

Lamnha's

Guide to USABO

Written by



Table of Contents

1. Introduction to USABO

1.1 What is USABO?

1.2 Why compete in USABO?

1.3 Competition Structure

1.4 Exam Topics

1.5 Getting Started with USABO

1.6 Other Competitions

2. Foundations & Strategy

2.1 Timeline

2.2 Effective Study Strategies

2.3 Exam Pacing

2.4 Common Mistakes

3. Study Resources

3.1 Textbook Recommendations

3.2 Practice Exams

3.3 Video Resources

3.4 Other Resources

4. Important Topics

4.1 Section Overview

4.2 Cell Biology

4.3 Genetics

4.4 Anatomy & Physiology

4.5 Plant Biology

4.6 Ethology

4.7 Ecology

4.8 Biosystematics

5. Practice Materials & Solutions

5.1 Practice Exam 1

5.2 Practice Exam 2

5.3 Solutions to Practice Exam 1

5.4 Solutions to Practice Exam 2

6. Conclusion

6.1 Concluding Thoughts

6.2 About Us

6.3 Author Credits

1. Introduction to USABO

1.1 What is USABO?

The USA Biology Olympiad (USABO) is a prestigious national biology competition challenging students with material far beyond the standard high school curriculum. It consists of three progressively more difficult rounds, with each exam assessing a wide range of biological material and knowledge.

1.2 Why Compete in USABO?

1. It helps you build a strong biological foundation. The exam has very challenging content, forcing you to apply a college-level understanding of biology.
2. You can gain national recognition. Performing well earns you prestigious awards and honors that can strengthen your college applications.
3. You can apply the biological knowledge learned in USABO to research opportunities and competitions, such as science fairs and internships.
4. Studying for USABO helps you to develop independent learning skills, due to the lack of an official curriculum or study guide.
5. Doing USABO connects you with similarly passionate and motivated students. You get to join an amazing community!

1.3 Competition Structure

- Opens Exam (early February):
 - Format: 50 multiple-choice questions (MCQs), each with five options and one correct answer. Each question is worth 1 point, totaling 50 points.
 - Duration: 50 minutes
 - Advancement: The top 10% of scorers advance to the semifinals.
- Semifinals Exam (late April):
 - Most years the format is similar, but not identical. The format discussed here will be the typical format.
 - Format: Divided into three parts, totaling 170 points.
 - * Part A: 60 MCQs (60 points). Each question consists of five options and one correct answer. Each question is worth one point.

- * Part B: 35 multiple true/false (MTF) questions (70 points). Each question includes four true/false statements graded as follows:
 - 0 or 1 correct: 0 points
 - 2 correct: 0.4 points
 - 3 correct: 1.2 points
 - 4 correct: 2 points
- * Part C: 4 free response questions (FRQs), worth 60 points total. Each individual question is worth 15 points, and each awards partial credit.
- Advancement: The top 20 scorers of the semifinals advance to the national finals.
- National Finals Training Camp & Exam (June):
 - Location: The training camp takes place at prestigious universities such as Harvard or MIT. It is 12 days long.
 - Curriculum: Students receive lectures from university professors and former national finalists, as well as practice lab techniques.
 - Format: At the end of the training camp, students take the final exam. It includes a theory section and a practical lab component. The exact format is not publicly released.
 - Advancement: The top 4 scorers of the final exam make team USA and compete in the International Biology Olympiad (IBO).

1.4 Exam Topics

The USABO covers a comprehensive range of biological topics. However, they can be approximately broken down as follows:

- Animal Anatomy & Physiology: 25%
- Cell Biology: 20%
- Genetics & Evolution: 20%
- Plant Anatomy & Physiology: 15%
- Ecology: 10%
- Ethology: 5%
- Biosystematics: 5%

1.5 Getting Started with USABO

Studying for USABO begins with building a strong foundation of knowledge through textbooks and videos, which are discussed more in-depth in section 3. Closer to the date of the opens or semis exam, the main focus becomes to do as many practice problems as possible to get used to the style of USABO questions. The official USABO organization (Center for Excellence in Education, CEE) has some resources, but none of them are up to par with the level of the exams.

This guide does **not** attempt to teach the entire USABO syllabus. Instead, it is designed to give you the groundwork to prepare most effectively. Here is an overview of the sections:

- Section 1: Overview of USABO and the exam structure
- Section 2: Effective learning methods and exam strategies
- Section 3: Curated list of resources, including books, videos, and question banks.
- Section 4: Breakdown of high-yield topics and where to study them.
- Section 5: Two full-length mock Open Exams with detailed solutions, plus 20 additional subject specific practice questions modeled on real USABO exams.

1.6 Other Competitions

In addition to the USABO, there are many other biology competitions that provide valuable practice and opportunities for awards. These competitions vary in format and difficulty, but share a focus on advanced biological knowledge and problem-solving.

- **British Biology Olympiad (BBO):**

- **Eligibility:** International students may participate in the Opens round.
- **Format:** The exam format is different from USABO, focusing more on logic and reasoning. It is generally considered easier than USABO.
- **Awards:**
 - * Gold Medal: Top 5%
 - * Silver Medal: Top 15%
 - * Bronze Medal: Top 30%
 - * Highly Commended: Top 45%

- * Commended: Top 60%

- **University of Toronto National Biology Competition (NBC):**

- **Eligibility:** Open to international students.
- **Format:** The competition closely mirrors the structure of the USABO Opens Exam, but features slightly easier questions.
- **Awards for International Students:**
 - * Biology Scholar with Distinction: Top 1%
 - * Biology Scholar: Top 5%

- **National Science Bowl (NSB):**

- **Eligibility:** Middle & High School
- **Format:** Team-based buzzer style competition. Although NSB features other subjects, the biology questions are good practice for USABO.
- **Awards:**
 - * Participation
 - * Regional
 - * National

- **United States Medicine and Disease Olympiad (USMDO):**

- **Eligibility:** Open to high school students.
- **Format:** This olympiad specifically focuses on anatomy and some cell biology topics. This competition is good practice for the USABO, as much of the anatomy knowledge needed for the USABO is covered by the USMDO.
- **Advancement:** The top 8 students qualify for the International Medicine and Disease Olympiad (USMDO).
- **Awards:**
 - * Honorable Mention
 - * Silver
 - * Gold
 - * IMDO qualification

- **Science Olympiad (SciOly):**

- **Format:** A team-based STEM competition for middle and high schoolers. There is a wide variety of events, and there are regional, state, and national tournaments.

- **Relevance to USABO:** The biology-related exam-based events have similar content to USABO.
 - * **Microbe Mission:** Strongly aligned with USABO's microbiology and cell biology content.
 - * **Anatomy & Physiology:** This is highly dependent on the systems that are being tested. Overall, USABO provides a solid foundation in physiology, but less so with anatomy.
 - * **Ecology:** USABO offers some preparation for this event. Additional practice with quantitative ecology problems and free-response style questions is recommended.
- Student-run competitions: These unofficial competitions are excellent for USABO-style practice and often provide detailed feedback, prizes, and a strong community of like-minded students.
 - **International Biology Bowl (IBB):**
 - * **Format:** A fast-paced, quizbowls style team competition available to both USA and international students. The competition format emphasizes quick recall, making it a fun alternative and break from USABO.
 - * **United States Biology Bowl (USABB):** This competition is run by the same people who run IBB, and is only available to US students.
 - **American Regional Biology Competition (ARBC):**
 - * This regional and national team-based competition consists of four rounds that test both USABO-related academic knowledge, and more applied, practical biology skills.
 - **Mitosisphere Monthly Challenge & $p + q = 1$ Exam Series:**
 - * Sponsored by our own organization! These challenges & exams are designed in the style of USABO, and are reviewed by experienced USABO competitors. Each exam includes a full, detailed solution key. Check out mitosisphere.org for more detailed information!
 - Monthly Challenge: A 15-question, 20 minute exam written each month. There are prizes for competitors who place in the top 3!
 - $p + q = 1$ Opens Exam: A USABO-style mock opens exam hosted biannually. The top competitors advance to the next round.

- $(p + q)^2 = 1$ Semifinal Exam: A USABO-style mock semifinals exam hosted biannually. The top competitors receive prizes and recognition!

2. Foundations & Strategy

2.1 Timeline

The timeline of USABO preparation largely depends on factors surrounding an individual's prior experience with USABO and goals within USABO. Here are a couple of example timelines for various situations (although your own situation will likely be different, try to adapt these timelines to your own circumstances and needs!)

Semifinals Qualification Timeline:

- Summer Break → Campbell's Biology
 - Understand and (attempt to) memorize much of the textbook.
- September to November → Reread Campbell's Biology
 - This time, focus on deep understanding and full memorization of the book's content.
- December to January → Practice Exams & Advanced Topics
 - Complete as many USABO Opens practice exams as possible.
 - * Aim to score comfortably (4-6 points) above the cutoff score.
 - * The day after completing an exam, review the problems you missed.
 - * If you are feeling up to it, try your hand at a few older USABO semis exams (don't waste the more modern ones until you are more confident.)
 - Study more advanced topics that are common in USABO and that interest you
 - * Dip your toes into more advanced topics such as Vander's Physiology and Brooker's Genetics.
 - * Study the important topics listed in Section 4.
- January to February → Final Review
 - * Review many of the foundational topics that you have learned earlier
 - * Finalize any problem solving techniques that you have learned in the past
 - * Devise a strategy for approaching the Opens exam

Finalist / Recognition of Academic Excellence (Top 50) / Honorable Mention (Top 125) Timeline:

If you are aiming for any kind of placement above semifinals, here is a more tailored and rigorous timeline.

- Summer Break → Campbell's Biology/Physiology Book
 - June to early July: Read Campbell's Biology fully and understand all topics.
 - * This can be done with note-taking, Anki, the Feynman technique, or other study methods.
 - Late July to August: Begin Vander's Physiology or Fox's Physiology
 - * These books build upon the physiology topics in Campbell's, and offer as much physiology knowledge as you will need to do well on the semifinals.
 - September to mid-November → Finish Physiology Book and Brooker's Genetics
 - * Finish reading and understanding the topics in your physiology book of choice, as these will dramatically increase your performance on the semifinals exam and are widely considered the most important textbook apart from Campbell's Biology.
 - * For Brooker's Genetics, memorization is not as important. Problem solving is much more so. Make sure you thoroughly review the problems at the end of each chapter. If you need extra problems, consider using the end of chapter problems in Griffith's Introduction to Genetic Analysis.
 - Mid-November to Early January → Finish memorizing and understanding Campbell's Biology
 - * This textbook is the most important to ensure that you excel on your Opens exam in February.
 - Early January to Opens exam → Review + Raven's Plant Biology
 - * Try to memorize and deeply understand as much of Vander's Physiology, Brooker's Genetics, and especially Campbell's in order to gain the intuition required to solve Semifinals problems as well as to securely pass Opens.
 - February to April → Deep Problem Solving + Review + Optional Readings
 - * During the months after Opens, your focus should be on problem solving and review of content you learned in the other textbooks. Make sure that you go through every past

Semifinals exam and even the IBO exams (to build up problem solving skills). Ensure that you note down any topics that show up on these exams that you have not already learned.

- * By this point, you should be extremely comfortable with all of the materials in the textbooks that you have read so far.
- * If you are interested, you may find reading Albert's Molecular Biology of the Cell, Lehninger's Biochemistry, and other advanced textbooks interesting. While these are not necessary to do well on Semifinals, they can help build your intuition, and can be fun to read amongst all the other review you're doing.
- * Do your own independent research on possible topics that could show up on the part C FRQ questions, ensuring that you know them extremely well.

An important point to note is the vast difference in time commitment between these two timelines. On average, in Timeline A, you will be spending around 30 minutes to an hour everyday studying for USABO. However, in Timeline B, you will be spending up to 2 hours per day, which may even increase as you get closer to the Semifinals Exam.

2.2 Effective Study Strategies

While there are many strategies that one can use to study, and the efficacy of each strategy varies on a case-by-case basis, here are a couple of strategies that have historically worked for individuals successful within Biology Olympiads.

- Note-taking
 - Note-taking actively engages the brain to encode, reinterpret, and explain information in an individual's own words.
 - * This is not an effective strategy if you simply copy down text from the textbook. You should write down notes in your own words.
 - When reviewing, you can either rewrite notes based off the information you don't remember from the textbook, or perform active recall strategies on your current notes.
 - Some people find writing notes on a digital document (i.e. Google Docs) is a more efficient strategy for them, while others find that handwriting notes helps boost retention. It is purely based on your preference, so you should give both a try!
- Flashcards (Anki)
 - Flashcards, specifically spaced-repetition technologies (i.e. Anki), are extraordinary at helping you retain and memorize information.

- It is the most consistent way to remember any given piece of information over a long period of time.
- A major con of Anki is that the memorization strategies it utilizes are rather association-based and “binary”. This can be partially circumvented by taking advantage of Anki extensions, such as Cloze Deletions and Image Occlusions.
- There is a 3-hour masterclass on YouTube that teaches you everything you need to know about Anki, give it a watch if you’re interested!
- Re-reading
 - Re-reading a textbook many times is a great way to understand concepts on a deeper level, rather than just superficially.
 - While many are skeptical of this method due to its lack of recall techniques, it is a tried-and-true method that has worked for many past national finalists.

2.3 Exam Pacing

Keep in mind that any tips presented in this section are most relevant to the 2025 USABO Opens & Semifinals Exams. This guide will receive periodic updates as new information is confirmed by CEE.

While exam pacing varies from person to person, a general guideline is the following:

- For Opens, you can qualify pretty easily without having much timed practice, as each question has 1 minute allotted for it. This should be more than enough time to complete the test.
- However, for Semifinals, where you get 120 minutes for varied types and amounts of questions, the time restriction places a much larger burden on the test taker. Thus, it is essential to integrate pacing when practicing for Semifinals, as time management is a common deficiency for many Semifinalists.
 - Section A (60 MCQs)
 - * You should be spending ~25-30 minutes on this section. While this may seem like very little, the questions on this section are much more superficial compared to the rest of the test, and are worth less points as a whole.
 - Section B (35 T/F with 4 parts per question)

- * You should be spending ~60 minutes on this portion. While this may seem like a lot, this section has lots of questions that require deep problem solving and graph-reading to interpret.
- Section C (4 FRQs)
 - * You should be spending ~25-30 minutes on this portion. This time should allow you to answer each question with sufficient depth.

Some people find that doing the sections in a different order helps them. A common strategy is to start with Section C, going to Section A, then ending with Section B. This way, you can get to the highest yield sections first, working through the harder sections with whatever time you have left. Another thing to consider is that ecology, ethology, plant biology, and biosystematics are typically located at the back of Section B, and are generally considered to be easier than other categories. For this reason, some people may find success in going through Section B backwards.

