Human Metabolism: Macronutrients

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Emma Allott, PhD allott@email.unc.edu

**TAs:** Laetitia Meyrueix lmeyruei@email.unc.edu  
Allison Maria Lacko amlacko@live.unc.edu

**Time/place:** Fall 2017: 10:10 -11:00 MWF / 2306 McGavran-Greenberg  
Kannapolis: class in room 2313. IP: 172.27.70.97

**Prerequisites:** NUTR 400 (or CHEM/BIOL 430) OR for PhD students, a biochemistry course; CHEM 261 (organic chemistry) & BIOL 252 (anatomy/physiology) or equivalents.

**Course Description:** My objective is to enable UNC students to understand the relationships between macronutrient biochemistry and metabolism during specific physiological and disease states. We will cover the metabolic and physiological functions of nutrients at different levels - molecular, cellular, organ and whole body. We will focus on aspects of current research that are relevant to macronutrient-related diseases (e.g. atherosclerosis, obesity, diabetes, cancer, perinatal growth). Students will be encouraged to develop their ability to analyze current articles/ reviews/ advertising/ diet and drug recommendations related to the topics of this course.

**Text:** PowerPoints for the lectures will be available to you before the relevant class. I recommend that you look at the PPTs before class. Lippincott's Illustrated Reviews, 4th, 5th or 6th edition Biochemistry is recommended, but optional. You can use another biochemistry text if you prefer.

**Exam questions will be based primarily on the lectures and PPTs.**

**Feynman technique for learning:**

**Important Points:**
1. **Practice questions** are available on page 12  
2. **Cell phones** must be off in class. If yours rings, you must leave the room and not return.  
3. **Plagiarism** will result in a zero for the work. Plagiarism is the use of someone else’s words or ideas as your own without giving credit to that person.  
4. **Sources for information:** Any source you use for an assignment must be cited AND you must tell me (briefly) why you considered this source to be a valid one. This includes the Web. If you use a poor or unreliable source, you will receive a poor grade.
5. **Exams.** No make-up exams will be given except for emergencies or illness. The latter must be documented by a letter from a physician. **Quizzes** – since you can drop your lowest quiz, there will be no quiz make-ups.
6. **Attendance is not taken.** Lectures are “captured” so that you can listen later. However, most students feel that class attendance is helpful.
7. Sakai is used to communicate from professors and TAs to the class. For questions from students to instructors and TAs, please use email.

Accommodations. We want to ensure an optimal environment for students with physical or other disabilities. Students with a disability should contact http://www.unc.edu/asp/index.html, UNC Learning Center. If you are experiencing life events or academic pressures that leave you feeling anxious, confused, lonely, angry, depressed or overwhelmed, please contact: Counseling and Wellness office, http://campushealth.unc.edu/index.php?option=com_content&task=blogcategory&id=33&Itemid=56

Assignments/Discussion sessions/Questions: The objective of these sessions and the assignments is to help you use and integrate information covered in the course. These sessions will help you understand disorders related to nutrition. You may be asked to participate in class. If you do not wish to be called on, please tell Dr. Coleman. Exams will cover information from assignments.

Assignments: Grading and Late Policy: Drs. Allott and Surzenko will grade assignments. Put your name and status (BSPH, MPH, PhD) at the top of each assignment. BSPH students will email their assignments to Dr. Surzenko. All others will email assignments to Dr. Allott. Please email as Word documents so that graders can insert comments. Assignments should be submitted/emailed before class on the day they are due. Unless you have permission, assignments turned in after class (hard copy or email) will be considered “late.” If an assignment is late, points will be deducted. Thus, for a 15 point assignment, you will receive 10 points if it is a) emailed after class begins or b) if a hard copy is received after class on the day assigned, and 5 points if it is received after midnight. These rules are in place 1) because we will discuss assignment answers in class and 2) to avoid discrepancies concerning the time a document was emailed vs. the time it was received. If your email is not working, bring a hard copy to class.

Course Policy: Topics discussed in class will appear on quizzes and tests. You are responsible for knowing the due dates for assignments and tests. If you must be absent, you must hand in your assignment BEFORE the class. There are no “make-ups”. If you are sick, you must have a letter from Student Health or a physician in order to receive additional time to complete an assignment.

Exams and Grading

Exams will contain ‘short answer’ and ‘discussion’ questions. The first part of the final exam will cover the last third of the semester and the second part will be a cumulative exam covering the first 2/3 of the course. There are no make-up exams without Dr. Coleman's permission obtained before the scheduled exam. Unless you are told otherwise, you are responsible for all material from lectures and assignments (primary focus) and, secondarily, from the parts of the chapters covered.

Quizzes (mostly but not all) multiple choice or short answer) will be given on material covered during the previous 2-5 lectures to ensure that everyone is keeping up. Quizzes are noted on your syllabus and will be 10 minutes long, starting precisely at 10:10 am.

