fatigue resistance**, at the expense of fast rate force production, is the hallmark of these fibres.

The average person has about fibres in locomotory muscles.

You can almost guarantee that the 100-meter Olympic sprint champion has around 80% fast twitch fibres in his quadriceps muscles.

{the proportions change with age and training, and possibly vary across genotypes}

To simplify things somewhat, a nice analogy can be used to explain the various actions of these two fibre types.

Chickens, like us, have both fast and slow-twitch fibres:

Chickens use their legs (**red meat**) while their wings & breasts (**white meat**)

{wild, migratory ducks have "red meat" breasts}

***ACTN3* genotype is associated with human elite athletic performance.**

Yang, N. *et al*. *Am. J. Hum. Genet.* 73, 627–631 (2003). Article

There is increasing evidence for strong genetic influences on athletic performance and for an evolutionary "trade-off" between ... speed and endurance ...

... the skeletal-muscle actin-binding protein **α-actinin-3 is specifically expressed in fast-twitch (type 2) myofibers responsible for generating force at high velocity**

... is absent in 18% of healthy white individuals because of homozygosity for a common stop-codon polymorphism in the *ACTN3* gene, *R577X*.
{allele R577 codes for α-actinin-3; *R577X is a defective ACTN3, homozygote R577XX results in no α-actinin-3}*

... highly significant associations between *ACTN3* genotype and athletic performance.

Both male and female elite sprint athletes have significantly higher frequencies of the *R577* allele than do controls.

The differential effects in sprint and endurance athletes suggests that the *R577* vs *R577X* polymorphism *{at the ACTN3 locus}* may have been maintained in the human population by balancing natural selection.

Loss of *ACTN3* gene function alters mouse muscle metabolism and shows evidence of positive selection in humans

D.G. MacArthur et al. ***Nature Genetics* 39**, 1261 - 1265 (2007)

All animals eat other organisms

dead or alive,
whole or by the patty

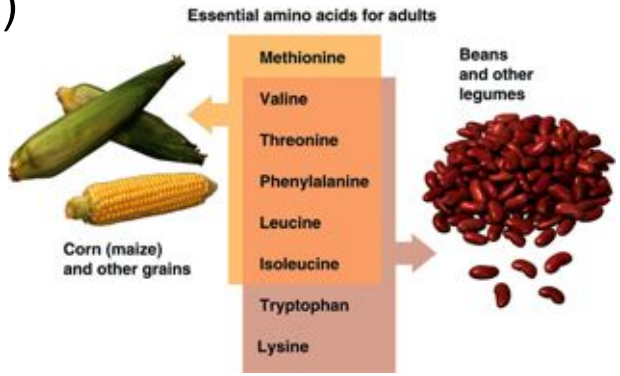
An adequate diet must satisfy three nutritional needs:

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

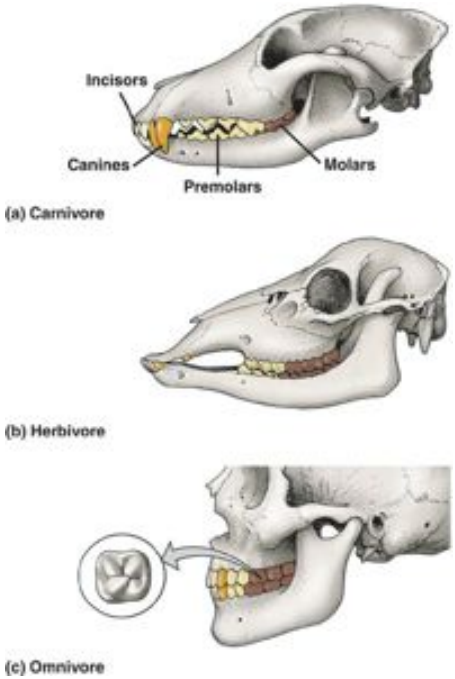
2 the organic raw materials animals use in biosynthesis;
Given a source of **organic carbon** (such as sugar)
& **organic nitrogen** (usually amino acids in protein),
animals can fabricate a great variety of organic molecules
- carbohydrates, proteins, and lipids;

