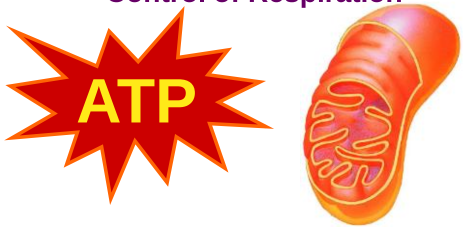
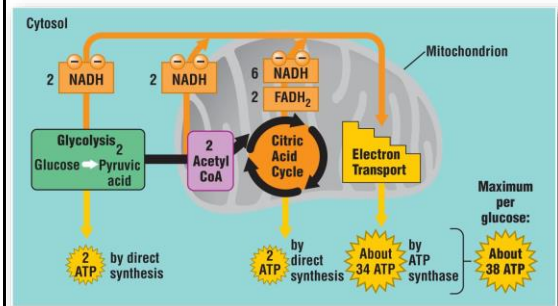
Chapter 49.4, 7.6

Cellular Respiration: Gas Exchange, Other Metabolites & Control of Respiration

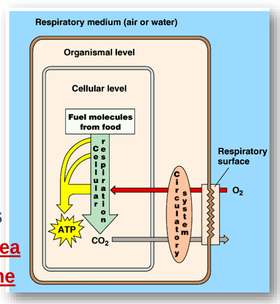


Cellular Respiration



Gas Exchange

- O_2 & CO_2 exchange
  - provides O_2 for aerobic cellular respiration
  - exchange between environment & cells
    - need high surface area
    - need moist membrane

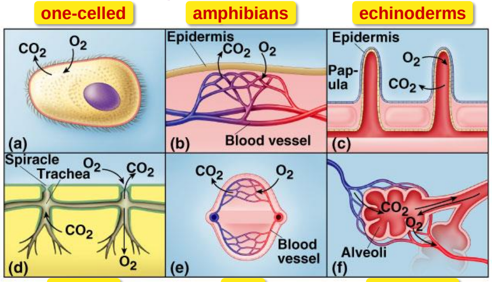


Optimizing Gas Exchange

- Why high surface area?
  - maximizing rate of gas exchange
  - CO_2 & O_2 move across cell membrane by diffusion
    - rate of diffusion proportional to surface area
- Why moist membranes?
  - moisture maintains cell membrane structure
  - gases diffuse only dissolved in water

Gas Exchange in Many Forms…

one-celled | amphibians | echinoderms



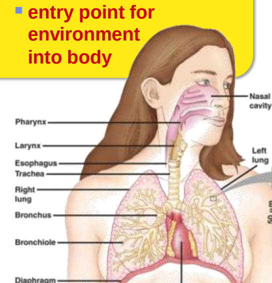
insects | fish | mammals

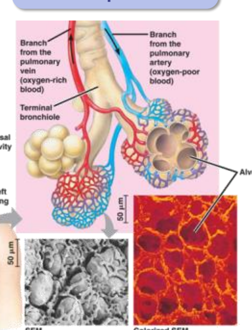
size | water vs. land | endotherm vs. ectotherm

Lungs

spongy texture, honeycombed with moist epithelium

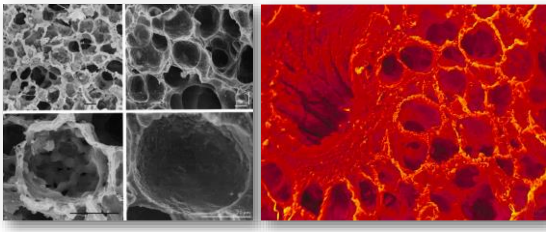
- Exchange surface, but also creates risk:
  - entry point for environment into body