Assignments are designed to enable you to think critically about nutrition and nutrient-related disorders. Some assignments will be graded in full and, for some, only a single section will be graded. For a 15 point assignment, 13.5 points are earned for a good answer with insignificant errors, 15 for an insightful answer. Fewer points are earned for answers that contain significant errors.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Points</th>
<th>%</th>
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<tbody>
<tr>
<td>Exam 1</td>
<td>90</td>
<td>17</td>
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<tr>
<td>Exam 2</td>
<td>90</td>
<td>17</td>
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<tr>
<td>Quizzes (you may omit one 10 point quiz)</td>
<td>45</td>
<td>8</td>
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<tr>
<td>Assignments (15 points each)</td>
<td>105</td>
<td>20</td>
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<tr>
<td>Final exam</td>
<td>200</td>
<td>38</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>530</strong></td>
<td><strong>100</strong></td>
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</table>
These are rough guidelines for determining your letter grade from your numerical average. This scale assumes a final class average of ~84%. The scale may shift depending on the final average for your group (BSPH, MPH, MS, PhD). In previous years, the vast majority of students received A, B, H, or P.

<table>
<thead>
<tr>
<th>YOUR FINAL AVERAGE (%)</th>
<th>LETTER GRADE</th>
<th>YOUR FINAL AVERAGE (%)</th>
<th>LETTER GRADE</th>
<th>YOUR FINAL AVERAGE (%)</th>
<th>LETTER GRADE</th>
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</thead>
<tbody>
<tr>
<td>93-100</td>
<td>A / H</td>
<td>83-85</td>
<td>B / P</td>
<td>70-74</td>
<td>C / L</td>
</tr>
<tr>
<td>89-92</td>
<td>A- / H</td>
<td>79-82</td>
<td>B- / P</td>
<td>66-69</td>
<td>C- / F</td>
</tr>
<tr>
<td>86-88</td>
<td>B+ / P</td>
<td>75-78</td>
<td>C+ / L</td>
<td>60-65</td>
<td>D / F</td>
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</tbody>
</table>

Expectations: Nutrition 600 integrates a large amount of material relevant to biology, physiology, biochemistry, metabolism, and human health. These are complex topics that require knowledge, understanding, and critical thinking, i.e. the ability to apply this knowledge to real life problems. Students should spend about 2 to 3 hours/day outside of class - reading, reviewing, and studying – in other words, 2-3 hours studying / hour of class (= 6 to 9 hours/week). I highly recommend Study Groups.

PLEASE: Do not cram the night before an exam. There is too much material and too much active learning that needs to go on in your brain to master these concepts when you are exhausted and stressed.

Collaboration: Since all graded work (including homework, quizzes, and examinations) is used to determine academic progress, no collaboration on this work is permitted unless the instructor explicitly states that some specific degree of collaboration is allowed. Students may study together and work together on assignments that are not collected.

Syllabus Changes:
The instructors reserve the right to make changes to the syllabus, including presentation dates when unforeseen circumstances occur. These changes will be announced as early as possible so that students can adjust their schedules.

Web Animations to help you understand. Let me know if any of these links do not work.
Co-transport, Sodium-Potassium Exchange Pump, Endocytosis and exocytosis, Proton pump
http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter6/ Click on “animations”
Feedback inhibition
http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter8/animations.html#
Hormone and G-protein (explanation of 1st and 2nd messenger) epinephrine, cAMP, PKA and nuclear signaling
http://www.sumanasinc.com/webcontent/animations/content/extracellularsignaling.html
G-protein→PKC→open ion channel
http://www.youtube.com/watch?v=A3AUhMCE9n0
GPCR and cAMP. See: Signal amplification & Second messengers (cAMP and IP3/calcium)
http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter7/animations.html#
Protein secretion (e.g. what happens to digestive enzymes, insulin & other peptide hormones)
Glycolysis
http://www.johnkyrk.com/
TCA Cycle
http://www.science.smith.edu/departments/Biology/Bio231/krebs.html
http://www.johnkyrk.com/
Electron transport and ATP synthase
http://www.science.smith.edu/departments/Biology/Bio231/etc.html
http://www.johnkyrk.com/mitochondrion.html
http://highered.mcgraw-hill.com/sites/0072437316/student_view0/chapter9/animations.html#
Cholesterol enters cells via receptor-mediated endocytosis
DNA replication
http://www.johnkyrk.com/DNAreplication.html
Dynamic DNA replication
http://www.youtube.com/watch?v=E8NHcQesYl8&mode=related&search=

mRNA synthesis (transcription)
http://www.youtube.com/watch?v=NJxobgkPEAo&mode=related&search=

