Midterm Review Slides
I. **Announcements**: Please check & sign attendance roster. Not on list? See Pat during a break or after class. *Lab 1 Histology* tomorrow in 130 HUE: 12 n & 1 pm sections.

II. **Introduction**: Staff, office hr, required sources, course overview, grading, expectations & success. Q?

III. **Human Physiology** LS ch 1, DC Module 1
   A. What? cf: Anatomy LS p 1
   B. Where? Body Levels of Organization LS pp1-6, DC pp1-5
   C. How? Different Study Approaches LS p 1

IV. **Homeostasis** LS ch 1, DC Module 1
   A. What? Maintenance of ECF LS p 8
   B. Where? ECF = Plasma + Interstitial LS fig 1-4 p 8
   C. How? Simplified Homeostatic Model cf: LS fig 1-7 p 14 Balances LS p 9, DC pp 5-6
   D. Why? Cell survival! LS fig 1-5 p 9, DC p 5
ANATOMY vs PHYSIOLOGY
STRUCTURE vs FUNCTION
WHAT? vs HOW?
WHERE? vs WHY?
Structure begets function!
Structure gives rise to function!
Structure & function are inseparable!
High-Tibial Osteotomy (HTO) to Realign the Joint

1. Oscillating saw cut
2. R plate/scaffolding insert
3. Align, stabilize w/screws & pack defect
Body Levels of Organization

1. Molecular
2. Cellular
3. Tissue
4. Organ
5. System

Entire Organism, like you & me!
Nerve conducts

Muscle contracts

Connective connects!!

Epithelial covers
Epithelial tissue gives rise to glands: (a) exocrine & (b) endocrine

(a) Exocrine gland

(b) Endocrine gland
Which body systems?
Maintenance of a relative constancy in the Internal environment = ECF = fluid outside of cells

milieu interieur?

100 trillion cells working intimately

Claude Bernard

Walter B. Cannon
I. **Announcements** Lab today 12 n & 1 pm. Q last time?

II. **Connections** Extracellular fluid (ECF) & Homeostasis
   A. ECF: Plasma vs. Interstitium?
   B. Dr Evonuk Balances LS pp 5 - 15
   C. *Physiology in the News* Are we like watermelons?
   D. Simplified Model DO Norris *cf:* fig 1- 8 LS
   E. Negative feedback? Positive feedback? LS pp 14 - 15
   F. Balances & e.g. H$_2$O, T°C, BP Dr Evonuk + LS pp 8 - 10

III. **Cell Anatomy, Physiology & Compartmentalization** ch 2 (LS)
   B. Basic survival skills ch 1 p 3
   C. Organelles ≡ Membranous, cytoplasmic specialty shops!
      1. Endoplasmic Reticulum (ER) 2. Golgi 3. Lysosomes
      fig 2-1, 2-2, 2-3, 2-4, 2-5, 2-6, 2-7, 2-8 pp 20-7 tab 2-1 p 36
   D. *Physiol News* Moms eggs execute Dad’s mitochondria?
   E. What about vaults? LS 2006, p 32 + *Science News*
ICF = Intracellular

ECF = Extracellular

Plasma (within CV System)

Interstitium (eg, between muscle cells)
Dr. Evonuk’s 6 Balances

Metabolic
ANA- CATA-

H₂O

T₀C

O₂/CO₂

Ion +/-
Drink about 1 L per 1000 calories energy expenditure!!