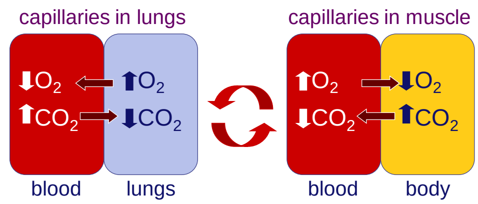
Alveoli

- Gas exchange across thin epithelium of millions of alveoli
  - total surface area in humans ~75 m^2



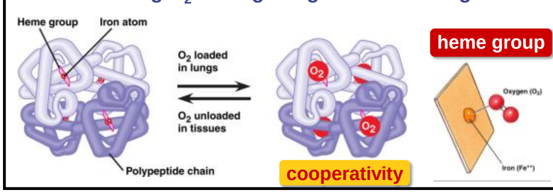
Diffusion of Gases

- Concentration & pressure drives movement of gases into & out of blood at both lungs & body tissue



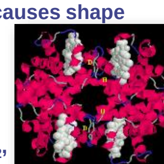
Hemoglobin

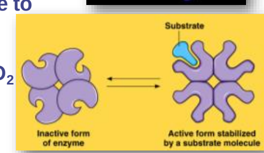
- Why use a carrier molecule?
  - O_2 not soluble enough in H_2O for animal needs
    - blood alone could not provide enough O_2 to animal cells
    - hemocyanin in insects = copper (bluish)
    - hemoglobin in vertebrates = iron (reddish)
- Reversibly binds O_2
  - loading O_2 at lungs or gills & unloading at cells



Cooperativity in Hemoglobin

- Binding O_2
  - binding of O_2 to 1st subunit causes shape change to other subunits
    - conformational change
  - increasing attraction to O_2
- Releasing O_2
  - when 1st subunit releases O_2, causes shape change to other subunits
    - conformational change
  - lowers attraction to O_2



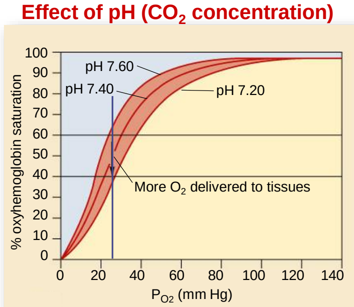


O_2 Dissociation Curve for Hemoglobin

Bohr Shift

- drop in pH lowers affinity of Hb for O_2
- active tissue (producing CO_2) lowers blood pH & induces Hb to release more O_2

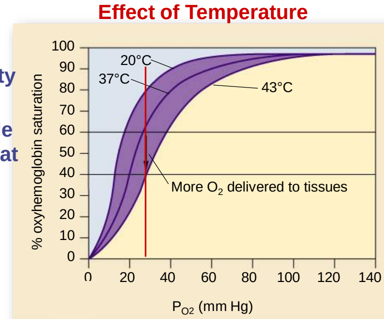
Effect of pH (CO_2 concentration)



O_2 Dissociation Curve for Hemoglobin

- increase in temperature lowers affinity of Hb for O_2
- active muscle produces heat

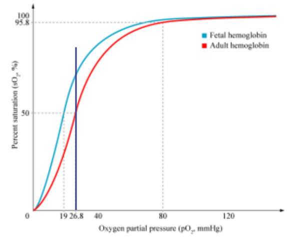
Effect of Temperature



Fetal Hemoglobin (HbF)

- HbF has greater attraction to O_2 than Hb
  - low O_2% by time blood reaches placenta
  - fetal Hb must be able to bind O_2 with greater attraction than maternal Hb

2 alpha & 2 gamma units

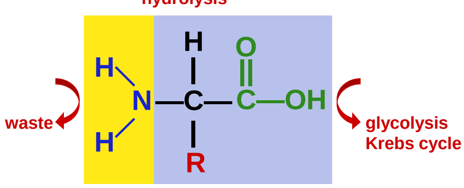


Beyond glucose: Other carbohydrates

- Glycolysis accepts a wide range of carbohydrates fuels
  - polysaccharides → → → glucose (hydrolysis)
    - ex. starch, glycogen
  - other 6C sugars → → → glucose (modified)
    - ex. galactose, fructose