Splicing (optional)
Protein synthesis (translation)

DNA, RNA, protein synthesis
https://www.youtube.com/watch?v=Kzgnl5-8WAk

PPAR receptor and ligand
https://www.youtube.com/watch?v=BPstJ2eHhYU

Fun: The Elements (click on ‘Broadband’)
http://www.privatehand.com/flash/elements.html

More fun: Inner life of the cell
https://www.youtube.com/watch?v=wJyUtbn0O5Y

Protein synthesis film from 1971, Department of Chemistry of Stanford University and imprinted with the “free love” aura of the period. Narrated by Paul Berg. 1980 Nobel Prize for Chemistry.
http://www.youtube.com/watch?v=u9dhO0iCLww&mode=related&search

Honor Code at the University of North Carolina. The principles of academic honesty, integrity, and responsible citizenship govern the performance of all academic work and student conduct at the University as they have during the long life of this institution. Your acceptance of enrollment in the University presupposes a commitment to the principles embodied in the Code of Student Conduct and a respect for this most significant Carolina tradition. Your reward is in the practice of these principles.

Your participation in this course comes with the expectation that your work will be completed in full observance of the Honor Code. Academic dishonesty in any form is unacceptable, because any breach in academic integrity, however small, strikes destructively at the University’s life and work.

I expect that all in-class exams will be taken without the assistance of books, notes, the web, other people, or looking at exams of fellow classmates. You must sign a pledge on each exam that indicates “On my honor, I have neither given nor received unauthorized aid on this assignment.”

If you have any questions about your responsibility or the responsibility of faculty members under the Honor Code, please consult with someone in either the Office of the Student Attorney General (966-4084) or the Office of the Dean of Students (966-4041).

A man cannot become a competent surgeon without the full knowledge of human anatomy and physiology, and the physician without physiology and chemistry flounders along in an aimless fashion, never able to gain any accurate conception of disease, practicing a sort of popgun pharmacy, hitting now the malady and again the patient, he himself not knowing which.
Sir William Osler (1849-1919)
Schedule: This schedule is approximate for individual lecture topics and may be modified.