2.4 Common Mistakes

1. Cramming before the test
 - (a) Cramming before the test forces your brain to keep the things you only recently studied in your immediate memory, hurting your chances of remembering many fundamental topics.
2. Poor time management
 - (a) As was stated before, many students spend more time than required on Parts A and B, meticulously checking over every answer. While this may net them a couple of extra points, it leads them to often leave part C entirely blank, causing them to perform worse on the test as a whole. It is better to write something to get partial credit, than to leave a question completely blank.
3. Over-focusing on memorization
 - (a) While memorization and repeatedly scrolling through your endless pile of flashcards can make you confident in your recall abilities, the reality is that many of the obscure facts that you spent hours memorizing just won't show up on the test. Instead, you should focus on understanding concepts at a deeper level, so that you can "reason out" many of the Semifinals problems.
4. Reading the questions
 - (a) Many people have nicknamed the USABO the USARO (USA Reading Olympiad), which is quite fitting for how long some of the

prompts are. Here are some different strategies that can be effective for understanding questions without having to read the entire thing:

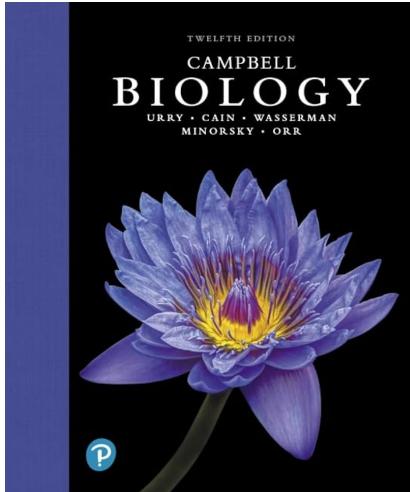
- i. Read backwards, starting with what the question is actually asking, then looking upwards to get context. Many USABO questions rely on a trap, or a trick, which if you recognize early, you can exploit to get the answer without having to comprehend the entire question.
- ii. Quickly reading over the first bit of the question. Much of this information is typically context, or background information, which is not useful to understanding the question.
- iii. Building intuition about what the question writers are looking to test. At some point, you will have become so accustomed to the style of USABO questions that you can get a large number of questions correct without even reading the question. This intuition can be extremely helpful when you are short on time, especially on Semis.

3. Study Resources

3.1 Textbook Recommendations

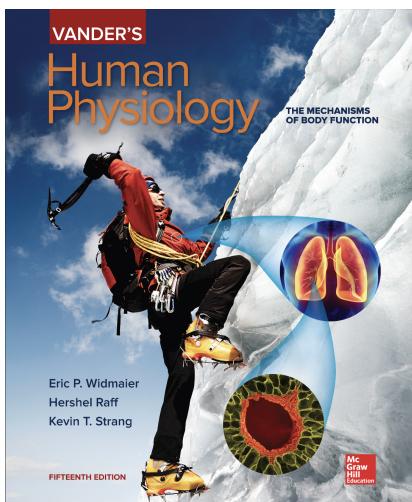
The following textbooks are our recommendations, and although there are alternatives, in our opinion, these are the most useful to study.

Campbell's Biology



Campbell's is like the Bible of USABO. Before you move onto ANY other textbook, it is highly recommended that you have a firm grasp on this text. Campbell's covers everything you need for the Opens exam. While it may feel slow, or even pointless, to try and learn all of Campbell's, it is by far the highest yield textbook in regards to USABO. Only after you feel 100% confident that you have mastered this text should you move on to more in-depth books. Here is a question bank for Campbell's separated by chapter: [Link](#)

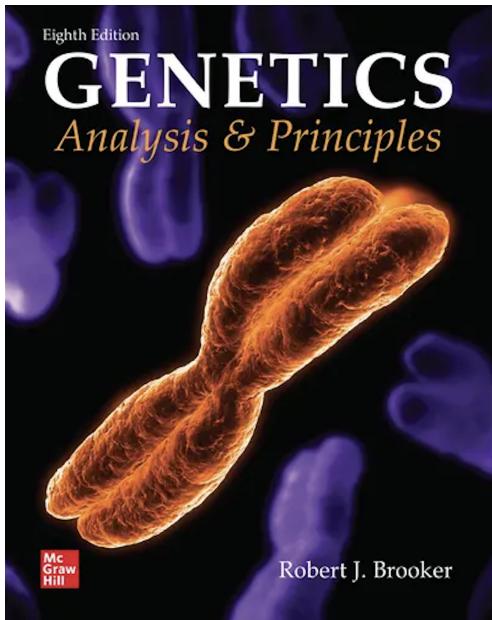
Vander's Human Physiology



Vander's Human Physiology covers all systems of the human body that are required for USABO. (Note that this text does not cover the integumentary system, however this rarely, if ever, shows up on USABO). Vander's Human Physiology is a dense textbook and covers a large volume of material. Its explanations are very thorough, and for the most part, not too difficult to understand. In theory, Vander's should be adequate for nearly all USABO questions, however, it should be kept in mind that USABO is well known for asking for very obscure facts quite often. For USABO, the most important chapters are Chapters 6-18. Chapters 1-5 cover basics of cell physiology that you ideally should have learned previous to diving into Vander's.

The alternative to this textbook is Fox's Human Physiology, and some people prefer this book over Vander's. This really comes down to preference, but either textbook is suitable for USABO and there is a large amount of overlap.

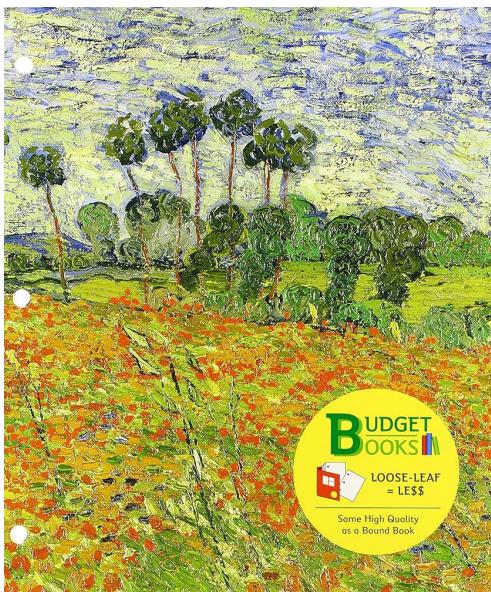
Brooker's Genetics: Analysis and Principles



Brooker's Genetics is a widely used textbook that introduces the fundamental concepts of genetics, from classical Mendelian inheritance to modern molecular genetics. It covers key topics such as DNA structure, gene expression, genetic variation, and the application of genetics in biotechnology and medicine. The book emphasizes problem solving and critical thinking, with numerous examples, figures, and exercises. It also integrates recent advances in genomics. It is important to note that textbooks like Brooker's go very heavy into the molecular side of things; it is not necessary to memorize extremely niche details. You should still read these parts carefully and attempt to understand these systems, but it's more important that you understand the ideas behind them.

The alternative to this textbook is Griffith's Introduction to Genetic Investigation. That book has many practice problems that are better suited to USABO. If you already have a strong foundation in molecular genetics, consider using this textbook instead.

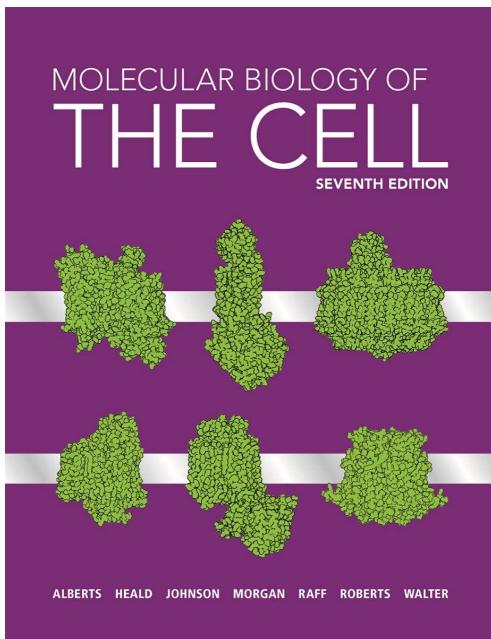
Raven's Plant Biology



Raven's plant biology is a comprehensive textbook that explores the structure, function, growth, reproduction, and evolution of plants. It emphasizes the molecular and cellular processes underlying plant physiology, along with ecological and environmental interactions. It covers important topics like photosynthesis, plant hormones, and plant biotechnology in an in-depth fashion. For USABO, the highest yield chapters are the angiosperm chapters (20s-30s). Note that this textbook is older, so some of the plant systematics chapters may be outdated.

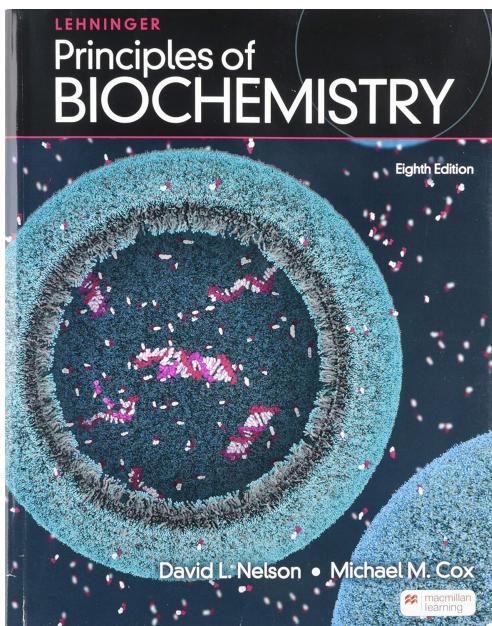
The alternative to this textbook is Taiz's Plant Physiology. This is the only other textbook that is really relevant towards USABO, however, it focuses a lot more on the molecular side of plant physiology and is simply not very high yield for USABO.

Alberts' Molecular Biology of the Cell



Albert's Molecular Biology of the Cell is a foundational textbook that explains the molecular mechanisms underlying cell structure, function, and regulation. It covers key topics such as gene expression, cell signaling, membrane dynamics, the cytoskeleton, and the cell cycle. The book emphasizes how molecular interactions drive complex cellular behaviors, supported by detailed diagrams and up-to-date research. Note that this textbook is very dense and advanced. It is likely not worth it for most people to ever use this book.

Lehninger's Principles of Biochemistry



Lehninger's Principles of Biochemistry is a classic textbook that provides a thorough introduction to the molecular basis of life, focusing on the structure and function of biomolecules. It covers essential topics such as enzyme kinetics, metabolism, bioenergetics, and molecular biology, with a strong emphasis on biochemical principles. Note that biochemistry itself is not a directly tested topic on USABO, however, it does show up in cell biology, genetics, and physiology. Understanding biochemistry can help with contextualization and understanding of many biological processes in application, but it should not be seen as a priority above more fundamental ideas.

3.2 Practice Exams

The best preparation strategy for USABO, other than reading textbooks, is gaining experience in applying your knowledge. You can do this through practice problems. While textbook problems may be helpful in testing whether you can retain information, Olympiad problems will prepare you in applying that knowledge in more complex ways. This is essential to USABO prep.

Below, we have compiled a list to a large bank of practice exams that will be helpful in preparing you for the type of thinking required to do well on USABO.

1. [USABO past exams](#)
2. [International Biology Olympiad past exams](#)
3. [British Biology Olympiad past exams](#)
4. [Indian National Biology Olympiad past exams](#)
5. [University of Toronto National Biology Competition past exams](#)

Note that past USABO exams are limited, and it is in your best interest to save those until you feel comfortable with the material that you have learned from the textbooks.

3.3 Video Resources

Watching videos is an excellent way to reinforce your understanding of complex biological concepts, especially when visual explanations are more effective than text-based ones. Videos can help you review efficiently, clarify confusing topics, and make connections between different areas of biology. Channels like Cararra, Shomu's Biology, Mito's Bio, Patricia Peng, Ninja Nerd, AK Lectures, MIT OpenCourseWare Introduction to Biology & Introduction to Genetics, and Nikolay's Genetics lessons are great resources to reinforce understanding of concepts.

3.4 Other Resources

- **An Introduction to Genetic Analysis** by Anthony Griffiths
- **Human Physiology** by Stuart Fox
- **Physiology** by Linda Costanzo
- **Human Physiology: From Cells to Systems** by Lauralee Sherwood
- **Human Physiology and Anatomy** by Elaine Marieb
- **Plant Physiology** by Lincoln Taiz

- **Elements of Ecology** by Thomas Smith

Please note that you do not need to read all the anatomy and physiology books! Just pick one or two that you think will actually teach you new information, or help you solidify old knowledge.

We have also prepared a Quizlet set with some USABO textbooks, along with other random USABO topics. You can access it here: [Link](#)

This is a student-run biology guide focused on teaching content, it has some useful handouts to review important concepts the weeks before Opens/Semis: [Link](#)

4. Important Topics

4.1 Overview

The following section outlines many of the most important topics that commonly appear on the USABO Opens and Semifinals exams that you should pay attention to during your reading. These topics were curated after many rounds of review and were informed using data from recent Opens and Semifinals exams. Each topic has details about what to focus on, and sometimes has an additional comment. We will use the following rating system for each topic:

- **5/5** - Core Topic: Absolutely essential, appears on nearly every exam.
- **4/5** - High Priority: Very common and heavily weighted on exams.
- **3/5** - Moderately Important: Appears regularly but may be more context-dependent.
- **2/5** - Background Knowledge: Adds context and depth but unlikely to be the focus.
- **1/5** - Low Yield: Very rarely tested; unlikely to be worth prioritizing.
- ***** - Fundamental: Essential to knowing other topics, but may not be tested directly.