Beyond glucose: Proteins

- proteins → → → → → amino acids (hydrolysis)



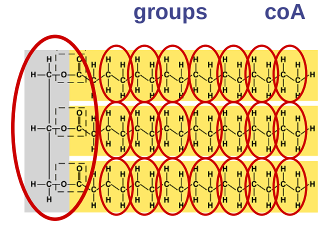
amino group = waste product excreted as ammonia, urea, or uric acid

carbon skeleton = enters glycolysis or Krebs cycle at different stages

Beyond glucose: Fats

- Fats → → → → → glycerol & fatty acids (hydrolysis)
  - glycerol (3C) → → DHAP → → glycolysis
  - fatty acids → 2C acetyl groups → acetyl coA → Krebs cycle

glycerol enters glycolysis as DHAP

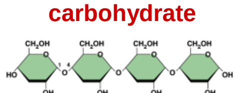


fatty acids enter Krebs cycle as acetyl CoA

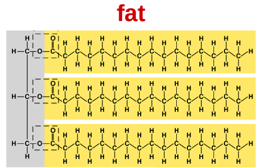
Carbohydrates vs. Fats

- Fat generates 2x ATP vs. carbohydrate
  - more C in gram of fat
  - more O in gram of carbohydrate
    - so it's already partly oxidized

carbohydrate



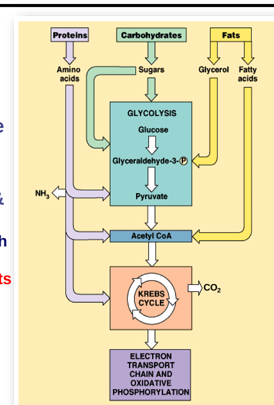
fat



Check the energy per gram listings on the Nutritional Fact sheet on all foods

Metabolism

- Coordination of digestion & synthesis
  - by regulating enzyme
- Digestion
  - digestion of carbohydrates, fats & proteins
    - all catabolized through same pathways
    - enter at different points
  - cell extracts energy from every source



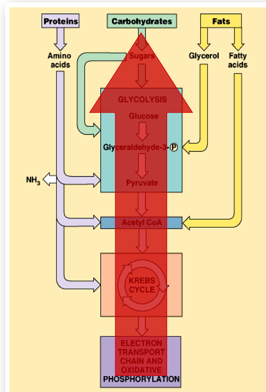
Metabolism

- Coordination of digestion & synthesis
  - by regulating enzymes
- Synthesis
  - enough energy? build stuff!
  - cell uses points in glycolysis & Krebs cycle as links to pathways for synthesis
    - run the pathways "backwards"
      - eat too much fuel, build fat

pyruvate → → glucose

Krebs cycle intermediaries → → amino acids

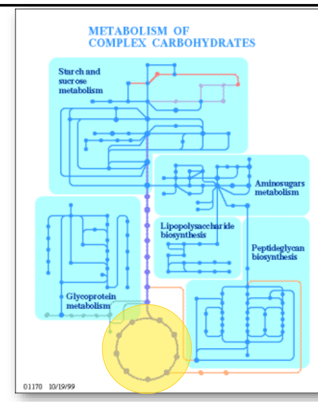
acetyl CoA → → fatty acids



Carbohydrate Metabolism

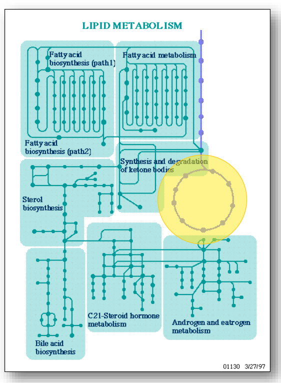
- The many stops on the "Carbo Line"

gluconeogenesis



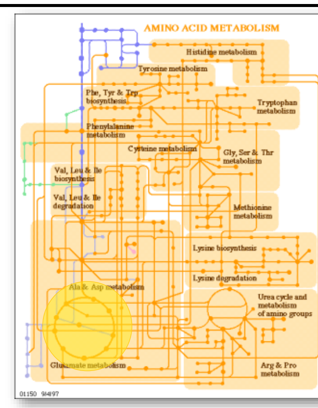
Lipid Metabolism

- The many stops on the "Lipid Line"