<table>
<thead>
<tr>
<th>DATE</th>
<th>Topic</th>
<th>Topic</th>
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<tbody>
<tr>
<td>8/23 W</td>
<td><strong>1. Intro to Metabolism</strong>: Introduction to metabolic regulation</td>
<td><strong>Self-Review</strong>: protein structure, amino acids, vitamins, nutrient and energy requirements, diet recommendations, diet and chronic disease</td>
</tr>
<tr>
<td>8/25 F</td>
<td><strong>2a. Glucagon &amp; insulin signaling</strong> in liver, muscle, &amp; fat</td>
<td>Review Ch. 1-4</td>
</tr>
<tr>
<td>8/28 M</td>
<td><strong>Quiz 1</strong>: (12 min) Write the pathway (glucose → acetyl-CoA) showing the names of the regulated enzymes (indicate only the regulated enzymes with a star *) [Do not show names of unregulated enzymes], names of all intermediates, # of carbons of intermediates; steps in which NAD⁺ &amp; NADH are used or produced, steps in which ATP &amp; ADP are used or produced, number of ATPs and NADHs produced or used at each of these steps (15 pts)</td>
<td>Ch. 8</td>
</tr>
<tr>
<td>8/30 W</td>
<td><strong>3a. Carbohydrates</strong>: CHO metabolism overview &amp; glycogen metabolism</td>
<td><strong>2b. Glucagon &amp; insulin signaling</strong> in liver, muscle, &amp; fat</td>
</tr>
<tr>
<td>9/1 F</td>
<td><strong>3b. Carbohydrates</strong>: Glycolysis regulation; Centrality of pyruvate; Tricarboxylic acid cycle, PDH</td>
<td>(Review Ch. 7), Ch. 8, 11</td>
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<tr>
<td>9/4</td>
<td>Labor Day</td>
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<tr>
<td>9/6 W</td>
<td><strong>4. Microbiome</strong></td>
<td>Glenny</td>
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<tr>
<td>9/8 F</td>
<td><strong>Assignment 1 due</strong>: (15 pts)</td>
<td><strong>Assignment 1 due</strong>: (15 pts)</td>
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<tr>
<td>9/11 M</td>
<td><strong>3c. Carbohydrates</strong>: ETC, uncoupling protein, PPP</td>
<td>Ch. 8</td>
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<tr>
<td>9/13 W</td>
<td><strong>3d. Carbohydrates</strong>: Gluconeogenesis; PEPCK, G6Pase; F-1,6-bisP/ PFK</td>
<td>Ch. 10</td>
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<tr>
<td>9/15 F</td>
<td><strong>Assignment 2 due</strong>: Lactate problem (15 pts)</td>
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<tr>
<td>9/18 M</td>
<td><strong>6a. Hormones</strong>: Overview</td>
<td>p. 246-</td>
</tr>
<tr>
<td>9/20 W</td>
<td><strong>Quiz 2</strong>: on carbohydrates (10 pts)</td>
<td>Ch. 18, pp. 93-60 pp. 237ff, 454-6</td>
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<td><strong>6b. Hormones</strong>: Peptide hormones &amp; cell signaling</td>
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<td>Date</td>
<td>Lecture/Assignment</td>
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<tr>
<td>9/22 F</td>
<td><strong>6c. Hormones:</strong> Amino acid-derived hormones</td>
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<tr>
<td>9/25 M</td>
<td><strong>Exam 1:</strong> Covers all lectures &amp; assignments AND review material on transport and enzyme kinetics (90 points)</td>
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<tr>
<td>9/27 W</td>
<td><strong>7a. Protein/Amino Acids:</strong> (Review chemistry, digestion &amp; absorption) N metabolism, transamination, oxidative deamination, amino acid products, special roles for amino acids &amp; proteins, malnutrition, branched chain AA &amp; diabetes,</td>
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<tr>
<td>9/29 F</td>
<td><strong>7b. Protein/Amino Acids:</strong> Protein degradation, ammonia, urea cycle, proteasomes, autophagy</td>
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<tr>
<td>10/2 M</td>
<td><strong>(Lipid Digestion: Review on your own)</strong></td>
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<tr>
<td>10/4 W</td>
<td><strong>8a. Fatty acid metabolism:</strong> Fatty acid synthesis, PUFA</td>
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<tr>
<td>10/6 F</td>
<td><strong>9. TAG metabolism:</strong> TAG synthesis &amp; lipolysis</td>
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<tr>
<td>10/9 M</td>
<td><strong>Quiz 3 on proteins/amino acids (10 pts)</strong></td>
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<tr>
<td>10/11 W</td>
<td><strong>10a. Cholesterol &amp; Lipoproteins:</strong> Cholesterol absorption, synthesis</td>
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<tr>
<td>10/13 F</td>
<td><strong>10b. Cholesterol &amp; Lipoproteins:</strong> Lipoproteins</td>
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<tr>
<td>10/16 M</td>
<td><strong>Assignment 4 due TBA (15 points):</strong> <strong>11. Atherosclerosis:</strong> Metabolic Regulation 1</td>
<td></td>
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<tr>
<td>10/18 W</td>
<td><strong>12. Pro- &amp; anti- Growth factors:</strong> AMPK, mTOR, autophagy: Metabolic Regulation 2</td>
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<tr>
<td>10/20 F</td>
<td>Fall Break</td>
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<tr>
<td>10/23 M</td>
<td><strong>14. Metabolic Syndrome:</strong> Metabolic Regulation 4</td>
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<tr>
<td>10/25 W</td>
<td><strong>15. Pregnancy &amp; Fetal growth:</strong> Metabolic Regulation 5 Physiological biochemistry, infant of a diabetic mother</td>
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<tr>
<td>10/27 F</td>
<td><strong>Exam 2:</strong> Covers all material from 9/27 to 10/23 (90 points) Rooms 2306, 2304, 2308</td>
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<tr>
<td>Date</td>
<td>Topic</td>
<td>Notes</td>
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<tr>
<td>10/30 M</td>
<td><strong>16a. Nutrients &amp; Genes</strong>: [Review transcription of eukaryotic genes, translation, protein synthesis]</td>
<td>How nuclear transcription factors work – regulation of gene expression [Review Ch. 30: pp. 422ff; Ch. 31] Ch. 32: pp. 454-7</td>
</tr>
<tr>
<td>11/1 W</td>
<td><strong>16b. Nutrients &amp; Genes</strong>: Nutrient control of gene expression: SREBP, PPAR</td>
<td>Ch. 18</td>
</tr>
<tr>
<td>11/3 F</td>
<td><strong>16c. Nutrients &amp; Genes C</strong>: Nutrient control of gene expression: PPAR, ChREBP, CREB</td>
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<tr>
<td>11/6 M</td>
<td><strong>17. Fatty liver</strong></td>
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<tr>
<td>11/8 W</td>
<td><strong>18a. Body Weight Regulation</strong>: Control of food intake, cannabinoids, appetite</td>
<td>Ch. 26</td>
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<tr>
<td>11/10 F</td>
<td>Assignment 6: Diet analyses (15 points)</td>
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<tr>
<td>11/13 M</td>
<td>Assignment 6: Diet analyses (15 points)</td>
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<tr>
<td>11/15 W</td>
<td>Assignment 6: Diet analyses (15 points)</td>
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<tr>
<td>11/17 F</td>
<td><strong>18b. Body Weight Regulation</strong>: Central control of food intake, leptin, insulin, satiety Gilbert</td>
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<tr>
<td>11/20 M</td>
<td><strong>19a. Cancer</strong>: Cancer cell metabolism Review glycolysis, PPP</td>
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<tr>
<td>11/23 W</td>
<td>Thanksgiving vacation</td>
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<tr>
<td>11/25 F</td>
<td>Thanksgiving vacation</td>
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<tr>
<td>11/27 M</td>
<td><strong>19b. Cancer B</strong>: Host metabolism &amp; cachexia; mTORC1 Assignment 7 due: Bed Rest (15 pts)</td>
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<tr>
<td>12/1 F</td>
<td><strong>21. Circadian Rhythm</strong>: Metabolic Regulation 7 Shift work, metabolic syndrome</td>
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<tr>
<td>12/4 M</td>
<td><strong>22a. Exercise</strong>: Muscle substrates, fiber types, energy Muoio</td>
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<tr>
<td>12/6 W</td>
<td><strong>22b. Exercise 2</strong>: Muscle &amp; metabolic adaptations Muoio</td>
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<tr>
<td>12/15 8:00 – 11:00 am</td>
<td><strong>Final Exam</strong>: Part 1 covers 10/25 - 12/6. Part 2 covers the entire course. The date &amp; time of the exam is given in compliance with UNC final exam regulations &amp; according to the UNC Final Exam calendar. Rooms: 2304, 2305, 2306 McGavran</td>
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Nutrition 600: Learning Objectives