The following abbreviations will also be used for textbook resources where you can find the topic:

- Campbell's Biology: Campbell's
- Albert's Molecular Biology of the Cell: MBOC
- Vander's Human Anatomy and Physiology: Vander's
- Brooker's Genetics: Brooker's
- Raven's Biology of Plants: Raven's

4.2 Cell Biology

I. The Cell

- **Types of solute movement**

- Active transport, passive transport, diffusion, osmosis, bulk diffusion, cotransport, symport, antiport
 - **4/5***
 - Campbell's 7.1-7.2, MBOC 11

- **Organelles**
 - Function, histology, prevalence in different cells
 - **3/5***
 - Campbell's 6, MBOC 12, 14, 16
- **Cell membranes**
 - Composition, integrated proteins, fluidity modifiers
 - **3/5***
 - Campbell's 7, MBOC 10
- **Cell degradation pathways**
 - Ubiquination, lysosomal, autophagy
 - **2/5**
 - MBOC 3, 6
- **Cell-cell junctions**
 - Desmosomes, tight junctions, adherens junctions, gap junctions, plasmodesmata
 - **2/5**
 - MBOC 19

- **Intracellular transport**

- 1/5
- MBOC 13

II. Macromolecules

- **Amino acids**
 - Structure, properties, 1 & 3 letter abbreviations
 - **5/5***
 - Campbell's 7.3-7.5
- **Protein folding**
 - Primary, secondary, tertiary, and quaternary structures
 - **2/5***
 - Campbell's 5.4, MBOC 3

- **Carbohydrates**
 - Structure, formulas
 - **2/5***
 - Campbell's 5.2
- **Nucleic acids**
 - Structure, bonding
 - **2/5***
 - Campbell's 5.5, MBOC 3

- **Polymer synthesis**

- 1/5*
 - Campbell's 5.1

- **Lipids**

- Structure
 - 1/5*
 - Campbell's 5.3

- **Protein motifs**

- 1/5
 - MBOC 7

III. Biochemistry

- **Enzymes**

- Kinetics, inhibition, specificity, lock/key & induced fit models, activation energy, ribozymes
 - **5/5**
 - Campbell's 8.3-8.4, MBOC 2-3, 6

- **Functional groups**

- Name, composition, properties
 - **3/5***
 - Campbell's 4.3

- **Molecular bonds**

- Covalent, hydrogen, ionic, peptide, glycoside
- **2/5***
- Campbell's 2.3-3.1, MBOC 2

- **Acids & Bases**

- pH calculations, H⁺ & OH⁻ concentration, Henderson-Hasselbach equation
- **2/5**
- Campbell's 3.3, [Microbe Notes](#)

- **Properties of water**

- Cohesion, adhesion, transpiration, high specific heat
- 1/5
- Campbell's 3.1-3.2

- **Gibbs' free energy**

- Entropy, enthalpy, equilibrium
- 1/5
- Campbell's 8.1

- **The atom**

- Electrons, valence, neutrons & protons, isotopes, nucleus
- 1/5
- Campbell's 2.2

- **Isomers**

- Calculating stereoisomers, stereocenters
- 1/5
- Campbell's 4.2

IV. Central Dogma

- **Types of RNA**

- lncRNA, siRNA, piRNA, miRNA, snRNA
- **3/5**
- Campbell's 18.3, MBOC 7

- **Post-transcriptional modifications**

- mRNA splicing, polyA tail
- 3/5
- Campbell's 17.3, MBOC 6

- **Transcription**

- Proteins involved, transcription factors, steps
- 2/5*
- Campbell's 17.2, MBOC 6

- **Translation**

- tRNA, wobble pairing, ribosomal subunits, APE sites, steps
- 2/5*
- Campbell's 17.4, MBOC 6

- **Cell division**

- Steps, molecules involved, different methods
- 2/5*
- Campbell's 12, MBOC 17

- **Meiosis**

- Steps, homologous recombination, independent assortment
- 2/5*
- Campbell's 13

- **Cancer**

- Checkpoints, proto-oncogenes, tumor suppressor genes
- 2/5
- Campbell's 12.3, MBOC 20-21

- **Post-translational modifications**

- Localization, phosphorylation, glycosylation, lipidation, bonding
- 2/5
- Campbell's 17.4

V. DNA

- **Chromosomes**

- Euchromatin/heterochromatin, histones, gene expression modification
- **3/5***
- Campbell's 16.3, MBOC 4

- **Gene Expression Control**

- Operons, transcriptional regulators
- **3/5***
- Campbell's 18, MBOC 7

- **Mutations**

- Point, frameshift, de novo, hereditary
- **2/5***
- Campbell's 16, Brooker's 8

- **Replication**

- Models (semi-conservative, conservative, dispersive), proteins involved, steps
- **2/5***
- Campbell's 16.2, MBOC 5

- **DNA repair mechanisms**

- Non-homologous end-joining, homologous recombination, direct reversal, base excision repair, nucleotide excision repair, mismatch repair, translesion synthesis
- **2/5**
- Campbell's 16.2, MBOC 5

VI. Signaling Pathways

- **Secondary messengers**

- **3/5***
- Campbell's 11.3

- **Surface receptors**
 - GPCR, RTK, ion gated channels
 - **2/5***
 - Campbell's 11.2, MBOC 15
 - **Apoptosis**
 - Molecules, pathway in humans, fruit fly
 - **2/5**
 - Campbell's 11.5, MBOC 18
- VII. Cell Metabolism**
- **Electron transport chain (ETC)**
 - Total ATP produced, ATP per FADH₂/NADH₂, Complexes, ATP synthase parts, common inhibitors of ETC.
 - **5/5***
 - Campbell's 9.4, MBOC 2
 - **Glycolysis**
 - Total ATP/NADPH produced, steps (enzymes, substrates, ATP produced, reversible/irreversible), location
 - **3/5***
 - Campbell's 9.2, MBOC 2
 - **Kreb's cycle**
 - Total ATP/NADPH/FADH₂ produced, steps (enzymes, substrates, ATP/NADH produced, reversible/irreversible), location
 - **3/5***
 - Campbell's 9.3, MBOC 2
 - **Photosynthesis**
 - Light dependent reactions, light independent reactions, electron carriers, steps, PS1/PS2, cyclic/non-cyclic, RuBisCo (C₃), PEPase (C₄/CAM)
 - **2/5***
 - Campbell's 10

- **Polymer Metabolism**
 - Carbohydrate, lipid, amino acid, protein
 - 2/5
 - Vander's 3
- Redox Reactions
 - 2/5
 - Campbell's 9.1

VIII. Biotechnology

- **Gel Electrophoresis**
 - 4/5*
 - Campbell's 20.1, MBOC 8
- **SDS page**
 - 4/5*
 - MBOC 8, [Wikipedia](#)
- **Blotting**
 - Southern, Western, Northern
 - 4/5
 - [Wikipedia](#)
- **PCR**
 - 4/5
 - Campbell's 20.1, MBOC 8
- **Chromatography**
 - Cation exchange, anion exchange, size exclusion, affinity
 - 3/5
 - MBOC 8
- **Centrifugation**
 - 2/5*
 - MBOC 8

- **Cloning**
 - DNA, whole organism
 - 2/5
 - Campbell's 20.3, MBOC 8
- **RNAi**
 - siRNA, miRNA
 - 2/5
 - MBOC 8
- **In situ hybridization**
 - 2/5
 - MBOC 8
- **Mass spectrometry**
 - 1/5
 - MBOC 8
- **Model organisms**
 - E. Coli, D. Melanogaster, C. Elegans
 - 1/5
 - MBOC 8
- **Microscopes**
 - 1/5
 - Campbell 6.1, MBOC 9
- **Stem cells**
 - 1/5
 - MBOC 22

4.3 Genetics

Inheritance

- Mendelian Inheritance

- Punnett squares, law of independent assortment, law of segregation
- $\textcolor{brown}{5}/\textcolor{red}{5}^*$
- Campbell's 14

- Non-Mendelian Inheritance

- Incomplete dominance, codominance, maternal effect
- $\textcolor{brown}{4}/\textcolor{orange}{5}^*$
- Brooker's 5

- Epistasis

- Dominant & Recessive epistasis ratios
- $\textcolor{teal}{2}/\textcolor{blue}{5}$
- $\textcolor{violet}{Scitable}$

Gene Linkage/Recombination

- Recombination and Chromosomal Alterations

- Recombination Frequency, Deletions, Translocations, etc...
- $\textcolor{brown}{4}/\textcolor{orange}{5}^*$
- Brooker's 6, 8

- Complementation

- $\textcolor{brown}{3}/\textcolor{teal}{5}$
- MIT video $\textcolor{violet}{part 1}$ & $\textcolor{violet}{part 2}$

- Transposition

- $\textcolor{teal}{2}/\textcolor{blue}{5}$
- Brooker's 10

Population Genetics

- Hardy-Weinberg

- Equilibrium & Equations
- $\textcolor{brown}{5}/\textcolor{red}{5}^*$
- Campbell's 23

- **Evolution**
 - 3/5
 - Campbell's 24-25
- **Genetic Variation**
 - Natural selection, genetic drift, etc...
 - 3/5
 - Campbell's 23
- **Fitness, selection coefficients, mutation rates**
 - 2/5
 - Brooker's 27
- **Phylogeny**
 - 1/5
 - Campbell's 23

Phylogenetics

- **Cladograms**
 - Features, information
 - 3/5
 - Campbell's 26
- **Evolutionary characteristics**
 - Homoplasy, symplesiomorphy, autapomorphy, synapomorphy
 - 2/5
 - Nikolay's Genetics

Viruses

- **Vaccines & antivirals**
 - 3/5
 - PMC link
- **Viral structure/function**
 - Viral proteins, structures
 - 2/5*
 - Campbell's 19

- **Lytic/lysogenic cycle**
 - 1/5
 - Campbell's 19, Brooker's 18
- **cro/cII interaction**
 - Brooker's 18.3
 - 1/5

Bacteria

- Conjugation/transduction/transformation
 - 2/5*
 - [Khan Academy Link](#)
- Plasmids
 - Use/structure of plasmid vectors
 - 1/5
 - Brooker's 21

Other Important Genetics Topics

- **Pedigree analysis**
 - Identifying autosomal/recessive/sex-linked/mitochondrial
 - 4/5*
 - [CMU link](#)
- **Hamilton's Rule**
 - 4/5*
 - [GeeksforGeeks link](#)
- **Meiosis**
 - Stages, crossing over, independent assortment
 - 2/5*
 - Campbell's 13

4.4 Anatomy & Physiology

Tissue Types

- Campbell's 40
- Compare and contrast characteristics
 - 3/5
- Histology
 - 2/5

Muscular System

- Campbell's 50, Vander's 9
- Excitation-contraction coupling
 - Steps
 - 4/5
- Contraction mechanisms
 - 3/5*
- Skeletal muscle structure
 - 3/5
- Calcium regulation
 - 3/5
- Fiber types
 - 2/5*
- Bone physiology
 - 2/5

Cardiovascular System

- Campbell's 42, Vander's 12
- Cardiac cycle
 - 3/5
- Heart structure & function
 - 2/5
- Vascular system
 - 2/5

- Blood flow mechanisms
 - 2/5
- Electrical conduction system
 - 2/5
- Coagulation cascade
 - 1/5

Respiratory system

- Campbell's 42, Vander's 13
- Anatomy of respiratory system
 - 4/5*
- Hemoglobin & oxygen transport
 - 4/5
- Gas exchange principles
 - 3/5
- Oxygen-hemoglobin dissociation curve
 - 3/5
- CO₂ homeostasis & transport
 - 3/5
- Neural control of breathing
 - 2/5

Nervous system

- Vander's 6
- Action potentials
 - 5/5*
- Neuronal physiology
 - 4/5
- Neurotransmitters
 - 4/5
- Synaptic transmission
 - 3/5

- Brain anatomy & physiology
 - 3/5
- Peripheral nervous system anatomy
 - 2/5

Sensory System

- Campbell's {x}, Vander's 7
- Vision
 - 4/5*
- Sensory system transduction
 - 4/5*
- Vestibular & auditory systems
 - 4/5
- Sensory pathways (integration)
 - 3/5
- Olfaction (smell)
 - 2/5
- Gustation (taste)
 - 2/5
- Sensory system disorders
 - 2/5

Endocrine System

- Campbell's 45, Vander's 11
- Endocrine structures
 - Pituitary gland, hypothalamus, adrenal glands, testes, ovaries, pancreas, thyroid gland, parathyroid gland, etc...
 - 4/5*
- Major hormones
 - Cortisol, epinephrine, aldosterone, insulin, glucagon, T3, T4, parathyroid hormone, etc...
 - 4/5*

- Hormone types & signaling mechanisms
 - Peptide, steroid, amine hormones; membrane vs intracellular receptors
 - 3/5*
- Endocrine disorders
 - Thyroid/parathyroid/pituitary disorders, Cushing's syndrome, Addison's disease, Type I & II diabetes mellitus
 - 3/5*
- Hormonal regulation & feedback loops
 - Negative feedback, positive feedback, axis control (e.g. HPA, HPT)
 - 2/5
- Endocrine homeostasis
 - Regulation of metabolism, glucose, calcium, etc...
 - 1/5

Digestive System

- Vander's 15
- GI tract anatomy & function
 - 3/5
- Enzymatic secretion & digestion
 - 3/5
- Absorption mechanisms
 - 3/5
- Liver & pancreas functions
 - 3/5
- Hormonal regulation of digestion
 - 2/5

Urinary System

- Vander's 14
- Nephron structure & basic function
 - 4/5*

- Glomerular filtration
 - 3/5
- Tubular reabsorption & secretion
 - 3/5
- Countercurrent multiplication & water balance
 - 3/5
- Electrolyte balance
 - 3/5
- Acid-base regulation
 - 3/5
- Nitrogenous waste types & excretion
 - 2/5

Reproductive System

- Vander's 17
- Male & female reproductive anatomy, hormonal regulation, spermatogenesis, gametogenesis, menstrual cycle
 - 2/5

Immune System

- Vander's 18
- Adaptive & innate immunity, lymphocytes, T-lymphocytes, immune responses
 - 4/5*
- Cell lineage of immune cells, natural killer cells, lymphatic system anatomy and physiology, autoimmune responses, toll and toll-like receptors
 - 3/5

Non-human anatomy

- Campbell's 33, 44
- Non-human urinary systems, non-human alimentary canals, non-human circulatory systems
 - 3/5

4.5 Plant Biology

Plant Structure

- **Plant cells**

- Special organelles
 - * 4/5*
 - * Campbell's 6, Raven's 2
- Water pressure & turgidity
 - * 3/5
 - * Campbell's 36, Raven's 3

- **Plant tissues**

- Vascular tissue
 - * Xylem, phloem
 - * 5/5
 - * Campbell's 35, Raven's 21
- Dermal tissue
 - * 3/5
 - * Campbell's 35, Raven's 21
- Ground tissue
 - * 3/5
 - * Campbell's 35, Raven's 23

- **Roots**

- 4/5
- Campbell's 35 Raven's 24

- **Shoots**

- 4/5
- Campbell's 35, Raven's 23, 25

- **Reproductive structures**

- Sepals, stamens, carpels, petals
 - * 4/5
 - * Campbell's 38, Raven's 19

- **Fruits, seeds**

- 3/5*

- * Campbell's 38, Raven's 19

- Flower genes

- * ABCDE hypothesis

- 3/5

- * Campbell's 35, Raven's 19

- Pollen

- * 2/5

- * Campbell's 38, Raven's 20

- **Monocots vs. dicots**

- 4/5

- Campbell's 30, 35, Raven's 19, 21-25

Plant Function

- **Nutrient, water, gas transport**

- Xylem/phloem

- * 5/5

- * Campbell's 35, Raven's 21

- Transpiration & root pressure

- * 4/5*

- * Campbell's 36, Raven's 4

- Stomatal regulation & guard cells

- * 3/5*

- * Campbell's 36, Raven's 25

- **Plant growth, development, reproduction**

- Double fertilization

- * 3/5

- * Campbell's 38, Raven's 20

- Primary/secondary growth

- * 2/5

- * Campbell's 35, 36, Raven's 23, 24, 25

- Pollination
 - * 2/5
 - * Campbell's 38, Raven's 20

- **Plant hormones**

- Auxin, cytokinins, gibberellins, abscisic acid, ethylene, salicylic acid, jasmonic acid, brassinosteroids
- 5/5
- Campbell's 39, Raven's 26

- **Plant responses**

- Campbell's 39, Raven's 27, 31
- Tropisms & nastic movements, flowering and photoperiodism
 - * 3/5
- Abiotic stress responses, plant immunology
 - * 2/5

4.6 Ethology

- Behavior

- Learning, imprinting, foraging, cognition, innate
- 4/5*
- Campbell's 51.2, [Pandorax link](#)

- Courtship

- Mate choice, monogamous/polygamous, sexual dimorphism
- 4/5
- Campbell's 51.3

- Fixed action patterns

- 3/5*
- Campbell's 51.3

- Biological rhythms

- Circadian, seasonal (hibernation and estivation), reproductive cycles
- 3/5*
- Campbell's 51.1

- Operant & classical conditioning

- 3/5
- [Khan Academy link](#)

- Communication

- Pheromones, bee waggle dance
- 3/5
- Campbell's 51.1

- Altruism, kin selection

- 2/5
- [Pandorax link](#)