Human ~ 2/3 H$_2$O
~ 60 – 70 %

= ~40 – 48 kg H$_2$O

NB: So 2000 kcal →
drink 2000 mL
≡ 67.63 fl oz
≡ ~ 8 cups!
Invariably, Negative Feedback
NB: Though most often negative feedback, there are exceptions:

Selected +FB eg:

LH Surge + Ovulation
Oxytocin + Uterine Contraction
Blood Clotting Cascade
cAMP Cascade
Na+ influx during AP
**INPUT**

- Dietary Drink: 1200 mL
- Dietary Eat: 400 mL
- Oxidation: 400 mL

Total = **2000 mL**

**OUTPUT**

- Urine: 1000 mL
- Sweat + Insensible: 900 mL
- Feces: 100 mL

Total = **2000 mL**

**OUTPUT** and **INPUT** are balanced.

- ICF = 35L
- ECF = 14L
- Interstitium = 11L
- Plasma = 3L

70% H\(_2\)O = **49L**

**70 kg**
Controller = Hypothalamus with Set Point

True Diurnal Variation

Protein Denaturation

Mild Hypothermia

Profound Hypothermia

Set Point 98.6°F

110°F
Venous Pooling

BP ↓

I → R

Baroreceptors/Pressure Receptors
eg, in Carotids & Aorta

I’ → C

CV Control Center
Brain Stem

O → E

Electrochemical Signal
eg, Symp Accel N

Seated to Standing

NB: Corrective Change
Opposes Original Input

↑ BP

Ef →

HR ↑

VC +

State →
I. **Announcements**  Q from lecture or lab?

II. **Cell Physiology Connections**  LS ch 2 pp 20-34, fig 2-1…2-8
   B. Exocytosis vs. Endocytosis fig 2-5 a & b, p 25
   C. **Physiol News**  Moms eggs execute Dad’s mitochondria?
   D. What about vaults? LS 2006, p 32 + *Science News*

III. **Anaerobic vs Aerobic Metabolism Summary**  LS ch 2 pp 26-33
   A. Key differences fig 2-15 + vpl
   B. Selected details: Glycolysis, CAC, ETC, fig 2-9 thru 2-12

IV. **Introduction to Genetics**  LS 2012 ch 2 p 20-1 + Appendix C
   A. What’s a gene? Where? p A-18, fig C-2, C-3
   B. Why are genes important? p A-18
   C. What’s DNA & what does it look like? pp A-18 thru A-20
   D. How does information flow in the cell? fig C-6
   E. How does DNA differ from RNA? pp A-20 thru A-22

Anatomy & Physiology Lab tomorrow!...
**Why Compartments? Advantage?**

*Incompatible* reactions can take place

*Simultaneously!!*

...gobble! gobble!

- **Lysosome**
- **DNA**
- **Nucleus**
Basic Cell Survival Skills?

1. Get food
2. Use food
3. Rid wastes
4. Move
5. Reproduce

Nucleus or nose?

How to live?
Lysosomes vs. Peroxisomes
Catalase Enzyme Reaction in Peroxisomes
Neutralize Toxin at Production Site!

\[ 2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2 \]
Mitochondria: Energy Organelles
Mom’s eggs execute Dad’s mitochondria

In “Hamlet,” Rosencrantz and Guildenstern deliver a letter to the rulers of England that carries the ill-fated duo’s own death sentence. Perhaps Shakespeare knew a bit about reproductive biology.

Scientists have now found that during a sperm’s creation, its mitochondria—energy-producing units that power all cells—acquire molecular tags that mark them for destruction once the sperm fertilizes an egg. This death sentence, a protein called ubiquitin, may explain why mammals inherit the DNA within mitochondria only from their mothers, a biospecies mitochondrial inheritance. Sperm mitochondria sometimes avoid destruction when two different species of mice mate, and Schatten’s team has shown this also holds true in cattle. It’s hard to understand how an egg distinguishes between paternal mitochondria of closely related species, says Schon.

When paternal mitochondria escape destruction in normal mating, the resulting embryo may suffer. Schatten notes that a colleague has found sperm mitochondria in some defective embryos from infertility clinics.

AEROBIC w/O₂ = MITOCHONDRIUM

ANAEROBIC without O₂ = CYTOSOL

1. Immediate/ATP-PC
2. Glycolysis
ATP Supplied

- Immediate ATP-PC/15 - 30 s
- Glycolysis 1.5 – 3 m
- Mitochondria

Modified after Mathews & Fox
Cleave One High Energy Phosphate Bond To Do Work!!