General Objectives: Students will be able to:

1. Explain how nutrients are transported in the blood and across cell membranes.
2. Explain how hormones transmit signals that regulate metabolic pathways.
3. Explain major metabolic pathways and critical regulatory points for the metabolism of macronutrients.
4. Integrate the metabolic interconversions of lipids, carbohydrates and amino acids.
5. Explain how metabolic pathways are regulated during different dietary and physiological conditions.
7. Explain concepts of appetite control, weight regulation, RQ, thermogenesis, circadian rhythm.
8. Apply concepts about metabolic pathways and their regulation to novel situations, including current popular diets, claims of health benefits, new therapies.

Review: DIGESTION AND ABSORPTION - from your prerequisite physiology course)

- Explain the digestive functions of the gastrointestinal (GI) tract (stomach, duodenum, jejunum, ileum, and colon) and associated organs (liver, gallbladder, and pancreas).
- Identify the sources and functions of secretions into the gastric and duodenal lumens.
- Define and explain the importance of zymogens.
- Describe three effects of hydrochloric acid (HCl) secretion by the stomach.
- Diagram the stepwise sequence of digestion of dietary protein in the GI tract.
- Describe the digestion of carbohydrates (CHO) in the stomach, duodenal lumen and duodenal mucosa; specify enzymes, CHO intermediates and end products.
- Identify barriers of diffusion and transport into cells for water soluble nutrients.
- Compare diffusion to facilitated and active transport with regard to concentration gradients, energy, carrier protein, and saturability.
- Describe the route by which water-soluble nutrients reach the interior of cells.
- Describe emulsification, digestion, and absorption of lipids and lipid-soluble vitamins. Specify the roles of pancreatic lipase, co-lipase, and bile salts. How do digestion, absorption, and metabolism differ for long-chain and medium-chain fatty acids?

Review: ENZYME REGULATION – from your prerequisite biochemistry course

- Describe five different mechanisms of metabolic regulation.
- Explain allosteric regulation and competitive inhibition.
- Understand and use concepts like affinity, Vmax, Km.

HORMONAL CONTROL

A. PEPTIDE HORMONES AND THEIR RECEPTORS

- Describe the general concepts of endocrine, paracrine, and autocrine, action (Review)
- Explain signal transduction and its benefits (e.g., G-proteins, cAMP, IP3, calmodulin)
- Explain the hormone cascade system: hypothalamus, pituitary, and target gland
- Explain the concept of negative feedback inhibition
- Describe the formation of a polypeptide hormone: e.g. insulin
- Describe the regulators of production and secretion of insulin, glucagon, growth hormone, ghrelin, etc.
- Describe how peptide hormones act on surface receptors of target cells to confer specificity
- Explain how insulin stimulates glucose uptake into cells and suppresses hepatic glucose production
- Explain the concept of insulin resistance
- Understand what incretins do
- Receptors: contrast tyrosine kinase receptors vs. G-protein coupled receptors (7-transmembrane). Show details of their signaling pathways.
B. NON-PEPTIDE HORMONES AND THEIR RECEPTORS
- Know organ sources of cortisol, aldosterone, progesterone, estradiol, testosterone
- Know what signals regulate the secretion of the steroid hormones listed above?
- Describe the function of the steroid hormones listed above
- Explain the mechanism by which steroid hormones act through their nuclear receptors
- Explain the synthetic pathway involved in thyroid hormone production and the role of iodine.
- Explain thyroid hormone action through its nuclear receptor
- Know the precursors of epinephrine, norepinephrine, and dopamine