- Game theory

- 1/5
- Campbell's 51.3

4.7 Ecology

Population Ecology

- K-selection vs. r-selection

- 4/5*
 - Campbell's 53

- Type of dispersion

- Clumped, random, uniform
 - 3/5*
 - Campbell's 53

- Survivorship curves

- Types I, II, III
 - 3/5*
 - Campbell's 53

- Logistic & Exponential Growth

- Formulas
 - 3/5*
 - Campbell's 53

- Density-dependent vs. density-independent factors

- 3/5*
 - Campbell's 53

- Extinction vortex

- 3/5*
 - Campbell's 53

- MVP (minimum viable population)

- 2/5*
 - Campbell's 53

- Effective population size (N_e)

- Formulas
 - 2/5
 - Campbell's 53

Community Ecology

- **Interspecific relationships**

- Predation, mutualism, competition, etc...
- **4/5***
- Campbell's 54

- **Shannon's diversity index**

- Formula
- **4/5***
- Campbell's 54

- **Ecological succession**

- **2/5***
- Campbell's 54

Ecosystem ecology & energy flow

- **Biogeochemical cycles**

- Water, carbon, phosphorus, nitrogen
- **3/5***
- Campbell's 55

- **Primary production and energy flow**

- GPP, NPP, NEP
- **3/5***
- Campbell's 55

- **Trophic levels & energy transfer**

- **2/5***
- Campbell's 55

- **Tropical vs. Temperate Ecosystems**

- **1/5**
- Campbells 52, 55

Global Ecology

- **Biomes**

- Temperate rainforest, tundra, savanna, etc...
- **4/5**
- Campbell's 52

- **Marine zonation**

- **3/5**
- Campbell's 52

- **Gyres and currents**

- Indian Ocean, South Atlantic Ocean subtropical gyres
- **2/5**
- Campbell's 52

- **Lake cycling**

- **2/5**
- Campbell's 52

- **Ozone depletion**

- **1/5**
- Campbell's 56

4.8 Biosystematics

Fungi

- Campbell's 31
- Heterotrophy, mycelia/hyphae networks, asexual & sexual lifecycles, heterokaryotic stages, key characteristics of different fungal phylums, lichen
- **Ascomycota**
 - 3/5*
- **Basidiomycota**
 - 3/5*
- **Cryptomycota, microsporidia, chytridiomycota, zoopagomycota, mucuromycota**
 - 1/5

Animals

- **Embryonic development**
 - Protostome vs. deuterostome, cleavages (determinate vs. indeterminate), animal vs. vegetal pole, coelom formation, gastrulation (in chicken/human/frog)
 - 4/5
 - Campbell's 32
- **Classification**
 - Taxon, phylogenetic tree/cladograms, examples
 - 3/5
 - Campbell's 26
- **Invertebrates**
 - Symmetry, body plan, tissues & germ layers, coelom
 - 3/5
 - Campbell's 33

- **Vertebrates**

- Derived traits of chordates (notochord + dorsal nerve chord), vertebratesgnathostomes, tetrapods, amniotes, mammalian diversity (perissodactyla vs cetartiodactyla)
- 2/5
- Campbell's 33

Plants

- Campbell's 29, 30
- Evolution from charophytes, derived traits and diversification
 - 3/5

- **Non-vascular**

- Bryophytes (mosses)
 - * 4/5*
- Hepatophytes (liverworts)
 - * 3/5
- Anthocerophytes (hornworts)
 - * 3/5

- **Vascular seedless**

- Monilophytes (ferns)
 - * 4/5*
- Lycophytes (club mosses)
 - * 3/5

- **Vascular plants**

- Angiosperms
 - * Life cycle, monocot vs. dicot classification
 - * 5/5*
- Sporophytes vs. gametophytes
 - * 4/5
- Gymnosperms
 - * Life cycle, phyla
 - * 4/5

- Plant families

– 3/5

Bacteria/Archaea

- Campbell's 27

- Bacteria

– Cyanobacteria

* 4/5*

– Gram positive bacteria

* 4/5

– Gram stain experiment, transformation & transduction, conjugation & plasmids, F factor, R plasmid, nitrogen fixation, antibiotics

* 3/5

– Proteobacteria & Spirochetes (heterotroph)

* 3/5

– Chlamydias (parasites)

* 3/5

- Symbiotic relationships

– Mutualism, commensalism, parasitism, ammensalism

– 5/5

- Archaea

– Extremophile nature

– 2/5

Protists

- Campbell's 28

- Alternation of generations, key subgroups

• 1/5

Endosymbiosis

- Campbell's 28

- Process, evidence

- Primary endosymbiosis (mitochondria)

– 5/5

- Secondary endosymbiosis (chloroplasts)
 - 5/5
- Tertiary endosymbiosis
 - 1/5*

Evolutionary & Phylogenetic Relationships

- Campbell's 26
- Hierarchy of classification
 - Domain, kingdom, phyla, class, order, family, genus, species
 - 3/5
- Analogous vs. Homologous traits
 - 3/5*
- Binomial nomenclature
 - 2/5*
- Monophyletic vs. paraphyletic vs. polyphyletic clades
 - 2/5
- Maximum parsimony, maximum likelihood
 - 1/5*

5. Practice Materials & Solutions

This section contains 2 full length practice Opens exams created by Mitosisphere, as well as 160 additional questions for the 8 USABO topics (20 questions each). There is also a full solution key for each question, in addition to difficulty rankings for the additional questions. You can click on any question's text, and it will take you to the solution for that question, and vice versa. Some questions are based on memorization, while others are based more on critical thinking. We hope these resources will be helpful for you!

Quick Links:

[Opens Exam 1](#)

[Opens Exam 2](#)

Topic Specific Questions:

- Anatomy & Physiology
- Cell Biology
- Genetics
- Plant Biology
- Genetics
- Ecology
- Ethology
- Biosystematics

[Solutions to Opens Exam 1](#)

[Solutions to Opens Exam 2](#)

Topic Specific Question Solutions:

- Anatomy & Physiology
- Cell Biology
- Genetics
- Plant Biology
- Genetics
- Ecology
- Ethology
- Biosystematics

5.1 Opens Exam 1

1. Isoprene, a talented biologist, wants to study the development of a newly discovered species called J. iggle. He engineers cells of the endoderm to express a foreign kanamycin resistance gene. If J. iggle develops similarly to humans, which of the following structures would be least expected to express the kanamycin resistance gene?
 - (a) Follicles of the thyroid gland
 - (b) White pulp of the spleen
 - (c) Hepatic lobules of the liver
 - (d) Acinar cells of the pancreas
 - (e) Epithelial lining of the terminal bronchioles
2. Which of the following is true regarding hormones of the menstrual cycle?

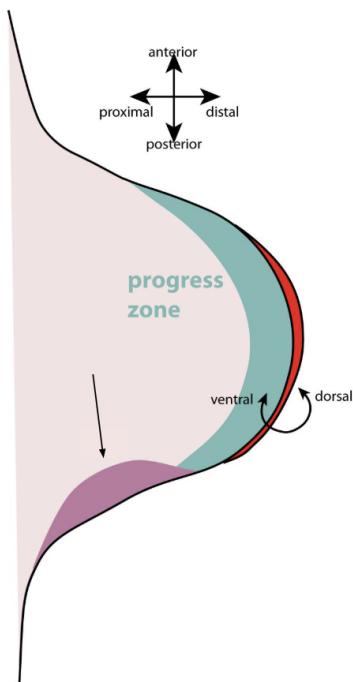


- (a) In the first week of the menstrual cycle, substance 1 directly stimulates cells to secrete substance 3.
 - (b) At high concentrations, substance 3 inhibits the release of substance 1 and substance 2.
 - (c) Substance 4 is synthesized from testosterone by the action of aromatase.
 - (d) Substance 1 is secreted from the hypothalamus and substance 2 is secreted from the anterior pituitary.
 - (e) Substance 3 increases the expression of receptors for substance 4 in some of its target cells.
3. Delphy has been locked in for USABO. In fact, he has read so many textbooks that he starts to wonder how his eyes work in the first place. Help Delphy determine the true statement below.
 - (a) Müller cells are glial cells that help photoreceptor cells maximize light absorption.
 - (b) Nearsightedness can be corrected by convex lenses.
 - (c) The fovea contains a high concentration of rods.

- (d) A rod with inactive rhodopsin molecules would not allow Na^+ to enter it.
- (e) Retinal is a derivative of Vitamin C.
4. A Spanish student was doing a comedy skit when they suddenly fell off the third story and damaged their brain. Afterwards, they had difficulty comprehending language but were able to speak words fine. Which of the following areas were damaged during the fall, and which location correctly corresponds to this region?
- (a) Wernicke's area, parietal lobe
- (b) Wernicke's area, temporal lobe
- (c) Wernicke's area, occipital lobe
- (d) Broca's area, parietal lobe
- (e) Broca's area, temporal lobe
5. Bhuvan was lifting weights in the gym (unexpectedly). As he did so, he wondered which type of molecular mechanisms were at work in his musculoskeletal system. Which of the following is correct?
- (a) Skeletal muscle: Dense bodies, which are mostly made of anchoring proteins, are important here.
- (b) Cardiac muscle: Desmosomes in intercalated disks are responsible for the synchronized contraction of the heart.
- (c) Skeletal muscle: Creatine phosphate is the primary source of energy for longer aerobic exercises here.
- (d) Skeletal muscle: Binding of ATP to myosin causes its disassociation from actin.
- (e) Smooth muscle: The DHP receptor is connected to the ryanodine receptor through foot proteins, thus releasing Ca^{2+} from the sarcoplasmic reticulum.
6. Which of the following would be MOST LIKELY to induce hypokalemia (low K^+) in an adult human?
- (a) Usage of triamterene, a diuretic that decreases sodium reabsorption in the cortical collecting duct.
- (b) Increased activity of H^+/K^+ ATPases throughout the renal tubule in response to moderate ketoacidosis.
- (c) Administration of enalapril, an ACE inhibitor, due to hypertension.

- (d) Usage of furosemide, a diuretic that decreases sodium reabsorption in the loop of Henle.
- (e) Partial death of juxtaglomerular cells due to the ingestion of a toxin.
7. Which of the following incorrectly pairs an animal with their type of cleavage and blocks to polyspermy?
- | | | |
|---------------|------------|----------------------|
| A. Seagull | Slow block | Meroblastic cleavage |
| B. Sea urchin | Fast block | Holoblastic cleavage |
| C. Lizard | Slow block | Meroblastic cleavage |
| D. Human | Slow block | Holoblastic cleavage |
| E. Beetle | Slow block | Holoblastic cleavage |
8. Uh oh! Isomerase has just been infected by the Brainrot virus, a newly discovered pathogenic species that integrates into the host genome before secreting Generation Alpha protein, which has not existed before this century. Which of the following parts of the immune system would be MOST effective against this foreign pathogen?
- (a) Neutrophils
 - (b) B cells
 - (c) T cells
 - (d) Macrophages
 - (e) Complement system
9. Bio Nerd has not been eating properly due to his constant quest for USABO insular knowledge. During his yearly check up he discovered that his blood has trouble clotting due to a vitamin deficiency. Which of the following is Mr. Nerd most deficient in?
- (a) Tocopherol
 - (b) Phylloquinone
 - (c) Niacin
 - (d) Calciferol
 - (e) Riboflavin

10. The region represented below in pink plays a large role in embryonic limb formation. Which option correctly identifies the name of the region in the purple, and the morphogen it mainly produces?



- (a) AER; Fibroblast Growth Factor
(b) AER; Sonic Hedgehog
(c) ZPA; Sonic Hedgehog
(d) ZPA; Tissue Plasminogen Activator
(e) TPA; Fibroblast Growth Factor
11. While Chloe the Cat was eating a blobfish composed of 100% fat, she began to wonder how the fish would be digested. The fat was mainly dissolved by ___ in the ___ then mainly absorbed by ___ the via the ___.
- (a) Salivary lipase; duodenum; lacteals; large intestine
(b) Gastric lipase; stomach; lacteals; jejunum/duodenum
(c) Pancreatic lipase; duodenum; lacteals; jejunum/duodenum
(d) Pancreatic lipase; duodenum; circulatory system; jejunum/duodenum

- (e) Gastric lipase; stomach; circulatory system; jejunum/duodenum
12. Nebulin, a neuroscience student, had trouble remembering information he learned in class. Desperate, he decided to do experiments on the neural mechanisms of I. ntelligent, a remarkable species with incredible memory capabilities. However, he soon discovered that I. ntelligent's neural mechanisms were the same as his own, and that he simply has a skill issue. Given this, which of the following about the species is correct?
- (a) If a loss-of-function genetic mutation is induced at the 11p15.5 locus, which codes for tyrosine hydroxylase, I. ntelligent will have trouble sleeping at night.
 - (b) In I. ntelligent, Na^+ -influx through the NMDA receptor causes the closing of AMPA channels in presynaptic neurons, allowing for LTP to occur.
 - (c) Atropine, a chemical that dilates pupils by inhibiting metabotropic AcH channels, has the opposite effect of muscarine on the I. ntelligent nervous system.
 - (d) If a genetic mutation is induced that causes loss of function in 5-HT_{2a} receptors, LSD's hallucinogenic effects on members of I. ntelligent will be amplified.
 - (e) Sarin, a potent inhibitor of acetylcholinesterase, can cause fatal muscle relaxation if administered to members of I. ntelligent.
13. A researcher at the IGBC lab has just discovered a new class of antibodies, which he has named IgBC. After this hallmark discovery, he wants to test the protein interactions between subunits of the IgBC antibody and other proteins. Which of the following lab techniques would most effectively accomplish this?
- (a) Sanger sequencing
 - (b) FRET
 - (c) Mass spectrometry
 - (d) Western blotting
 - (e) Electroporation
14. The endoplasmic reticulum plays roles in a wide range of biological functions. Knowing what you do about the endoplasmic reticulum, order the following cell types in the order you would expect to have the highest to lowest ratio of smooth ER to rough ER.
- I. Beta-Cell of the pancreas
 - II. Plasma cell

III. Hepatocyte

IV. Cardiac muscle cell

- (a) III, IV, I, II
- (b) III, II, I, IV
- (c) IV, III, II, I
- (d) IV, III, I, II
- (e) IV, II, I, III

15. In E. coli, DNA replication at the replication fork travels at a rate of roughly 1000 nucleotides per second. Assuming that the E. coli genome is roughly $4.6 * 10^6$ bp long, in minutes, how long would you expect it to take for an E. coli cell to completely replicate its genetic material?