7 – 10 KiloCalories/KCal

Adenosine

1. Synthesis of Macromolecules
   Make big things from little things!

2. Membrane Transport
   Move things! Microscopic!

3. Mechanical Work
   Move things! Macroscopic!

P ➔ P ➔ P ➔ P

P_i
Anaerobic vs. Aerobic Metabolism

**Anaerobic Glycolysis**
"sugar dissolving" without O₂. Net of 2 ATP per molecule of glucose

**Aerobic Metabolism**
+mitochondrial processing of glucose with O₂. Net of 32 ATP per molecule of glucose

II. **Cell Metabolism Connections** LS 2012 fig 2-9 thru 2-12 +…

III. **Introduction to Genetics** LS ch 2 p 20-1 + Appendix C
B. How does information flow in the cell? fig C-6
C. How does DNA differ from RNA? pp A-20 thru A-22
E. How & where are proteins made? fig C-7, C-9
F. Class skit: Making proteins @ ribosomes!

IV. **Nutrition Primer** DC Module 2, Sizer & Whitney (S&W) Sci Lib
A. Essential Nutrients: H₂O, 1⁰ Carbohydrates, 2⁰ Fats, 3⁰ Proteins, Vitamins, Minerals; Macro- vs Micro-?
B. Dietary Guidelines: USDA, AICR, Eat Like the *Rainbow*!
D. *Nutrition Quackery*, *Balanced Approach* Kleiner, Monaco+...
Goals of Aerobic Metabolism

AEROBIC
w/O$_2$

= MITOCHONDRION

CITRIC ACID CYCLE

harvest electrons $e^- \rightarrow e^- \rightarrow e^- \rightarrow e^-$

“cash in”

ELECTRON TRANSPORT CHAIN

for ATP Energy!!
What does DNA look like? Double-helix!!
Gene = Stretch of DNA that codes for a protein

cf: LS fig C-3

Gene  DNA Double Helix

Histones

Supercoiling
What does DNA do, day-to-day?

Replication

DNA → Transcription → RNA → Translation → Protein

Nucleus

Cytoplasm

@ ribosomes

cf: LS fig C-6
## DNA vs RNA?

<table>
<thead>
<tr>
<th>DNA</th>
<th>RNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Double-stranded</td>
<td>1. Single-stranded</td>
</tr>
<tr>
<td>2. Deoxyribose (without oxygen)</td>
<td>2. Ribose (with oxygen)</td>
</tr>
<tr>
<td>Thymine</td>
<td>Uracil</td>
</tr>
<tr>
<td>4. Self-replicative (can copy itself)</td>
<td>4. Needs DNA as template</td>
</tr>
<tr>
<td>5. Nucleus (+mitochondria)</td>
<td>5. 1&lt;sup&gt;0&lt;/sup&gt; Cytoplasm (but Nucleus origin)</td>
</tr>
<tr>
<td>6. mRNA, rRNA, tRNA</td>
<td></td>
</tr>
</tbody>
</table>
**Triplets of bases code for amino acids, the building blocks of proteins**

<table>
<thead>
<tr>
<th>DNA code word</th>
<th>mRNA codon</th>
<th>tRNA anti-codon</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAT</td>
<td>AUA</td>
<td>UAU</td>
</tr>
<tr>
<td>ACG</td>
<td>UGC</td>
<td>ACG</td>
</tr>
<tr>
<td>TTT</td>
<td>AAA</td>
<td>UUU</td>
</tr>
<tr>
<td>TAC</td>
<td>AUG</td>
<td>UAC</td>
</tr>
</tbody>
</table>
Translation? Ribosomes Make Proteins