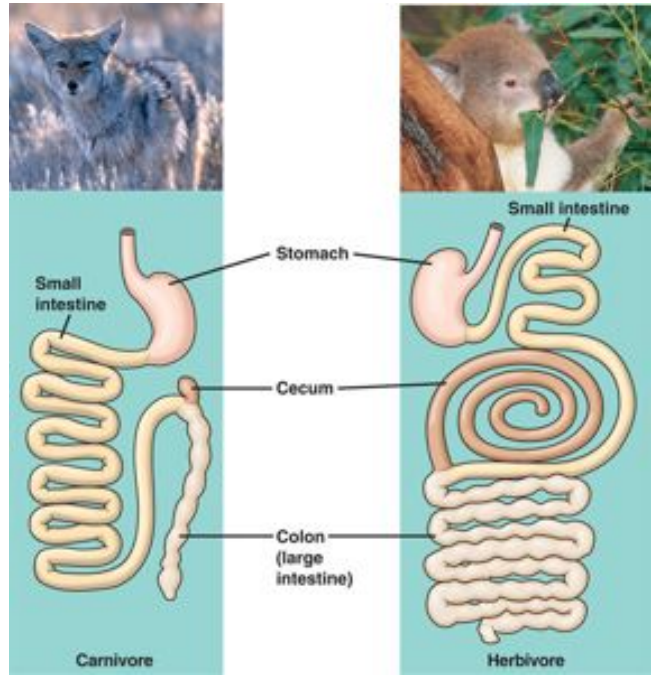
3 _____
from any raw material and must obtain in food in prefabricated form: essential
amino acids (8 or 9, see http://en.wikipedia.org/wiki/Essential_amino_acid)
fatty acids (omega-3 & -6: http://en.wikipedia.org/wiki/Essential_fatty_acids)
vitamins, and minerals (Table 41.1)

_____
{not complimentary}
_____
across plant foods



Teeth **and** **Guts** are great indicators of diet





The vestigiality of the human vermiform appendix

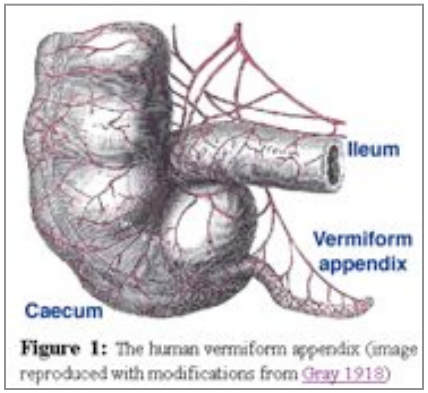


Figure 1: The human vermiform appendix (image reproduced with modifications from Gray 1918)

... 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;

The gene that makes your mouth water
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.

than those that follow low-carbohydrate diets, says a new study in *Nature Genetics*[1].

Glucose Regulation as an Example of *{push-pull –FB}* Homeostasis

When an animal takes in more calories than it needs ...
the liver and muscle cells store energy in the form of **glycogen**,
a polymer made up of many **glucose** units.