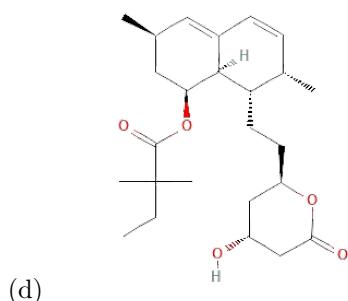
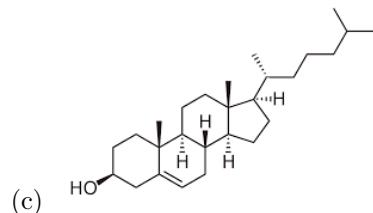
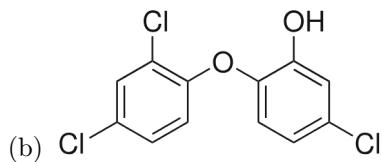
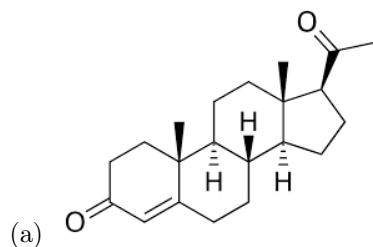
- (a) 77 minutes
- (b) 38 minutes
- (c) 30 minutes
- (d) 24 minutes
- (e) 87 minutes

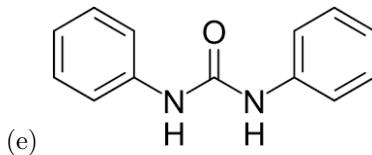
16. While eating their lunch of agar plates, Joy Chestnut begins to wonder how horizontal gene transfer works between the delicious bacteria. Which of the following is INCORRECT regarding a method of horizontal gene transfer and its mechanism of action?

- (a) Conjugation involves the transfer of a plasmid from a F+cell to a F cell from the pili.
- (b) Transformation involves the uptake of compatible free DNA from the environment.
- (c) The lytic cycle does not involve integration of the viral genome into the host genome.
- (d) Bacteria can retain multiple copies of a plasmid.
- (e) Hfr cells are unable to conduct conjugation due to their F+ gene being integrated into the chromosome.

17. While working in the Mitosisphere laboratory, Wsgcuhladoo has discovered a new protein! The protein, which he has named the Skibidi transporter, is a chloride ion transporter. Which of the following is not a likely candidate for the sequence of the transmembrane portion of this protein?

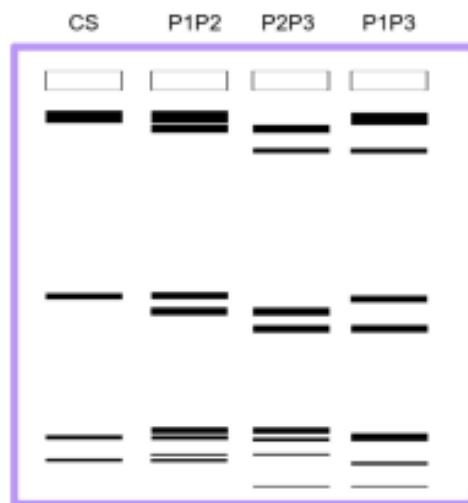
- (a) GEGTRASHYKTGKGRG
(b) KGCTRHSGGAAAKRHGG
(c) DADEAEDEDGDEGDEAA
(d) KRHAAGVRHKTKHRRR
(e) GYRGYKYYFKCYRSAFAY
18. The newly discovered Rizz receptor was discovered on the surface of the nuclear membrane. Which of the following molecules would be the LEAST likely to target the receptor?





19. Which of the following about signal transduction mechanisms is INCORRECT?
- PIP2 is converted to DAG and IP3 by phospholipase C
 - DAG acts as a secondary messenger by activating protein kinase C and indirectly phosphorylating other proteins involved in signal transduction
 - In receptor tyrosine kinases, phosphorylation of the intracellular tyrosine residues attracts signaling molecules
 - IP3 acts by releasing additional calcium ions from the ER to act as secondary messengers
 - Cortisol acts by activating cAMP-dependent signaling pathways to induce cell metabolism and division.
20. Gain-of-function mutations in which of the following genes may result in cancerous growth?
- TP53 (codes for p53)
 - HRAS (codes for a Ras protein)
 - BRCA1
 - EGF1
- I only
 - II and III only
 - II and IV only
 - I, II, and IV only
 - II, III, and IV only
21. Roughly 50% of cells' dry weight is made up of proteins. However, protein coding genes only account for roughly 2% of the genome. The other 98% is made up of genes whose end products are RNAs, termed ncRNAs. Which of the following choices incorrectly describes the function of a ncRNA?
- miRNAs: Binding to mRNAs, targeting them for degradation and inhibiting translation.
 - piRNAs: Protecting the germ cell line from transposable elements

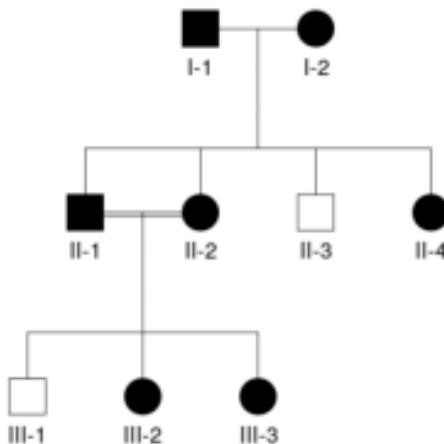
- (c) snoRNAs: Processing and modifying rRNAs
 - (d) rRNAs: forms the subunits of ribosomes
 - (e) snRNAs: Scaffold for RNAs and proteins, complexing them together.
22. Detective Ken is investigating a crime scene. Nathaniel was murdered and there are currently 3 major suspects: Euna (P1), Charles (P2), and Connor (P3). Detective Ken was able to find a blood sample at the crime scene that was not Nathaniel's, he sent this sample to forensics, who purified the DNA from the sample and subjected it to multiple rounds of PCR. They then placed the sample in a solution with various restriction nucleases and stained the resulting DNA with ethidium bromide and ran it on a polyacrylamide gel to separate the fragments. The data can be found below:



Forensics also ran the DNA from the 3 major suspects that Detective Ken was able to come up with, however somehow forensics mixed up the samples of blood and ended up with samples of different pairs of people as shown above. The different pairs were run adjacent to the sample found at the crime scene labeled "CS". Which of the following people murdered Nathaniel?

- (a) Euna
- (b) Charles
- (c) Connor
- (d) Either Euna or Charles, but it cannot be determined which one.
- (e) Either Charles or Connor, but it cannot be determined which one.

23. DUBQ is a gene that causes the overproduction of deubiquitinase, an enzyme that removes ubiquitin from proteins. A mutation in the DUBQ gene causes Ubiquitin syndrome, characterized by a severe deficiency in reading comprehension. Jiggle is curious why his sisters all have the disease but he doesn't, and wants to trace the history of the disease in his family. Based on the pedigree, what is the most likely genotype of I-2?



- (a) aa
 - (b) AA
 - (c) $X^A X^A$
 - (d) $X^A X^a$
 - (e) $X^a X^a$
24. Which of the following conditions is incorrectly stated as a requirement for Hardy-Weinberg Equilibrium?
- (a) Large population to minimize the effects of genetic drift
 - (b) No immigration/emigration to eliminate gene flow.
 - (c) Random mating
 - (d) Equal reproductive success for all genotypes
 - (e) Allele frequencies remain constant, but genotype frequencies fluctuate over generations
25. A rabbit lives in an environment where the gene that expresses fur color has two alleles, white and black. However, the trait shows incomplete dominance and the most common rabbit color is gray. What type of selection is likely occurring?

- (a) Disruptive Selection
 - (b) Directional Selection
 - (c) Stabilizing Selection
 - (d) Negative Selection
 - (e) Artificial Selection
26. John Mingleford is breeding mice, studying three different traits. He conducts a trihybrid cross studying three different traits: fur color (b), ear size (e), and eye color (c). Assume black fur, large ears, and blue eyes are dominant to grey fur, small ears, and brown eyes. The results of the cross can be found below:
- | | |
|-----|-----|
| bEC | 485 |
| Bec | 512 |
| bEc | 79 |
| beC | 97 |
| bec | 45 |
| BEC | 48 |
| bEc | 8 |
| BeC | 5 |
- Which of the following choices correctly describes the distance between the genes for fur color, ear size, and eye color in map units?
- (a) b(14.4)e(10.4)c
 - (b) b(10.4)c(14.4)e
 - (c) e(14.4)b(10.4)c
 - (d) b(10.4)e(14.4)c
 - (e) e(10.4)b(14.4)c
27. Which one of the following diseases is incorrectly matched with its mode of inheritance?
- (a) Marfan Syndrome: Autosomal dominant inheritance
 - (b) Hemophilia A: X-linked recessive inheritance
 - (c) Tay-Sachs Disease: Autosomal recessive inheritance
 - (d) Rett Syndrome: Autosomal dominant inheritance
 - (e) Albinism: Autosomal recessive inheritance
28. In an attempt to locate which chromosome the gene for a new novel genetic disorder, Dhawandrome, is on, a researcher decided to analyze the occurrence of different SNPs in three groups of people. Group 1

consisted of 500 women from Australia who were all healthy and showed no signs or history of Dhawandrome, Group 2 consisted of 500 men from the United States, who were all affected by Dhawandrome, and Group 3 consisted of a mix of 250 healthy, and 250 affected men and women from Chile. The data for different SNP occurrences among individuals can be found below:

	Ch3 B27182 T	Ch7 B482 T	Ch7 B91399 T
Group 1	87%	58%	42%
Group 2	84%	56%	50%
Group 3	85%	52%	54%

	Ch9 B922744 T	Ch10 B67828 T	Ch14 B28982 T
Group 1	12%	98%	13%
Group 2	94%	99%	17%
Group 3	44%	95%	11%

Ch1 B2418 A would correspond to an adenine nucleotide at base pair 2418 on chromosome 1; likewise, ChX B1784 C would correspond to a cytosine nucleotide at base pair 1784 on the X chromosome. The percentage corresponds to the occurrence of that nucleotide at that position in each group. Which of the following statements about Dhawandrome is likely true based on the data?

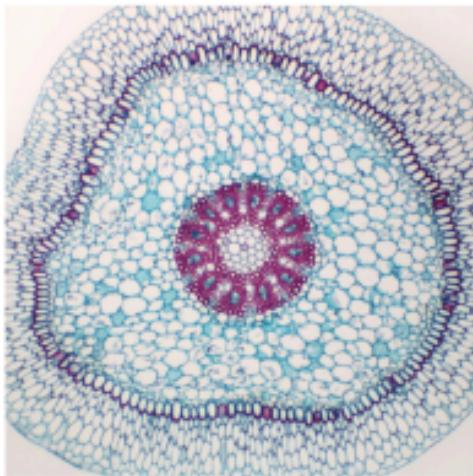
- (a) Dhawandrome is linked to a thymine SNP located on chromosome 10.
 - (b) Dhawandrome is likely more prevalent in the Americas due to environmental factors.
 - (c) Dhawandrome is linked to a thymine SNP located on chromosome 9.
 - (d) Dhawandrome is more prevalent in group 2 due to a mix of SNPs on chromosomes 10 and 14.
 - (e) Dhawandrome likely follows an X-linked recessive pattern of inheritance.
29. Identify all the NON-pleiotropic genes in the following list:
- I. TUBA1A (Alpha-Tubulin)
 - II. XPB (a DNA helicase)
 - III. LCT (lactase)
 - IV. PAH (phenylalanine hydroxylase)
- (a) II only
 - (b) III only
 - (c) II, III
 - (d) I, III, IV

- (e) I, II, III, IV
30. A trihybrid cross investigating three linked genes (A, B, and C) is performed between two Drosophila flies. By carefully counting the offspring, you determine the gene linkages to be A-B: 20%, B-C: 12%, and A-C: 28%. Which of the following COULD NOT have been the genotypes for the two parental flies?
- (a) ABC/abc × ABC/abc
 - (b) ABC/abc × abc/abc
 - (c) ABC/abc × abc/ABC
 - (d) ABC/ABC × abc/abc
 - (e) ABC/abc × aBC/abc
31. Selena is starting a new business that sells genetically engineered fluorescent sea-horses, called Selena-Horses. They are all purple, and the idea is that you can customize the degree of pigmentation. There are 5 simple dominant/recessive genes for pigmentation. Each dominant allele corresponds to a graded increase in pigment production, each recessive allele corresponds to no pigment production. Assuming each dominant allele contributes an equal amount of pigment, how many possible Selena-Horse color phenotypes are there?
- (a) 5
 - (b) 11
 - (c) 32
 - (d) 64
 - (e) 81
32. Xander is interested in the dragon color gene (g), which is a simple dominant/recessive gene. He is puzzled by its pattern of inheritance though. When Xander crossed a golden female (gg), with a wild-type, black male (GG), the offspring produced were all golden. However, when he crossed a true breeding black female with a true-breeding golden male, he observed all black offspring. When he crossed the all black F1 generation with the all golden F1 generation, he once again observed all black offspring! If Xander was to self-cross this F2 generation, what would be the expected ratio of black to golden offspring on the F3 generation?
- (a) All black
 - (b) 2:1
 - (c) 3:1

- (d) 9:7
(e) 15:1
33. Which of the following plant hormones would be BEST for resistance against a herbivore?
- (a) Salicylic acid
 - (b) Abscisic acid
 - (c) Jasmonic acid
 - (d) Auxin
 - (e) Gibberellins
34. Which of the following INCORRECTLY pairs a plant cell type with its role and a plant it can be found in?

A. Parenchyma	Storage, wound healing	Monocots
B. Vessel elements	Xylem conduction through perforated plates	Conifers
C. Sclerenchyma	Heavily lignified, dead at maturity	Monocots
D. Strassburger cells	Companion cells to sieve cells	Cycads
E. Sieve tube elements	Phloem symplastic transport	Eudicots

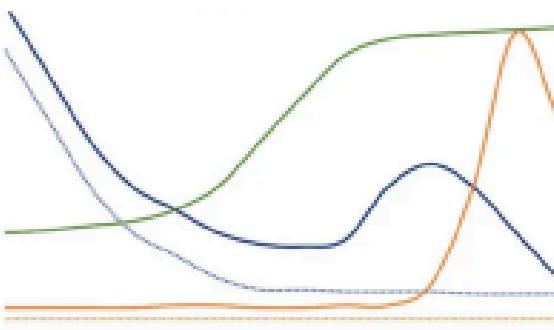
35. Which of the following choices best describes this plant cross section?



- (a) Monocot root
- (b) Angiosperm stem
- (c) Eudicot root
- (d) Monocot stem

- (e) Eudicot stem
36. Which of the following conclusions can be drawn based on the image below?
-
- (a) Double fertilization is an ancestral trait to all angiosperms
- (b) Seeds are a derived trait to all plants
- (c) Mosses and hornworts are direct descendants of liverworts
- (d) The length of the line segment is an exact measurement of time since divergence
- (e) Embryonic protection is a derived trait to land plants
37. According to the ABCDE hypothesis of flower development, which of the following statements is NOT true?
- (a) A plant expressing only genes A, B, E would develop only sepals and petals
- (b) A plant exhibiting only genes A, B, D would not develop sepals or petals.
- (c) A plant exhibiting only genes A, C, E would be unable to produce microspores
- (d) A plant exhibiting genes B, C, D, E would be unable to produce megasporangia

- (e) A plant exhibiting genes A, B, E would be unable to produce megasporangia
38. Which of the following statements regarding plant tissue is NOT true?
- (a) Most parenchyma, sclerenchyma, and collenchyma are derived from the ground meristem.
 - (b) Fibers' cell walls are rigid due to the presence of lignin, while collenchymas are pliable due to the presence of pectin.
 - (c) In woody plants the epidermis is usually replaced by the periderm.
 - (d) Sclerenchyma is dead at functional maturity, while parenchyma and collenchyma are not.
 - (e) Sclerenchyma occurs as horizontal "rays" in the secondary vascular tissue.
39. Richard lives on a farm and is researching fruit development and the physiological controls of the plant that occur during this time. He is also interested in the difference between climacteric fruits and nonclimacteric fruits. (Climacteric fruits may continue to ripen after being harvested). In order to conduct his study, Richard monitors several different variables regarding his fruits development up until the day of harvest. The data can be found below:

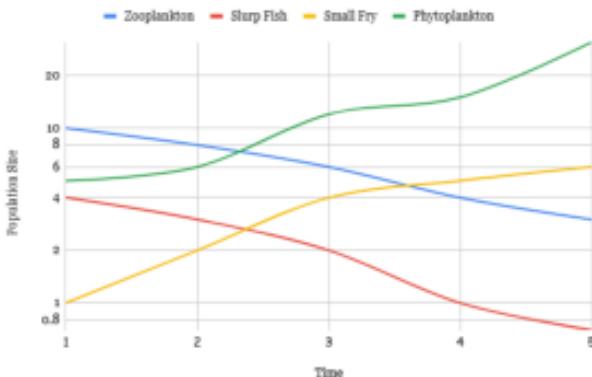


Which of the following statements correctly determines what the dotted lines likely refer to, as well as what the orange and blue lines are measuring respectively?