C. INTRACELLULAR SIGNALING I: GENERAL MECHANISMS
- Understand the role of phosphorylation and dephosphorylation of proteins in cell signaling.
- Understand the role of cyclic nucleotides in cell signaling.
- Understand the role of intracellular calcium and phospholipids in cell signaling
- Define a “signal cascade” and tell why it is useful in amplifying a signal
- Understand the importance of signaling pathways in nutrition

D. INTRACELLULAR SIGNALING II: SPECIFIC PATHWAYS
- Understand the signaling pathways used by: insulin, glucagon, epinephrine
- Understand the function of AMP-activated kinase (AMPK) and its role in metabolism
- Understand the function and role of mTOR

CARBOHYDRATES AND INTERMEDIARY METABOLISM
- Describe glycolysis (glucose to pyruvate), identifying major regulated steps, oxidation, ATP generation
- Differentiate the metabolic circumstances under which aerobic or anaerobic glycolysis would operate; compare the means of regenerating NAD, energy yield and end products.
- Locate the entry points into glycolysis for glucose, glucose derived from glycogen, fructose, and glycerol. What are the hexose monophosphate shunt end products and what are they used for?
- Identify glycolysis "branch points" that lead to glycogen, pentoses, and glycerol.
- Explain the metabolic circumstances that direct pyruvate metabolism to acetyl-CoA, oxaloacetate, alanine, or lactate.
- In these reactions, specify the names and metabolic functions (the type of chemical reaction catalyzed) of niacin, riboflavin, thiamin, pantothenic acid, biotin and pyridoxine coenzymes.
- Outline the oxidation of pyruvic acid to acetyl-CoA and the oxidation of acetyl-CoA to CO₂ by the Krebs/ TCA cycle, indicating the reactions that (1) yield ATP directly, (2) require NAD, (3) require FAD or (4) yield CO₂. Summarize the energy (ATP) yields from glucose, from glycogen, and from pyruvate.
- Explain why it is advantageous to have a system that extracts energy from reduced fuels to regenerate ATP (regeneration of ADP to ATP).
- Summarize oxidative phosphorylation; name substrates and products; identify oxidized and reduced components and reactants, and energy equivalency of coenzymes of niacin and riboflavin.
- Explain what uncoupling protein does?
- What are the major regulated steps in glycolysis, gluconeogenesis, glycogen synthesis and glycogenolysis? How do these function during feeding, starvation, exercise, diabetes, stress, and other physiological changes?

AMINO ACIDS and PROTEINS
- Describe the main interconversions of amino acids and how they facilitate gluconeogenesis
- Understand the urea cycle and its role during normal metabolism, protein excess, and starvation
- Know the major physiological differences between stress and starvation
- Explain the concepts: essential amino acid, ketogenic amino acid, glucogenic amino acid
- Describe the different mechanisms of protein degradation (proteasome, ubiquitination, autophagy...) and the physiological circumstances that control them
Understand how specialized proteins relate to dementia, Parkinson’s, Alzheimer’s

LIPIDS, LIPOPROTEINS, ENERGY STORAGE
- Describe the ACS activation step that precedes fatty acid metabolism. What is the ATP energy cost?
- Explain the mechanism by which activated fatty acids are transported from the cytoplasm into the mitochondria, why this mechanism is important, and how it is regulated.
- Describe the end products of β-oxidation; name the coenzymes involved.
- Calculate the net energy yield, after activation, from beta-oxidation of fatty acids and oxidation of resultant acetyl-CoA via the TCA cycle.
- Provide an overview of the reactions and coenzymes involved in palmitate synthesis from acetyl-CoA.
- Compare fatty acid oxidation vs. fatty acid synthesis, in terms of substrates, products, energy considerations, coenzymes.
- Describe the elongation and desaturation of palmitate. Name the primary products of lipogenesis in the liver (long chain fatty acids incorporated into VLDL-triacylglycerol).
- Describe triacylglycerol synthesis in liver and in adipose tissue, comparing the sources of glycerol and the predominant fatty acids.
- Explain why linoleic and linolenic acids are dietary essentials.
- What are the structural and regulatory roles of polyunsaturated fatty acids (PUFA)?
- Summarize the assimilation (absorption, transport and storage and/or metabolism) of dietary triacylglycerol and the disposition of excess energy from protein and carbohydrate after a meal.
- Compare the plasma lipoproteins (chylomicra, VLDL, LDL, HDL) with respect to size and the relative amounts and types of core lipids.
- Explain the functions of each plasma lipoprotein by specifying the origin, transfer mechanism and destination of core lipid and the disposition of the apoprotein shell.
- Know the regulated steps in the synthesis of cholesterol from acetyl-CoA. Describe the function of cholesterol in membranes and in embryogenesis. Identify other sterols that are synthesized from cholesterol.
- Explain how dietary cholesterol regulates endogenous cholesterol synthesis.
- Distinguish circumstances for stimulation of lipid mobilization by glucagon, cortisol or catecholamines.
- Explain how fatty acids are released from adipose stores and delivered to muscle vs. liver; describe the circumstances, tissues involved and mechanisms of ketone body production and oxidation.
- Explain how triacylglycerol synthesis and degradation are regulated under conditions of excess caloric intake or fasting/starvation.
- Explain how cholesterol synthesis and lipoprotein metabolism are regulated by statin drugs and by dietary cholesterol, saturated fatty acids, and carbohydrates.