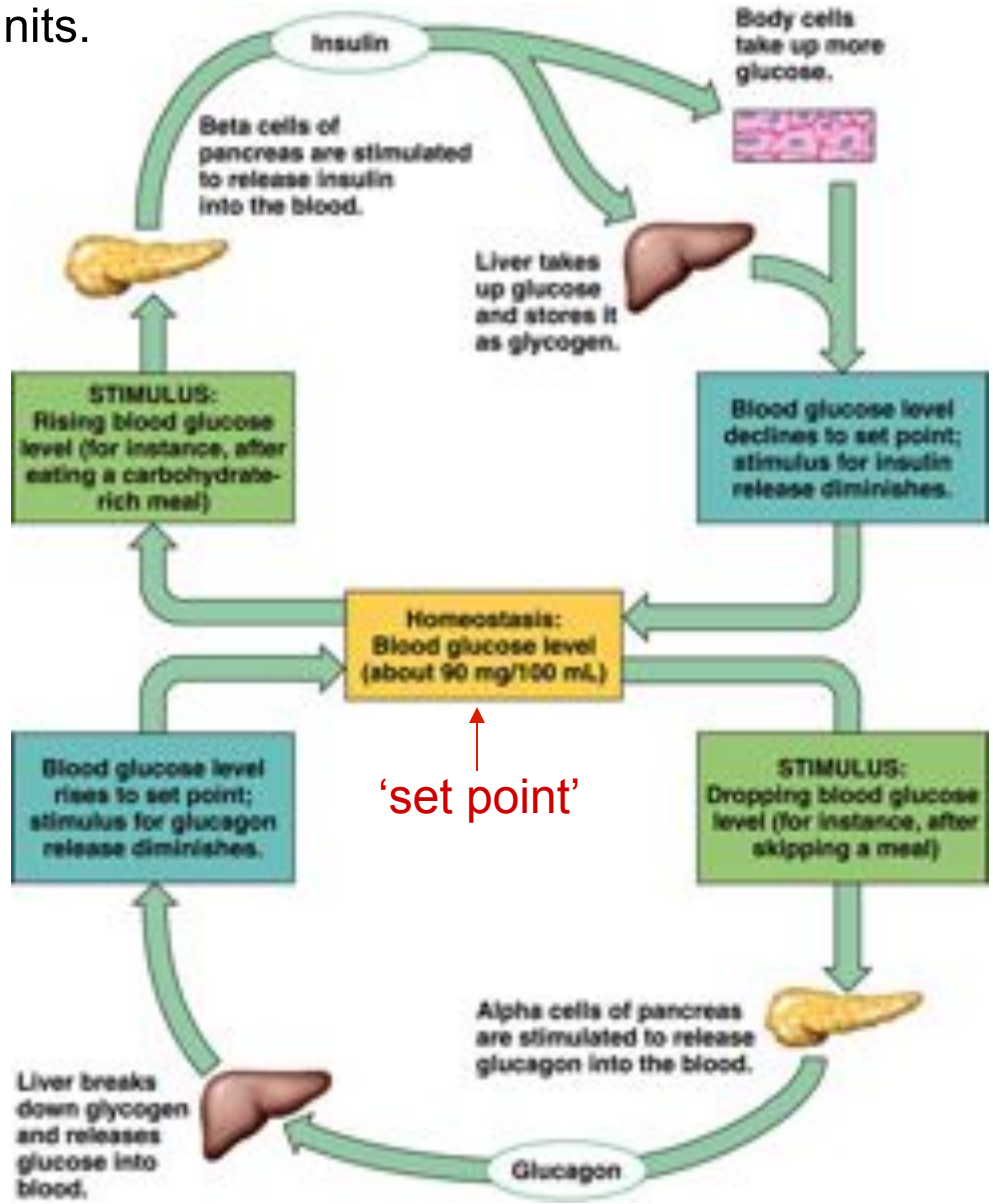
If the body's glycogen depots are full
the excess is usually stored as **fat**.

When fewer calories are taken in
than are expended ...
the body expends liver glycogen,
then muscle glycogen and fat.
{released as glucose, into blood}