- (a) Dotted: Climacteric, Orange: Ethylene, Blue: Respiration rate
- (b) Dotted: Climacteric, Orange: Ethylene, Blue: Photosynthesis rate
- (c) Dotted: Climacteric, Orange: Brassinosteroid, Blue: Respiration rate
- (d) Dotted: Non-climacteric, Orange: Ethylene, Blue: Respiration rate

- (e) Dotted: Non-climacteric, Orange: Brassinosteroid, Blue: Photosynthesis rate
40. Which of the following incorrectly matches a fruit with its type?
- (a) Apple; Simple fruit
 - (b) Raspberry; Aggregate fruit
 - (c) Peanut; Simple fruit
 - (d) Fig; Multiple fruit
 - (e) Pomegranate; Multiple fruit
41. You steal a time machine from the 12th century, wishing to claim the discovery of fixed action patterns as your own. In your experiments, you first inject a mother bird with a known chemical that acts as a sign stimulus for the birds to feed their offspring. You then swap the bird's hatchlings with a bunch of rats that are clearly not related in any way to the birds. If the bird were to continue on the basis of a fixed action pattern, which of the following observations would be true?
- (a) The bird ignored the rats, deciding to feed themselves to increase fitness.
 - (b) The bird was unable to find the nest due to the lack of its offspring to help it pilot.
 - (c) The bird was killed by the rats.
 - (d) The bird continued to feed the rats.
 - (e) The birds did not feed the rats and left to form a new nest.
42. Male satin bowerbirds construct and decorate bowers to attract mates. Researchers observed that females prefer bowers with more blue objects and symmetrical arrangements. Which of the following statements BEST explains this behavior?
- (a) Male bowerbirds with more decorated bowers have higher reproductive success because they are more visible to predators, demonstrating their survival skills.
 - (b) Female preference for decorated bowers likely arises from intersexual selection, where traits indicating male fitness are favored.
 - (c) The preference for symmetrical bowers may reflect an evolved tendency to associate symmetry with genetic diversity.
 - (d) The behavior of bower building is primarily driven by kin selection, as it increases the fitness of related males in the population.

- (e) Female bowerbirds use the complexity of bower decoration as a signal of the male's cognitive abilities.
43. For some reason, Fletcher is thoroughly interested in birds. . . . However, his best friend Anthony couldn't care less about birds. To mess with Fletcher, he likes to tell him random bird facts that are not true. Which of the following statements is NOT something that Anthony might've told Fletcher?
- (a) Fletchings are more closely related to crocodiles than turtles.
 - (b) Blue jays are viviparous.
 - (c) Birds first appeared in the Cambrian explosion.
 - (d) Quails have relatively large cerebellums compared to reptiles.
 - (e) Birds have highly reduced teeth, which is a consequence of evolving beaks.
44. Kian is exploring the countryside of Virginia when the green-eared leopard piques his interest. However, throughout the duration of his trip, he only encounters 5 of them. He concludes this might be because one time that he saw a green-eared leopard near another green-eared leopard, they began to attack one another. Despite their violent nature however, Kian is determined to learn about these green-eared leopards and manages to get near enough to paint their ears red. He ends up coming back to the countryside 3 weeks later, and this time, he is much luckier, encountering 17 green-eared leopards. To his shock, out of these 17 leopards, only 3 of them have red ears. Calculate the estimated population size of the green eared leopards and identify their most likely pattern of dispersion.
- (a) 255 individuals, clumped dispersion
 - (b) 28 individuals, uniform dispersion
 - (c) 21 individuals, random dispersion
 - (d) 255 individuals, uniform dispersion
 - (e) 28 individuals, random dispersion
45. Meowscles is monitoring the oxygen levels of Loot Lake in order to make sure they don't fall too low. Everything had been fine for many years; however, recently the levels began to fall substantially. In an attempt to figure out what was going on, he decided to check his data on the relative population sizes of different organisms in the lake. The data can be found below:



Which of the following conclusions that can be drawn based on the data would account for the rapid decrease in oxygen concentration in the lake?

- Loot Lake is a bottom-up ecosystem, the increase in phytoplankton caused a decrease in small fry populations.
 - Loot Lake is a top-down ecosystem, the decrease in slurp fish caused an increase in phytoplankton.
 - Loot Lake is a bottom-up ecosystem, the increase in slurp fish caused an increase in small fries.
 - Loot Lake is a bottom-up ecosystem, the decrease in small fry caused a decrease in zooplankton.
 - Loot Lake is a top-down ecosystem, the increase in slurp fish caused a decrease in phytoplankton.
46. After watching Avengers' Endgame, you have decided to embody the ideals of Thanos. You wonder how you can use the principles of Thanos to help improve the ecosystem of your fish tank. Which of the following are correct statements?

Species	Count
Vander fish	5
Raven fish	3
Albert fish	10
Insular fish	25

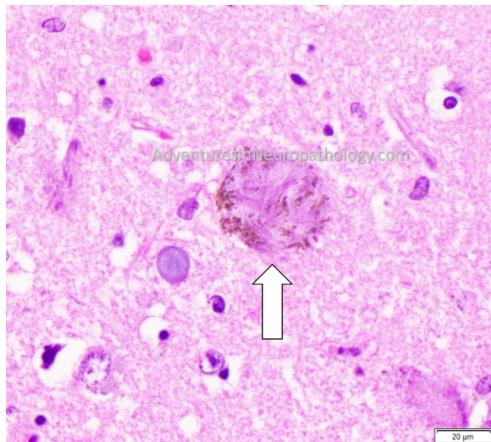
- Using a machine to transform 5 Insular fish to Raven fish would increase the Shannon's diversity index
- The Shannon's diversity index of this community is currently approximately 1.5
- Adding an additional 20 Albert fish would increase the Shannon's diversity index

- (a) I only
 - (b) I, II only
 - (c) II, III only
 - (d) I, III only
 - (e) I, II, III only
47. The BDNF server, which was previously uninhabited, was just colonized by Ubiquitin, who, through his insular knowledge, allowed for the formation of the nerd community there. Which of the following best describes the type of succession and role of Ubiquitin?
- (a) Primary succession, climax species
 - (b) Secondary succession, climax species
 - (c) Primary succession, pioneer species
 - (d) Secondary succession, keystone species
 - (e) Secondary succession, pioneer species
48. Consider a trophic cascade in a marine ecosystem where an oviparous keystone predator reduces the density of herbivores that feed on algae. How would the introduction of an invasive species that competes with the keystone predator for its habitat and preys upon its eggs likely affect stability of the trophic cascade?
- (a) The invasive species would stabilize the trophic cascade by reducing predation on herbivores.
 - (b) The invasive species would likely destabilize the cascade, leading to an overabundance of herbivores and a reduction in algae abundance and primary productivity.
 - (c) The invasive species would enhance the effects of the trophic cascade by increasing predation on primary producers.
 - (d) The invasive species would disrupt the trophic cascade by increasing predation on herbivores, reducing their impact on algae.
 - (e) The invasive species would have no impact on the trophic cascade due to the redundancy of ecological functions in the system.
49. Which of the following regarding fungi is NOT true?
- (a) Microsporidians are unicellular parasitic fungi with highly reduced mitochondria.
 - (b) Cryptomyctes and microsporidians are the only two classes of fungi known to have retained flagellated spores.

- (c) Mucormycetes are the fungi responsible for the rotting of food like bread and strawberries.
 - (d) Ascomycetes produce non-motile spores called ascospores which develop inside of saclike structures called asci.
 - (e) Basidiomycetes life cycle is characterized by a long lived dikaryotic mycelium.
50. Which of the following is NOT a trait shared by all members of the phylum Chordata?
- (a) Pharyngeal slits
 - (b) Dorsal hollow nerve cord
 - (c) Backbone
 - (d) Notochord
 - (e) Post-anal tail

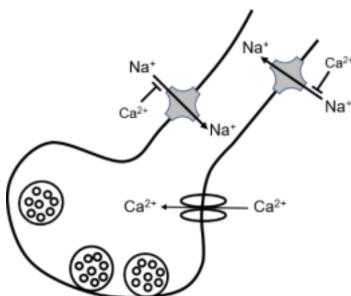
5.2 Opens Exam 2

1. You're an endocrinologist, and a 28 year old man enters your clinic. He tells you that he has experienced rapid weight gain without any significant changes in diet. He also presents with a feeling of extreme cold in the extremities. What medication should you prescribe for him?
 - (a) Miacalcin - synthetic form of calcitonin
 - (b) Levothyroxine - synthetic form of thyroxine
 - (c) Aspirin
 - (d) Ibuprofen
 - (e) 1, 25 dihydroxycholecalciferol - active form of vitamin D
2. Shown below is an image taken from the brain of an individual who suffers from a certain neurodegenerative disease. The region marked by the arrow corresponds to buildups of a mutated version of a certain microtubule associated protein (MAP) that functions in both the structural maintenance of, and transport of nutrients inside neurons. Which of the following diseases does this individual suffer from?



- (a) Parkinson's
- (b) Alzheimer's
- (c) Schizophrenia
- (d) Huntington's
- (e) Creutzfeldt-Jakob Syndrome
3. The movement of sodium and calcium ions at the nerve terminal end is shown. Accordingly, which of the following is the most accurate

observation made from the nerve terminal of an individual suffering from hypercalcemia?



- (a) Increased depolarization as well as synaptic vesicle fusion causing hyper-excitability of neurons.
 - (b) Reduced depolarization and reduced synaptic vesicle fusion affecting muscle function.
 - (c) Normal depolarization but enhanced synaptic vesicle fusion causing muscle weakness.
 - (d) Increased depolarization, normal synaptic vesicle fusion leading to unperturbed muscle functions.
 - (e) Reduced depolarization and reduced synaptic vesicle fusion causing hyper-excitability of neurons.
4. Bob is a very active person living in Phoenix, Arizona, but during a routine checkup, the doctor, feeling something is not right, orders a blood test and determines that he has a condition that leads to a Bohr shift of his hemoglobin saturation curve, but he is unable to figure out what is causing that shift. He has developed a possible list and asks for your help. Identify all of the following that could be the problem:
- I. Bob is exercising too little.
 - II. Bob is severely dehydrated.
 - III. Bob has consumed too many carbonated drinks.
 - IV. Bob has undiagnosed hypophosphatemia.
- (a) I and II
 - (b) I and III
 - (c) II and III
 - (d) II and IV
 - (e) III and IV

5. After losing a bet to a med student, Jeff Bezos agrees to undergo a supervised endocrine suppression test. After ACTH is administered, his plasma cortisol rises significantly. However, when given metyrapone, cortisol levels drop and ACTH spikes dramatically. Which of the following best explains this physiological response?
- (a) Metyrapone blocks 21-hydroxylase, which impairs aldosterone synthesis and directly stimulates ACTH release
 - (b) Cortisol's inhibition of the anterior pituitary is disrupted by metyrapone blocking its conversion into cortisone by 11β -HSD
 - (c) Metyrapone inhibits 11β -hydroxylase, decreasing cortisol, increasing ACTH
 - (d) ACTH stimulates zona glomerulosa to secrete cortisol, but metyrapone selectively blocks its synthesis only in zona fasciculata
 - (e) Cortisol levels decrease with metyrapone, and increased ACTH indicates pituitary failure
6. You are looking to target the signaling cascade behind the epinephrine receptor to treat a patient. Which of the following receptor types should you be inhibiting?
- (a) GPCR
 - (b) Receptor tyrosine kinase
 - (c) Ion-gated channel
 - (d) Golgi apparatus receptor
 - (e) Nuclear membrane receptor
7. A patient comes into your clinic with an observable “cherry-red spot” in their eye and a loss of motor skills. You eventually come to the diagnosis of an autosomal recessive disease related to a dysfunctional hexosaminidase A protein. Which of the following conditions is this patient afflicted with?
- (a) Sandhoff disease
 - (b) PKU
 - (c) Tay Sachs
 - (d) Cystic Fibrosis
 - (e) Lesch-Nyhan
8. John Billington has recently decided to go on a diet to prepare for his upcoming fight. However, he has limited what he is eating so much that

he has begun suffering from various nutrient deficiencies. Specifically, he has become deficient in vitamin K (phylloquinone), Vitamin B3 (Niacin), and B5 (Pantothenic acid). Which of the following symptoms is John LEAST LIKELY to be experiencing?

- (a) Fatigue
 - (b) Excessive bleeding
 - (c) Muscle cramps
 - (d) Impaired coordination
 - (e) Impaired immune function
9. Lipid nanoparticles (LNPs) are small, lipid-based particles utilized as drug delivery vehicles. Specifically, instead of heat killed viruses, they provide an efficient and effective way to deliver mRNA to patients. LNPs are typically spherical vesicles composed of a variety of lipids in order to maintain stability as well as facilitate interactions with target cells. Which of the following choices is NOT a reason why LNPs may be preferable to other forms of mRNA delivery?
- (a) LNPs are unlikely to elicit an unfavorable immune response.
 - (b) LNPs allow for a higher degree of control to where drugs are released.
 - (c) LNPs protect the mRNA from degradation by enzymes en route.
 - (d) LNPs provide a long circulation period in the bloodstream.
 - (e) LNPs may improve the solubility and stability of certain drugs.
10. Jerry is presenting to the ER, complaining of weight loss, frequent urination, fatigue, and a strange craving for salty foods. The doctors take Jerry's BP, and see that it's 85/55 and subsequently decide to run some blood work. The data can be found below:

	Jerry	Healthy Range
Na+	132	135-145
TSH	3.4	0.05-5
T ₄	9	5-12
Glucose	48	70-99
ACTH	250	20-50
Aldosterone	2.4	7-30
Cortisol	2.1	5-25

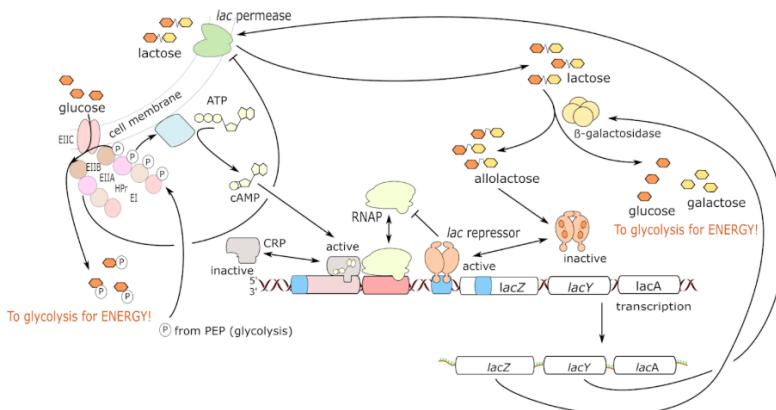
Which of the following diseases best explain Jerry's symptoms?