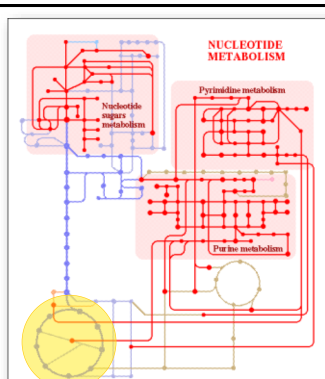
Amino Acid Metabolism

- The many stops on the "AA Line"



Nucleotide Metabolism

- The many stops on the "GATC Line"

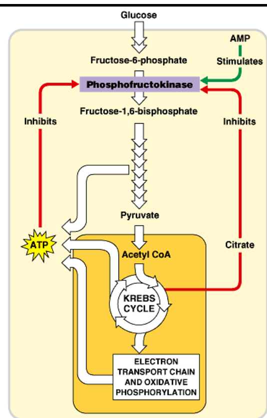


What – rather – where is this???

Name the city in 10 seconds to earn Sheldon's respect!

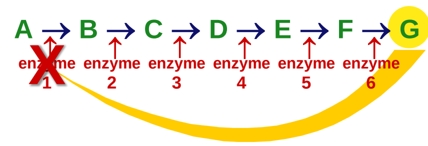
Control of Respiration

Feedback Control of Cellular Respiration



Feedback Inhibition

- Regulation & coordination of production
  - production is self-limiting
  - final product is inhibitor of earlier step
    - allosteric inhibitor of earlier enzyme
  - no unnecessary accumulation of product



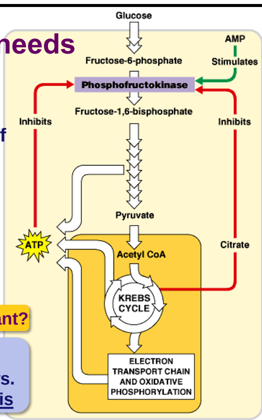
G is an allosteric inhibitor of enzyme 1

Respond to cell's needs

- Key points of control
  - phosphofructokinase
    - allosteric regulation of enzyme
      - "can't turn back" step before splitting glucose
    - ↑ [AMP] & [ADP] stimulate (activators)
    - ↑ [ATP] inhibits
    - ↑ [citrate] inhibits

Why is this regulation important?

Balancing act:
availability of raw materials vs. energy demands vs. synthesis

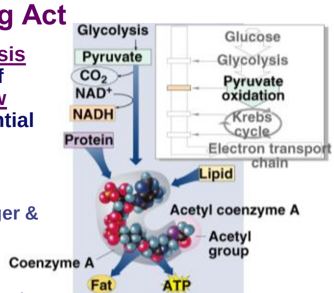


A Metabolic Economy

- Basic principles of supply & demand regulate metabolic economy
  - balance the supply of raw materials with the products produced
  - these molecules become feedback regulators
    - they control enzymes at strategic points in glycolysis & Krebs cycle
      - AMP, ADP, ATP
        - regulation by final products & raw materials
      - levels of intermediates compounds in the pathways
        - regulation of earlier steps in pathways
      - levels of other bio-molecules in body
        - regulates rate of siphoning off to synthesis pathways

It's a Balancing Act

- Balancing synthesis with availability of both energy & raw materials is essential for survival!
  - do it well & you survive longer
  - you survive longer & you have more offspring
  - you have more offspring & you get to "take over the world"



Acetyl CoA is central to both energy production & synthesis
make ATP or store it as fat