APPETITE AND SATIETY
- Diagram the systems involved in the complex behavior of food intake; the brain, adipose tissue, the GI tract, the environment, and the endocrine system.
- Identify the areas of the brain involved in the regulation of hunger and satiety.
- Specify the source and function of central nervous system controllers of food intake, NPY, MSH, and CRH.
- Identify the neurotransmitters that regulate food intake; serotonin, dopamine, norepinephrine, and cannabinoids, and describe the signaling steps involved in their synthesis.
- Describe the endocrine (peripheral) controllers of food intake; insulin, glucocorticoids, leptin, gonadal steroids.
- Distinguish between the signals that regulate short-term food intake (meal size) and long-term food intake (adipose stores).

NUTRIENTS AND GENE EXPRESSION
- Know the structure and function of DNA (Review)
- Understand DNA replication (Review)
• Describe the 3 types of RNA and how they are involved in protein synthesis (Review)
• Explain the difference between transcription and translation (Review)
• Understand the difference between cis and trans acting factors (Review)
• Understand and describe promoters and their function (Review)
• Understand regulatory elements and their function
• Explain how nutrients alter gene expression:
  SREBP1 (PUFA, insulin), SREBP2 (cholesterol), FXR (bile acids)
  PPARγ, PPARα, PUFA (poly-unsaturated fatty acids), carbohydrate and ChREBP

EXERCISE
• Describe the fuels used by muscle during different types of exercise
• Describe how exercise alters muscle structure and function (fiber type, blood flow, use of fuels)
• Explain how AMP kinase improves glucose metabolism in diabetic people
• Explain the regulation of different fuel use (glucose vs. fatty acid)
• Explain how mitochondrial metabolism is controlled by PPARα and PGC1α

CLINICAL PROBLEMS
• Understand the biochemical and metabolic alterations that occur in starvation vs. stress
• Understand the relationship(s) between obesity, insulin resistance, the metabolic syndrome, diabetes, atherosclerosis, and cancer
• Understand how statins, fibrates, and PUFAs work to treat dyslipidemias
• Understand how TZDs, incretins, and metformin work in the treatment of diabetes
• Understand the biological and physiological differences between types 1 and 2 diabetes
• Understand the biochemical and histological changes that occur in atherosclerosis
• Understand what occurs during a myocardial infarction
• Describe the components of nitrogen balance and what happens during protein deficiency or excess
• Understand the physiological and biochemical responses that occur to combat hypoglycemia
• Understand the consequences of malabsorption problems (e.g. cystic fibrosis)
• Understand the causes and consequences of hypothyroidism and hyperthyroidism
• Understand the causes and consequences of lactase deficiency (Review)
• Understand recent nutritional research related to shift work (circadian rhythm), aging, longevity
• Be able to evaluate the biochemical effects of low CHO diets and low fat diets
• Be able to evaluate the pros and cons of new popular diets.
• Understand the altered metabolism of cancer cells
• Understand effects, including cachexia, of cancer cells on their host
Typical exam questions: Judge the detail required for your answer by the number of points

1. (4 points each)
   a. Define ‘substrate level phosphorylation’ and give an example.
   b. Premature babies are susceptible to severe inflammation of the small intestine. If the small intestine becomes gangrenous (suffers tissue death), it is removed surgically. Briefly describe what you think the result would be on digestion and absorption of rice cereal if most of the small intestine was removed and only 10 cm remained. Briefly explain your reasoning.
   c. In an experiment performed on rats, a drug was given to increase the activity of uncoupling protein (UCP) in brown adipose tissue. Explain biochemically why the drug increased the rats’ respiratory rate.
   d. Explain the difference between primary and secondary active transport.
   e. Explain the difference between allosteric regulation and regulation by phosphorylation. Is one faster than the other? Why or why not?