- (a) Cushing's disease

- (b) Addison's disease
 - (c) Grave's disease
 - (d) Hashimoto's disease
 - (e) Congenital hyperplasia
11. During the cardiac cycle, what event directly triggers the closing of the mitral valve and what is the immediate consequence?
- (a) Atrial contraction increases atrial pressure, closing valves and starting rapid ejection
 - (b) Ventricular pressure exceeds atrial pressure after ventricular depolarization, closing valves and beginning isovolumetric contraction
 - (c) Aortic pressure rises first, forcing AV valves to close and reducing ventricular volume
 - (d) Papillary muscles relax, causing valves to close and starting filling phase
 - (e) Semilunar valves open first, causing AV valves to close before systole
12. Which of the following cell types is the most abundant type of white blood cell as well as a granulocyte?
- (a) Monocytes
 - (b) NK cells
 - (c) Macrophages
 - (d) Eosinophils
 - (e) Neutrophils
13. Identify all of the following genes which are pleiotropic:
- I. Tubulin- α
 - II. SLC45A2 (melanin gene)
 - III. OCA2 (red eyes)
 - IV. 9q34 (blood type)
 - V. PAH (phenylalanine hydroxylase)
- (a) I, II, IV
 - (b) I, II, V
 - (c) III, III, IV
 - (d) II, III, V

- (e) II, III, IV, V
14. Joseph has recently discovered the protein FEMBAO, which he is studying in mice. Specifically, he is interested in its effects on the expression of SOX9, a gene located on chromosome 17 responsible for the proper formation of testis. In order to better understand the mechanisms behind FEMBAO, Joseph has decided to run a western blot in the presence of siRNAs for FEMBAO (FB-siRNA). The data may be found below. Which of the following statements is not true?
-
- | | +/+ | +/m | +/m
+ FB-siRNA | m/m |
|----------------|-------------|-------------|-------------------|----------------|
| SOX9 | Strong band | Weak band | Very weak band | Strong band |
| FEMBAO | Strong band | Strong band | Strong band | Very weak band |
| β -Actin | Strong band | Strong band | Strong band | Strong band |
- (a) If FEMBAO acted genetically downstream of SOX9, Joseph would have observed different results on his western blot.
- (b) In a cross between a heterozygous female and a WT male mouse, 25% of offspring would show mutant phenotypes.
- (c) FB-siRNA is insufficient to rescue the heterozygous condition of FEMBAO for proper development of testis.
- (d) Female mice homozygous for the mutant FEMBAO gene would be indistinguishable from heterozygote females.
- (e) The mutant form of FEMBAO may disrupt wild type FEMBAO by directly interacting with it.
15. If the cristae in the mitochondrion get unflattened, without changing the overall volume, the efficiency of cellular respiration will:
- (a) Increase because there's more surface area for the electron transport chain.
- (b) Decrease because there'll be less NADH and FADH in the mitochondrion.
- (c) Increase because there'll be more NADH and FADH in the mitochondrion.
- (d) Decrease because there's less surface area for the electron transport chain .
- (e) Be unaffected.

16. Shown below is a model of the lac operon. The lac operon is under dual positive and negative control, regulated by both internal glucose and lactose concentrations. When glucose levels are high, cAMP levels are low and the cell preferentially catabolizes glucose. When glucose levels are low, cAMP levels are high and the cell resorts to lactose catabolism.



If you were to introduce a competitive inhibitor of cAMP phosphodiesterase into a cell under low glucose and high lactose conditions, how would the levels of beta-galactosidase expression compare to that of a cell under the same conditions without this inhibitor, and to that of a cell with high glucose and low lactose without this inhibitor, respectively?

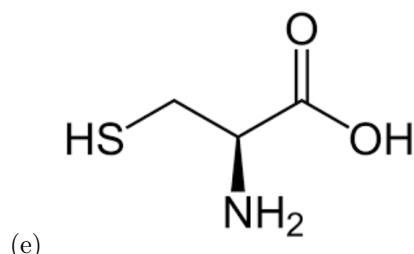
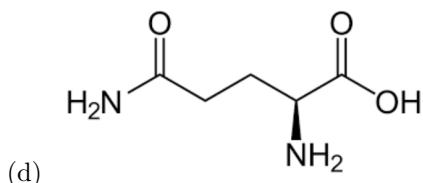
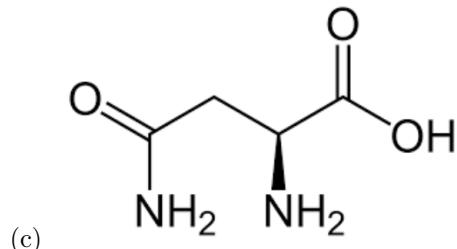
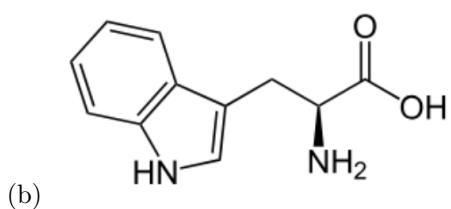
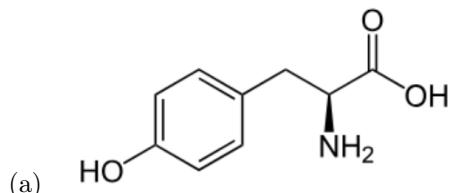
- (a) Higher, Higher
 - (b) Lower, Lower
 - (c) Higher, Lower
 - (d) Lower, Higher
 - (e) Same, Lower
17. Gauchers is a condition caused by a deficiency of an enzyme to break down lipids, hence leading to accumulation of fats in organs including the spleen, liver, kidneys, lungs, brain and bone marrow. Identify which of the following organelles may be involved in this disease:
- (a) The mitochondria are most likely defective and do not produce adequate amounts of ATP needed for cellular energy.
 - (b) The rough ER contains too many ribosomes, which results in an overproduction of the enzyme involved in lipid breakdown.
 - (c) The lysosomes lack sufficient amounts of enzymes necessary for the metabolism of lipids.

- (d) The Golgi apparatus produces vesicles with faulty membranes, which fail to be transported to the plasma membrane for secretion.
- (e) The smooth ER is likely overstimulated, and produces too much phospholipids.
18. The enzyme JIGGLE helps with the conversion of BRIAN to ASPARAGINE. Isoprene makes four different mixtures. In mixture 1, he adds JIGGLE, BRIAN, and DESTROYER. In mixture 2, he adds JIGGLE, BRIAN, and BETA. In mixture 3, he adds JIGGLE, BRIAN, and BOMB. Finally, in mixture 4, he only adds JIGGLE and BRIAN. Then, he plots $1/[S]$ versus $1/V_0$ to obtain the following graphs:
- Mixture 1

Mixture 2

Mixture 3
- The black line in each of the graphs represents the plot for mixture 4. Based on this data match BETA, DESTROYER, and BOMB to which type of inhibitor they are, respectively.
- (a) Uncompetitive, Competitive, Mixed
- (b) Noncompetitive, Mixed, Competitive
- (c) Mixed, Noncompetitive, Competitive
- (d) Noncompetitive, Uncompetitive, Competitive
- (e) Uncompetitive, Noncompetitive, Competitive
19. You are testing to see if two mitochondrial proteins have affinity for each other. Which of the following lab techniques would be effective in accomplishing this task?
- (a) Chromatin immunoprecipitation
- (b) Next generation sequencing
- (c) FRET
- (d) Western Blot
- (e) FRAP
20. You are working at the Mitosisphere clinic when your patient reports symptoms of insomnia, anxiety, and impaired memory. Suspecting a

hormonal deficiency, you prescribe which of the following hormone precursors?

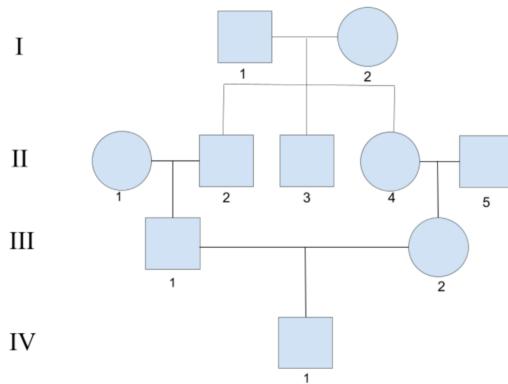


21. Suzuko, who has taken a deep interest in Connor's peanut allergy, has decided to run an experiment to measure the relative concentration of antibodies present in Connor's blood before and after he gives him some Nutter Butters. In his experiment, he has a membrane with small bits of peanuts fixed to it. He runs both samples of Connor's blood (pre- and

post-Nutter Butter exposure) across the membrane in the presence of fluorophore-conjugated antibodies which bind to the same antigen as Connor's peanut antibody. Which of the following choices best describes the data Suzuko would likely encounter and how he should interpret it?

- (a) Increased fluorescence after exposure to peanuts indicating lower antibody concentration in Connor's blood.
 - (b) Decreased fluorescence after exposure to peanuts indicating lower antibody concentration in Connor's blood.
 - (c) Increased fluorescence after exposure to peanuts indicating higher antibody concentration in Connor's blood.
 - (d) Decreased fluorescence after exposure to peanuts indicating higher antibody concentration in Connor's blood.
 - (e) Equal levels of fluorescence since the amount of fluorescent labeled antibodies is the same in both tests.
22. Exposure of zebrafish nuclei to cytosol isolated from eggs at metaphase of mitosis resulted in phosphorylation of NEP55 and L68. NEP55 is a protein of the inner nuclear membrane, and L68 is a protein of the nuclear lamina. What is the most likely role of phosphorylation of these proteins in the regulation of mitosis?
- (a) They enable the attachment of the spindle microtubules to kinetochore regions of the centromere.
 - (b) They are involved in chromosome condensation.
 - (c) They are involved in the disassembly of the nuclear envelope.
 - (d) They assist in the migration of centrosomes to opposite sides of the nucleus.
 - (e) All of the above.
23. Which of the following is an example of negative-frequency dependent selection?
- (a) The ratio of left to right mouthed fish in a lake periodically oscillates.
 - (b) Antibiotic resistant bacteria becoming more prevalent over time.
 - (c) Black mice become more prevalent after lava has cooled into igneous rocks.
 - (d) Multiple toxic species of butterflies resemble one another.

- (e) A certain population of finches evolves to have either extremely short or extremely long beaks.
24. Gregory is breeding fruit flies for an experiment. He has two separate groups, 1 group is composed of true breeding homozygous recessive black body, vestigial winged fruit flies. Group 2 is composed of true breeding, gray body, normal winged flies. He then crosses the F1 generation with group 1, and finds the following frequencies. Calculate the distance between the genes for color and wings.
- | Gray,
Normal wings | Gray,
Vestigial wings | Black,
Normal wings | Black,
Vestigial wings |
|-----------------------|--------------------------|------------------------|---------------------------|
| 653 | 58 | 74 | 628 |
- (a) 10.41mu
 (b) 9.98mu
 (c) 4.78mu
 (d) 5.2mu
 (e) 11.78mu
25. You are studying the prevalence of the Pepperoni trait in a population of a certain species, p.izza. After many years of research you determine that the trait is x linked and that the prevalence of the trait in the male (assume that the p.izza reproductive system is the same as humans) is 26% and recessive. Determine the prevalence of the Peopporoni trait carriers in the female p.izza individuals.
- (a) 28%
 (b) 33%
 (c) 38%
 (d) 43%
 (e) 48%
26. Jerry (I-1) and Izzo (I-2) are two alums of the University of Alabama (take me home!). However, unbeknownst to them, Jerry and Izzo are heterozygous for the rare autosomal recessive trait cestin. Assuming that II-1 and II-5 do NOT carry alleles for cestin, what is the probability of IV-1 having the cestin trait?



- (a) 1/12
 (b) 1/32
 (c) 1/8
 (d) 1/16
 (e) 1/20

27.

- (a) 5
 (b) 11
 (c) 32
 (d) 64
 (e) 81

28. In a population of *Drosophila melanogaster*, balancing selection acts on this population. Shown in the table are the fitness values for different genotypes about a gene located on Chromosome 4 that is important for determining whether the fly has 1 or 2 antennae. What is the frequency of the dominant allele in this population?

Genotype	Fitness value
AA	0.7
Aa	1
aa	0.4

- (a) 2/3
 (b) 3/4
 (c) 4/5

- (d) 1/2
(e) 6/7
29. Which of the following proteins involved in DNA replication/transcription is incorrectly matched to its function?
- (a) Helicase, creates a replication fork during DNA replication
(b) Topoisomerase, promotes supercoiling after DNA replication
(c) DNA polymerase, attaches DNA nucleotides to the template strand
(d) RNA polymerase, creates an mRNA strand out of a template strand
(e) Exonuclease, removes RNA primers in DNA replication
30. Ethan is trying to find the recombination frequency between A and B on the same chromosome of a diploid fungus. After performing a cross, he gets the following results. What is the distance between genes A and B?
- | Type | Number |
|--------------------|--------|
| Parental Ditype | 200 |
| Nonparental Ditype | 42 |
| Tetratype | 33 |
- (a) 51.8 mu
(b) 62.3 mu
(c) 43.6 mu
(d) 43.6 cM
(e) 42.9 mu
31. On the island of Ubi-land, there lives a population of 125 Ubi-people. Unfortunately, a new mutation affecting the ebl1 locus has occurred on the island of Ubi-land which causes the loss of left eyebrows. What is the probability that the new ebl1 mutation will be eliminated from the island and what is the expected amount of generations that it would take for this allele to become fixed respectively?
- (a) 99.6%, 500 generations
(b) 99.2%, 250 generations
(c) 99.6%, 500 generations
(d) 99.2%, 250 generations
(e) 99.8%, 250 generations

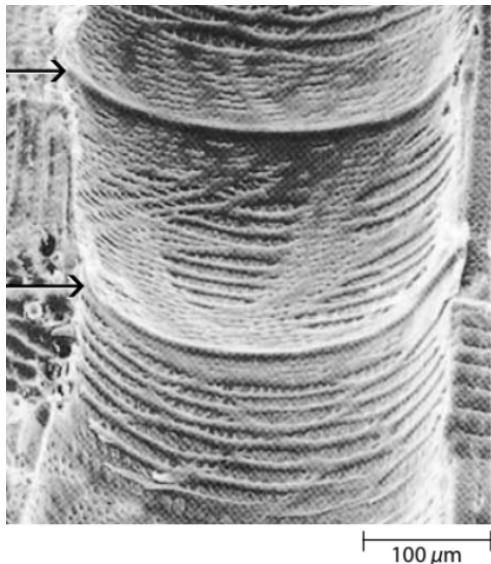
32. Connor is studying the inheritance of elbow pointiness in gophers. He has concluded that 3 genes A, B, and C, all add quantitatively to increase elbow pointiness. Assuming each dominant allele for A, B, and C each provides 1 “point” of pointiness, and that pointiness ranges from 0-6, in a trihybrid cross, what fraction of offspring would you expect to have less than 5 points of “pointiness?”
- (a) 7/64
 - (b) 1/8
 - (c) 21/32
 - (d) 57/64
 - (e) 63/64