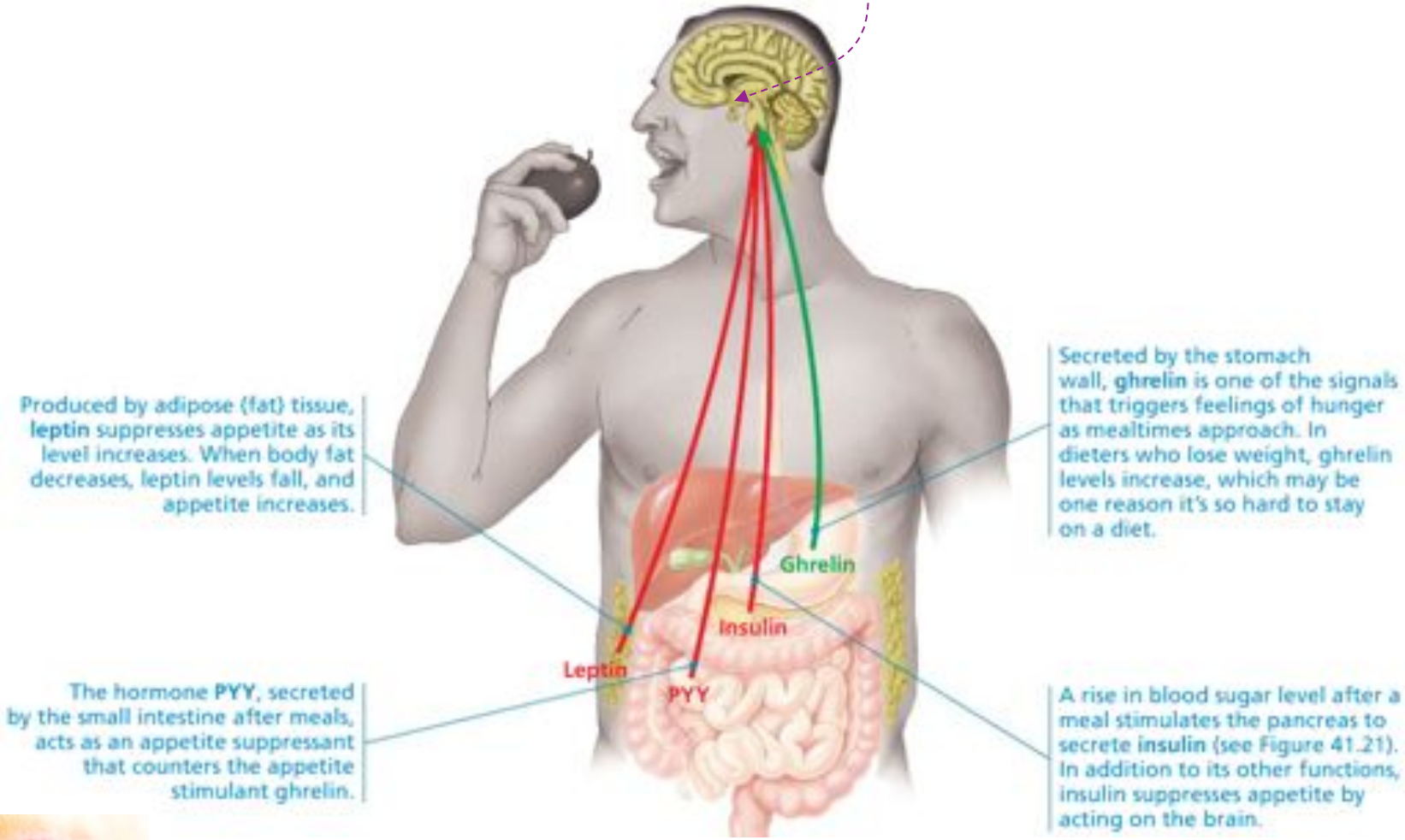
Blood glucose levels are regulated by complementary 'push-pull' negative feedback systems:
insulin pulls high blood glucose down
glucagon pushes low glucose up
(Figs 40.8 & 41.21)

Type 1 diabetes mellitus:
loss of insulin-producing beta cells;
autoimmune, juvenile onset

Type 2 diabetes is often due to
reduced responsiveness to insulin,
associated w/ obesity in adults



Over the long term, homeostatic mechanisms, involving hormones in feedback circuits to **a "satiety center" in the brain** *{a group of cells in the ventromedial hypothalamus}* control the body's storage and metabolism of **fat**.



Most diet pills on the market are not required to get approval by the FDA; the 1994 Dietary Supplement Health and Education Act (DSHEA) treats weight loss supplements as food.

•Leptin, The Fat Feedback Hormone •

Both of these mice have a defect in a gene called *obese* (*ob*).
This mutation results in a marked increase in the amount of fat.

Administration of the protein encoded by the *ob* gene, called **leptin**, *{Greek –"thin"}*
reduced the body weight of the *ob* mice. *{In obese humans, defective receptor}*

A MUST-READ!
The Most Important Health Discoveries of Our Time!

Mastering Leptin explains how we can conquer the obesity epidemic in America.
Finally the mysteries of the hormone leptin have been unlocked,
opening the door for permanent weight loss *{ too good to be true?}*

Coming of age

Body fat mass, leptin and puberty.

Kiess et al. 2000. J. Ped. Endo. & Metab 13:717-722.

By modulating the hypothalamo-pituitary-gonadal axis both directly and indirectly,
leptin may thus serve as the signal from fat to the brain
about the adequacy of fat stores for pubertal development and reproduction.

Normal leptin secretion is necessary for normal reproductive function to proceed
and leptin may be a signal allowing for … progression toward puberty.

Role of leptin in reproduction.

Bajari et al. CURRENT OPINION IN LIPIDOLOGY 15 (3): 315-319 JUN 2004

The development of therapeutic agents against obesity must consider
the consequences of treatment on the bioactivity of **leptin**
in the context of growth, glucose homeostasis, and last but not least, fertility.