1. Large subunit
2. Small subunit
3. Anticodon
4. tRNA
5. mRNA
6. Leader sequence
7. First codon
8. Second codon
9. Steps 5 through 8 are repeated

First ribosomal binding site
Second ribosomal binding site

CGUCCG AUCG CAU GUAG
CGUCCG AUCG CAU GUAG
CGUCCG AUCG CAU GUAG
CGUCCG AUCG CAU GUAG

LS 2012 fig C-7
BI 121 Lecture 5

I. Announcements Data + Flashdrive for Thursday’s lab! Q?
Thanks for recording dietary data on LM p 3-7 & exploring

II. Nutritional Physiology in the News Pondering Paleo Nutrition
Action Health Letter, Marlene Zuk, U Minn. Animal sources,
inflammation & disease? Drink Your Calories? PEBB Shake the
salt habit! UC Berkeley Newletter. Successful Dieting?

III. Nutrition Primer DC Module 2, Sizer & Whitney (S&W) Sci Lib
A. Dietary Guidelines: USDA, AICR, Eat Like the Rainbow!
B. Best path to weight loss? Diet or exercise or both?
  Dietary composition & endurance? Fasting?
  Zuti & Golding 1976; Sacks AHA NPAM 2009; AMDR?
C. Nutrition Quackery, Balanced Approach Kleiner, Monaco+

IV. Digestion LS 2012 ch 15, pp 437-9, DC Module 3 pp 17-23
A. Steps of digestion Dr. Evonuk + LS pp 437- 9; DC p 23
B. Hydrolysis + monomer to polymer: central linking themes!
  LS p 438, Fox 2009 +
C. What’s missing? LS fig 15-1 p 438
D. GI-Donut analogy + Control mechanisms. Dr. Brilla @ WWU
E. Gut secretions LS p 438, 440-1
F. Organ-by-organ review LS tab 15-1 pp 440-1 + DC fig 3-1

Nutrition Lab 3 Thursday! More personal data…
Pondering Paleo?

Evolutionary Biologist
Behavioral Ecologist
U Minnesota

http://www.nutritionaction.com/daily/how-to-diet/pondering-paleo/
Gut Bacteria Involved in **Inflammation & Atherosclerosis**?

Meat & Eggs → L-Carnitine & Choline → Trimethyl Amine (TMA) → TMAO → **Inflammation & Atherosclerosis**

The pathway linking diet, gut microbes and TMAO to a growing collection of disease states:

- Atherosclerosis
- Heart Failure
- Kidney Disease
- Atherosclerosis

Dietary Choline & L-Carnitine

Gut Flora

Hepatic FMOs

TMAO

Trimethyl Amine

5 times per wk? ≡ 106,600 calories/yr ≡ ± 30.5 lb fat/yr

Starbucks Cinnamon Dolce Latte, whipped cream (Venti, 20 oz.) 410 calories

Jogging 50 min.

Better choices!
More Reasons to Shake the Salt Habit

Stop me!

①↓ blood vessel vasodilation w/in 30 min by ingesting 1500 mg Na+!

②↑ Ca^{2+} excretion ↑ bone loss, risk of osteoporosis & fractures.

③May directly impair kidney function & ↑ risk of kidney stones.

④GI cancer risk, inflammation?

UCB Wellness Letter Jun 2011 p 5
Successful Dieting – National Weight Control Registry

- 5000 people, ≥ 30 lb weight loss, ≥ 5 yr
- High-carbohydrate (55-60%), low-fat (24%) diet with the rest (~16-21%) from protein
- Wholesome vs. high-sugar carbohydrates including fruits, vegetables, high-fiber foods
- Conscious of calories knowing that total calories count, no matter what diet type
- Eight of 10 ate breakfast daily which may help better manage calories during the day
- Self-monitor, weigh themselves ≥ 1x/wk & many still keep food dairies
- Much planned physical activity, 60-90 min/d, 10 walking + looked for other ways to be active

http://www.nwcr.ws/Research/published%20research.htm
UC Berkeley Wellness Engagement Calendar, September 2013
# Macronutrients & Micronutrients