2. (5 points each)
   a. Enzyme A has a lower Km for its substrate than enzyme B. Will enzyme A have a higher Vmax, too? Explain why or why not? Draw a graph showing the substrate dependence for enzymes A and B.
   b. How do incretin drugs work and why are they used?

3. (10 points) Jack’s boat sinks in a storm and he swims to a island where there is fresh water to drink but nothing to eat. When he is rescued 8 hours later, his liver glycogen stores are (circle the best answer): close to normal / increased 30% / decreased 30% / almost absent. Explain your answer by describing, in detail, the hormonal pathways and the activation and inactivation of the regulated enzymes involved in glycogen metabolism at the time of Jack’s rescue. You may draw a pathway, but explain your answer in words.

4. (10 points) Jack’s friend Joe swims to another island where there is fresh water to drink but nothing to eat. When Joe is rescued 2 weeks later, his blood glucose is ___ (make an X at a point on the line that shows the most likely glucose concentration. The normal range for glucose is 64-126 mg/dl):

   ![Graph showing glucose concentration range]

   At the time Joe is rescued, describe the 2 primary hormones that are important (active and inactive) and how these hormones are working to regulate the major enzymatic steps that control the synthesis and output of glucose from Joe’s liver. Remember—the inactive hormone also plays a role.

5. (6 points)
   You have been hired to advise a large pharmaceutical company. Propose a new weight loss drug that works by decreasing the function of pancreatic lipase. Describe how the proposed drug would work biochemically. Why do you think this biochemical approach would be effective (discuss the mechanism)? What limitations, problems, or side effects might occur?

6. (15 points)
   Tom Price MD, the US Secretary of Health and Human Services, was previously a US Representative from Georgia. He was an orthopedic surgeon and a former member of the Association of American Physicians and Surgeons, which was founded to “fight the government takeover of medicine.” He has minimal background in nutrition or internal medicine, so you hired to write a position paper for him about current research on drugs that affect glucose metabolism and diabetes. Describe the signaling pathway of insulin. If a drug were available to increase the amount of insulin secreted after a meal, what biochemical changes would you see in two (2) major regulated steps of glycolysis or glucose production by the liver? Would it be good idea to increase the amount of insulin secreted after a meal?
Normal Blood Chemistries (you do NOT need to memorize these values, except for the glucose ranges that indicate “normal,” “pre-diabetes,” and “diabetic”)

What is called “normal” will vary in different labs. Remember, there is no point in worrying about “low normal” or “high normal” values. Values within the normal range are normal!

Normal Values

- Albumin: .................................................. 3.9 to 5.0 g/dl
- Alkaline phosphatase: ................................. 44 to 147 IU/L
- ALT (alanine transaminase): .......................... 6 to 59 IU/L
- AST (aspartate aminotransferase): ................. 10 to 34 IU/L
- Bilirubin, total: ........................................... 0.2 to 1.9 mg/dl
- Bilirubin: .................................................... 0.0 to 0.3 mg/dl
- BUN (blood urea nitrogen): ......................... 7 to 20 mg/dl
- Calcium - serum: ....................................... 8.5 to 10.9 mg/dl
- Chloride, serum: ........................................... 101 to 111 mmol/L
- Cholesterol, total: ....................................... <200 mg/dl (see Athero section of syllabus)
  HDL-cholesterol: Women ≥50 mg/dl
  Men ≥40 mg/dl
- CO2 (carbon dioxide): ................................. 20 to 29 mmol/L
- Creatinine: .................................................. 0.8 to 1.4 mg/dl
- GGT (gamma-glutamyl transpeptidase): ......... 0 to 51 IU/L
- Glucose: ..................................................... 64 to 126 mg/dl

  Fasting plasma glucose
  Normal 70 - 99
  Prediabetes 100 - 125 (impaired fasting glucose)
  Diabetes ≥126 (≥7.0 mM)

  Oral glucose tolerance test: 75 g glucose dissolved in H2O. Peak level:
  Normal < 140
  Prediabetes ≥140 - <200 (impaired glucose tolerance)
  Diabetes ≥200 at 2 h after glucose ingestion

- LDH (lactate dehydrogenase): ....................... 105 to 333 IU/L
- Phosphorus - serum: .................................... 2.4 to 4.1 mg/dl
- Potassium: .................................................. 3.7 to 5.2 mEq/L
- Protein, total: ............................................. 6.3 to 7.9 g/dl
- Sodium - serum: ......................................... 136 to 144 mEq/L
- Triglycerides: ............................................. <150 mg/dl
- Uric acid: .................................................. 4.1 to 7.0 mg/dl

Key to abbreviations:
- IU = international unit
- L = liter
- dl = deciliter = 0.1 liter
- g/dl = gram per deciliter
- mg = milligram
- mmol = millimole
- mEq = milliequivalents