**Essential for Life**

## Macronutrients

<table>
<thead>
<tr>
<th>Type</th>
<th>Sample Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O/Water</td>
<td>Water, other drinks, fruits &amp; vegetables</td>
</tr>
<tr>
<td>1° Carbohydrates</td>
<td>Grains, vegetables, fruits, dairy products</td>
</tr>
<tr>
<td>2° Fats/Triglycerides/Lipids</td>
<td>Meats, full-fat dairy products, oils</td>
</tr>
<tr>
<td>3° Proteins</td>
<td>Meats, legumes, dairy vegetables</td>
</tr>
</tbody>
</table>

## Micronutrients

<table>
<thead>
<tr>
<th>Type</th>
<th>Sample Food Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamins (A, D, E, K; C + B)</td>
<td>Vegetables, vegetable oils, fruits, citrus, grains, dairy</td>
</tr>
<tr>
<td>Minerals (K⁺, Na⁺, Ca²⁺, Mg²⁺, Fe²⁺, Zn²⁺,...)</td>
<td>Fruits, vegetables, grains, nuts, dairy, meats, processed foods</td>
</tr>
</tbody>
</table>

**NB:** Need only minute quantities!

 кажет заключительная метка для продукта, который не считается основным продуктом. С тем же успехом, его можно деинсталировать. Это поможет упростить и улучшить представление о продукте.
1. Vary your veggies. Fill ½ your plate with fruits & vegetables!

2. Focus on fruits. Whole fruit preferable to juice, but any fruit counts! Fill ½ your plate with fruits & vegetables!

3. Make at least ½ of your grains whole grains!

4. Go lean with protein. Keep protein to < ¼ plate! Nuts, beans, peas, seeds, poultry, lean meat, seafood,…

5. Get your calcium-rich foods. Buy skim or 1% milk. Go easy on cheese!

MyPlate launched June 2, 2011
Diet & Health Guidelines for Cancer Prevention

1. Choose a diet rich in variety of plant-based foods.
2. Eat plenty of vegetables & fruits.
3. Maintain a healthy weight & be physically active.
4. Drink alcohol only in moderation, if at all.
5. Select foods low in fat & salt.

And **always**, remember...

Do not smoke or use tobacco in any form.

*American Institute for Cancer Research (AICR)*

NB: Each group 500 kcal deficit/day, 16 weeks
Dietary Composition & Physical Endurance

eg, Atkins!

High-fat diet

Normal mixed diet

High-carbohydrate diet

Maximum endurance time:

57 min

114 min

167 min

~ 1/3 endurance!
Negative Effects of Low Carbohydrate

1. ↑ fatigue/exhaustion central & peripheral!
2. ↓ glucose – brain+spinal cord, rbcs thrive upon.
3. ↓ variety which reduces intake of phytochemicals, vitamins, minerals & fiber.
4. ↑ risk of respiratory infections.

+ gall stones,
↓ thermoregulation...
We’re better at storing fat vs carbohydrate!

Dietary Fat

3 % Kcal

Body Fat

23 % Kcal

Dietary Carbohydrate
To Help Lower Body Wt & %Fat
EXERCISE!! +Minimize These!!

FAT  9 Kcal/g
ETOH 7 Kcal/g
CARB 4 Kcal/g
PRO  4 Kcal/g

NB: Minimize not Eliminate! Moderation not Abstinence!!
60-day Fast???

Lost 60 lb!! Wow!!

Yet

\[
\begin{align*}
26 \text{ lb Water} \\
20 \text{ lb Lean Body Mass} \\
14 \text{ lb Fat}
\end{align*}
\]

Fat < \(\frac{1}{4}\) total wt loss!
Kleiner's & Monaco's Top 10 Hit List for Nutrition Quackery

1. Treatment based on unproven theory calling for non-toxic, painless therapy.

2. Author's/purveyor's credentials aren't recognized in scientific community.

3. No reports in scientific, peer-reviewed literature but rather mass media used for marketing.

4. Purveyors claim medical establishment is against them & play on public's paranoia about phantom greed of medical establishment.

5. Treatments, potions, drugs manufactured according to secret formula.

6. Excessive claims promising miraculous cures, disease prevention or life extension.

7. Emotional images rather than facts used to support claims.

8. Treatments require special nutritional support including health food products, vitamins and/or minerals.

9. Clients are cautioned about discussing program to avoid negative.

10. Programs based on drugs or treatments not labeled for such use.
Eliminate calories or food groups. Encourage fasting.

Lower carbohydrate

Adequacy, balance, consistency, & moderation.

Lower fat
Digestion Steps

1. Ingestion
2. Mechanical Digestion
3. Chemical Digestion
4. Peristalsis
5. Absorption
6. Storage
7. Defecation

Hi gang!!
You need me for digestion!!

$\text{H}_2\text{O} + \text{Enzyme}$
BI 121 Lecture 6 + Q + ½ Midterm Review

I. **Announcements**
   Next session Q? ~½ review, then Midterm.
   Fun Lab 3 Nutrition today! Sample Suisse Calculation? Q?

II. **Nutrition in the News**
    Be a whiz at healthy grilling!
    *American Institute for Cancer Research*, Grilling Quiz!

III. **Digestion Connections**
    LS ch 15, DC Module pp 17-23
    A. Histology of the gut LS fig 15-2, 15-3 p 442-3
    B. Stomach protein digestion + zymogens? LS fig 15-7, 15-9
    C. Accessory organs: Pancreas & Liver + Recycling!
       LS pp 457-63
       [http://www.cdc.gov/ulcer](http://www.cdc.gov/ulcer) Beyond the Basics LS p 456
    E. Summary of chemical digestion LS tab 15-5 p 466
    F. Large intestine? LS fig 15-24 pp 472-4

IV. **Midterm Review**
    Discussion + Q?
How Do I Calculate the % of Total Calories from Carbohydrate, Fat & Protein?

**Carbohydrate**  46 g x 4 kcal/g = 184 kcal

% Carbohydrate  = 184/567 = 0.326 ≡ ~33%

**Fat**  39 g x 9 kcal/g = 351 kcal

% Fat  = 351/567 = 0.619 ≡ ~62%

**Protein**  8 g x 4 kcal/g = 32 kcal

% Protein  = 32/567 = 0.056 ≡ ~6%

\[ \sum = 567 \text{ kcal} \]
Marinade, marinade, marinade! By doing so, you can decrease carcinogens formed during grilling by < 96%!

Cover the grill with aluminum foil, turn gas down or wait for low-burning embers, cook to the side.

Best choices for grilling include vegetables and fruits (no HCAs + enzymes to inactivate HCAs!), and lean meats (e.g., fish & skinless chicken ↓ PAHs).

Flip meat every minute to reduce charring & remove charred portions prior to eating.

To limit cancer risk, eat no more than 3 oz grilled red meat. Cook small portions/kebabs.
GI-DONUT ANALOGY

GI LUMEN

BODY
# Gut Secretions

<table>
<thead>
<tr>
<th>Secretion</th>
<th>Release Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mucus</td>
<td>into GI Lumen</td>
</tr>
<tr>
<td>2. Enzymes</td>
<td>into GI Lumen</td>
</tr>
<tr>
<td>3. H₂O, acids, bases+</td>
<td>into GI Lumen</td>
</tr>
<tr>
<td>4. Hormones</td>
<td>into Blood</td>
</tr>
</tbody>
</table>
1. **Mouth**
   - **Ingestion** entry way
   - salivary gland secretion
   - mucus + enzymes
   - enzymatic digestion: carbohydrate
   - mastication = chewing
   - deglutition = swallowing

2. **Esophagus**
   - **Rapid transit**
   - peristalsis
   - secretion mucus

3. **Stomach**
   - **Mixing**
   - peristalsis
   - secretion mucus + HCl
   - + enzymes
   - enzymatic digestion:
     - protein + butter fat!

4. **Liver-Gall Bladder**
   - **Emulsification** = detergent action of bile
   - + secretion

5. **Pancreas**
   - **Secretion** mucus + NaHCO$_3$ + enzymes
   - enzymatic digestion:
     - carbohydrate, fat, protein

6. **Small Intestine**
   - **Absorption**
   - Secretion mucus
   - + enzymes
   - enzymatic digestion:
     - carbohydrate, fat, protein
   - Peristalsis

7. **Large Intestine**
   - **Dehydration**
   - secretion + absorption
   - storage + peristalsis
Zymogen = an inactive precursor

Autocatalysis

Pepsinogen → Pepsin

Digestion

Protein

HCl

Peptide fragments

Gastric lumen

Various amino acids

Enzymatic splitting of a chemical bond

LS 2012 fig 15-9 p 452
Endocrine + Exocrine functions; Makes enzymes for digesting all 3 energy nutrients!
Ulcer Facts

• Most ulcers are caused by an infection, not spicy food, acid or stress.
• The most common ulcer symptom is burning pain in the stomach.
• Your doctor can test you for *H. pylori* infection.
• Antibiotics are the new cure for ulcers.
• Eliminating *H. pylori* infections with antibiotics means that your ulcer can be cured for good.
### Table 15-5 Digestive Processes for the Three Major Categories of Nutrients

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Enzymes for Digesting the Nutrients</th>
<th>Source of Enzymes</th>
<th>Site of Action of Enzymes</th>
<th>Action of Enzymes</th>
<th>Absorbable Units of the Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>Amylase</td>
<td>Salivary glands</td>
<td>Mouth and (mostly) body of stomach</td>
<td>Hydrolyzes polysaccharides to disaccharides (maltose)</td>
<td>Monosaccharides, especially glucose</td>
</tr>
<tr>
<td></td>
<td>Disaccharidases (maltase, sucrase, lactase)</td>
<td>Exocrine pancreas</td>
<td>Small-intestine lumen</td>
<td>Hydrolyze disaccharides to monosaccharides</td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td>Pepsin</td>
<td>Stomach chief cells</td>
<td>Stomach antrum</td>
<td>Hydrolyzes protein to peptide fragments</td>
<td>Amino acids</td>
</tr>
<tr>
<td></td>
<td>Trypsin, chymotrypsin, carboxypeptidase</td>
<td>Exocrine pancreas</td>
<td>Small-intestine lumen</td>
<td>Attack different peptide fragments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aminopeptidases</td>
<td>Small-intestine epithelial cells</td>
<td>Small-intestine brush border</td>
<td>Hydrolyze peptide fragments to amino acids</td>
<td></td>
</tr>
<tr>
<td>Fats</td>
<td>Lipase</td>
<td>Exocrine pancreas</td>
<td>Small-intestine lumen</td>
<td>Hydrolyzes triglycerides to fatty acids and monoglycerides</td>
<td>Fatty acids and monoglycerides</td>
</tr>
<tr>
<td></td>
<td>Bile salts (not an enzyme)</td>
<td>Liver</td>
<td>Small-intestine lumen</td>
<td>Emulsify large fat globules for attack by pancreatic lipase</td>
<td></td>
</tr>
</tbody>
</table>
Large Intestine Structure & Function

- Transverse colon
- Haustra
- Descending colon
- Ascending colon
- Ileocecal valve
- Cecum
- Appendix
- Rectum
- Sigmoid colon
- Internal anal sphincter (smooth muscle)
- External anal sphincter (skeletal muscle)
- Anal canal

LS 2012 fig 15-24 p 472