33. Which of the following nutrients is the given plant most likely deficient in? The image shown is of an older leaf.



- (a) Zinc
 - (b) Chloride
 - (c) Magnesium
 - (d) Potassium
 - (e) Nitrogen
34. Joseph is clumsy and accidentally dropped decoupling proteins into the plant he recently bought for his girlfriend. Unbeknownst to him, this might lead to a fight pretty soon... The uncoupling proteins were taken up by the plant’s root cells, but did not localize anywhere else. Which of the following functions would be most disrupted by Joseph’s mistake?
- (a) Lateral root formation
 - (b) Cation exchange
 - (c) Root hair formation
 - (d) Polar transport of cytokinins

- (e) Perception of gravity
35. Gibberellins (GAs) were first discovered in 1934 by T. Yabuta and Y. Sumiki during their research on a fungal disease affecting rice. Since then, over 100 different gibberellins have been identified, each playing vital roles in plant development. One key role of GAs is in seed germination, where they promote the production of hydrolytic enzymes. These enzymes break down the stored nutrients in the seed's endosperm, converting them into usable molecules like sugars and amino acids. In barley seeds, the molecules that are created by the broken down endosperm by such enzymes are quickly sent over to what part of the seed to be absorbed?
- (a) Pericarp
(b) Aleurone layer
(c) Scutellum
(d) Testa
(e) Coleoptile
36. Suppose you have a microsporocyte and a megasporocyte, both with initial DNA content "S". What is the ratio of the final amount of DNA you will have from the microsporocyte to that from the megasporocyte after all divisions to produce gametophytes have occurred?
- (a) 1/2
(b) 1
(c) 2
(d) 4
(e) 8
37. Shown below is an image taken using a scanning electron microscope on the secondary xylem of a red oak (*Quercus rubra*). Which of the following choices correctly identifies the type of cells, and what the arrows are pointing to, respectively?



- (a) Tracheid, perforation plates
(b) Vessel element, perforation plates
(c) Tracheid, pit membranes
(d) Vessel element, pit membranes
(e) Sclereid, pit membranes
38. According to the ABCDE model, which of the following choices would maximize fruit yield?
- (a) Knock out A
(b) Knock out B
(c) Knock out C
(d) Knock out D
(e) Knock out E
39. Unlike the water conducting cells of the xylem, the elements of the phloem are living at functional maturity. Despite being alive however, they lack many of the key organelles present in the majority of living cells, which are instead contained in closely associated companion cells. Identify which of the following organelles you would expect to be present in a functionally mature sieve-tube element?
- I. Mitochondria
II. Golgi Apparatus

- III. Endoplasmic reticulum
IV. Centriole
- (a) I, II
(b) I, III
(c) I, II, III
(d) II, III
(e) II, IV
40. Ayan is studying the vascular system in plants. In particular, he is studying the meristematic cells of the vascular cambium in order to try and get a better idea of how the vascular system develops. In order to monitor this, he injects a red fluorescent marker into fusiform initial cells and a green fluorescent marker into ray initial cells. Which of the following situations will Ayan likely NOT observe during his study?
- (a) Both red and green markers in both the secondary phloem and secondary xylem
(b) Elongated strands of red fluorescence with green fluorescence interspersed between
(c) Storage of lipids and starches closely associated with fluorescence
(d) Movement of fluorescence from the secondary phloem to secondary xylem and vice versa
(e) Green fluorescence percolating into the cortex and red fluorescence deeper into the pith
41. Johnny the jackrabbit has recently turned green (Oh no!) following the dropping of large amounts of garbage onto his grassland. Feeling horrible since this garbage was released from your helicopter, you decide to go on a mission to clean up all the trash you dropped. Miraculously, after cleaning up all the garbage, Johnny begins to gain his normal color back. Which of the following types of species best describes Johnny?
- (a) Keystone species
(b) Pioneer species
(c) Indicator species
(d) Invasive species
(e) Flagship species
42. Worker bees closely mimic other worker bees and are greatly influenced by the Queen bee in the same colony. What type of mimicry is shown?

- (a) Batesian Mimicry
 - (b) Mullerian Mimicry
 - (c) Vavilovian Mimicry
 - (d) Wasmannian Mimicry
 - (e) Emsleyan Mimicry
43. A forester is concerned about a rainforest, which is declining in size due to habitat fragmentation and invasive species. The ecosystem has also been experiencing soil erosion and is also the center for a lot of timber trade, which the cities near it are heavily dependent on. What forest management technique would be best to ensure the rainforest's and economy's survival?
- (a) Clear cutting
 - (b) Sustainable development
 - (c) Selective cutting
 - (d) Slash and burn
 - (e) Shelterwood cutting
44. Which of the following animals are k selected?
- (a) Elephant
 - (b) Salmon
 - (c) Frog
 - (d) Mosquito
 - (e) Mouse
45. /hyperref[loc:Opens2-45]Which of the following scenarios best illustrates negative reinforcement?
- (a) A young gorilla hears a loud buzzer each time it attempts to climb a forbidden ladder, causing the gorilla to stop climbing the ladder over time.
 - (b) A trained falcon, upon flying to higher vantage points, discovers more prey. Because the payoff is greater hunting success, it repeatedly seeks out higher perches.
 - (c) A laboratory rat is placed in a chamber where it receives a mild electric shock until it presses a lever. After pressing the lever, the shock stops, and the rat begins pressing the lever more often.

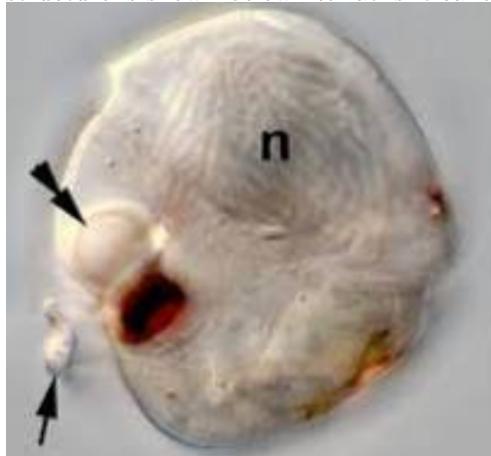
- (d) A cat that meows persistently for food at night gets ignored by its owner. Over time, the cat's excessive meowing decreases due to lack of response.
- (e) A student receives praise from a teacher every time they turn in homework on time, leading the student to become more consistent with assignments.
46. /hyperref[loc:Opens2-46] You've recently decided to start training your cat Sparky to use and flush the toilet himself. You need to get this done within the next month or so, since your family is coming for Christmas and you want to impress them. You only see them once a year though, so you do not care if he continues to do so after they've left. In order to train Sparky, which of the following reinforcement schedules should you use?
- (a) Fixed ratio
 - (b) Fixed interval
 - (c) Variable ratio
 - (d) Variable interval
 - (e) Either C or D
47. Which of the following is the best example of altruism?
- (a) A bird calls out a warning when a predator is approaching, though the call may attract the predator to the caller.
 - (b) A mother rat nurses her pups, ensuring their survival and her own reproductive success.
 - (c) A male peacock displays his colorful feathers to attract a mate.
 - (d) A wolf sacrifices itself to humans invading its territory to save the nearby sheep.
 - (e) A dog learns to fetch a ball after watching its owner do so.
48. In her online Living Earth experiment assignment, Emma was shown a scenario where a female guppy is given a choice between two males: one with bright orange coloration and another with light yellow coloration. Before making a choice, the female observes another female mate with the light yellow male. What is the most likely behavior the observing female will display?
- (a) She ignores both males and chooses a male with dull gray coloration in a different tank

- (b) She still chooses the bright orange male due to strong innate preference
 (c) She copies the model female and chooses the light yellow male
 (d) She avoids mating entirely due to the presence of competition
 (e) None of the above
49. Which of the following statements is true regarding the phylogenetic tree below?
-
- ```

graph TD
 CA1((Common ancestor 1)) --- virus6
 CA1 --- virus7
 CA1 --- virus8
 CA1 --- virus9
 CA1 --- virus10
 CA2((Common ancestor 2)) --- virus5
 CA2 --- virus4
 CA2 --- virus3
 CA2 --- virus2
 CA2 --- virus1
 CA3((Common ancestor 3)) --- virus3
 CA3 --- virus2
 CA4((Common ancestor 4)) --- virus1
 scale[0.07]

```
- I. A group containing virus5, virus4, virus3, virus2, virus1, and Common ancestor 1 can best be described as paraphyletic.  
 II. Common Ancestor 2 is the same, genetically, as Common Ancestor 3.  
 III. virus8 and the lineage of Common ancestor 1 make up a sister taxon
- (a) I only  
 (b) I and II  
 (c) I and III  
 (d) II only  
 (e) I, II, and III
50. You look at one of your protistan samples under a microscope and see your sample looking back at you! Well, not literally. However, upon closer inspection, you realize that the dinoflagellate sample contains an interesting eye-like organelle that resembles the lens and retina of vertebrates. Apparently it helps in prey detection. An image of the

structure is shown below. What is it called?



- (a) Ocelloid
- (b) Nephridia
- (c) Chelicera
- (d) Operculum
- (e) Extrusome

### 5.3 Solutions to Practice Exam 1

1. Embryonic question layers can often be solved by envisioning the body as a hollow tube; the outside of the tube is ectoderm while its inner surface is endoderm. Thus, we see that option E (bronchiole lining) is derived from endoderm. Then, we notice that most internal organs are derived from endoderm, except the spleen and kidneys, which are derived from mesoderm. Therefore, our answer is option B.
2. First, let's identify each of the numbered substances. By looking at the graph, we see that substance 1 is LH, substance 2 is FSH, substance 3 is estrogen, and substance 4 is progesterone. Now, we go through each of the options.
  - A. In the first week of the menstrual cycle, LH directly stimulates cells to secrete estrogen. This statement is false. In the first week of the menstrual cycle, LH stimulates the theca cells to secrete androgens while FSH stimulates the granulosa cells to synthesize estrogens. It is only by the second week of the cycle that granulosa cells become sensitive to LH.
  - B. At high concentrations, estrogen inhibits the release of LH and FSH. This statement is false. High concentrations of estrogen are actually responsible for the midcycle spike in LH and FSH; low concentrations of estrogen earlier in the cycle, however, do inhibit LH and FSH secretion.
  - C. Progesterone is synthesized from testosterone by the action of aromatase. This statement is false. This is true of estrogens, specifically estradiol. Progesterone is earlier in the steroid biosynthetic pathway than testosterone.
  - D. LH is secreted from the hypothalamus and FSH is secreted from the anterior pituitary. This statement is false. LH and FSH are both secreted from the anterior pituitary.
  - E. Estrogen increases the expression of receptors for progesterone in some of its target cells. This statement is true; this effect is called "estrogen priming."

Therefore, the correct answer is E.

3. Let's go through each of the choices.

A. Müller cells are glial cells that help photoreceptor cells maximize light absorption. This statement is true; in addition to metabolic support, Müller cells funnel light to photoreceptors, analogous to fiber-optic cables.

- B. Nearsightedness can be corrected by convex lenses. This statement is false. Nearsightedness is correct using concave lenses.
- C. The fovea contains a high concentration of rods. This statement is false. The fovea is the region of the retina with the highest concentration of cones.
- D. A rod with inactive rhodopsin molecules would not allow  $Na^+$  to enter it. This statement is false. Inactive rods are depolarized and permeable to sodium.
- E. Retinal is a derivative of Vitamin C. This statement is false. Retinal is a derivative of vitamin A.

Therefore, the correct answer is A.

4. Wernicke's area is responsible for language comprehension, while Broca's area is responsible for speech production. Since Wernicke's area is located in temporal lobe, the correct answer is B.
5. Again, let's go through each option.

A. Skeletal muscle: Dense bodies, which are mostly made of anchoring proteins, are important here. This statement is false. Dense bodies are found in smooth muscle, not skeletal muscle.

B. Cardiac muscle: Desmosomes in intercalated disks are responsible for the synchronized contraction of the heart. This statement is false. Gap junctions in cardiac muscles are responsible for the synchronized contraction of the heart.

C. Skeletal muscle: Creatine phosphate is the primary source of energy for longer aerobic exercises here. This statement is false. Creatine phosphate is a short-term source of energy that allows for extremely rapid production of ATP at the beginning of a muscle contraction.

D. Skeletal muscle: Binding of ATP to myosin causes its disassociation from actin. This statement is true.

E. Smooth muscle: The DHP receptor is connected to the ryanodine receptor through foot proteins, thus releasing  $Ca^{2+}$  from the sarcoplasmic reticulum. This statement is false. DHP receptors are characteristic of skeletal muscle; smooth muscles have L-type calcium channels.

Therefore, the correct answer is D.

6. Again, we analyze each option.
- A. Usage of triamterene, a diuretic that decreases sodium reabsorption in the cortical collecting duct. This statement is false. Sodium absorption in the cortical collecting duct occurs through  $Na^+$  channels, which has no effect on potassium reabsorption.
- B. Increased activity of  $H^+/K^+$  ATPases throughout the renal tubule in response to moderate ketoacidosis. This statement is false.  $H^+/K^+$  ATPases in the renal tubule are involved in the import of potassium and export of hydrogen; increased activity of these ATPases would lead to higher potassium levels in the body.
- C. Administration of enalapril, an ACE inhibitor, due to hypertension. This statement is false. ACE is a part of the RAAS which leads to aldosterone release; since aldosterone increases potassium secretion, inhibiting it would lead to decreased potassium secretion and higher potassium levels in the body.
- D. Usage of furosemide, a diuretic that decreases sodium reabsorption in the loop of Henle. This statement is true. Sodium absorption in the loop of Henle occurs through NKCC cotransporters; inhibiting these leads to higher potassium in the urine and thus lower potassium in the body.
- E. Partial death of juxtaglomerular cells due to the ingestion of a toxin. This statement is false. Like with option C, inhibiting the RAAS leads to higher potassium levels in the body.
- Therefore, the correct answer is D.
7. Beetles are insects, which primarily undergo meroblastic cleavage, not holoblastic cleavage. Beetles do actually have a fast block to polyspermy (unlike most insects). The main indicator, however, should be holoblastic cleavage. The answer should be E.
8. The primary effector cells against viral infections are T cells, corresponding to option C.
9. The vitamin primarily implicated in clotting is vitamin K, or phylloquinone (option B).
10. This question is just memorization of embryonic limb regions. The answer is C.
11. Notice that pancreatic lipases are the primary enzymes involved in fat digestion (salivary lipases only have a limited amount of time and the stomach does not produce lipases). Thus, we can immediately eliminate options A, B, and E. Finally, since fats are absorbed through lacteals

(not the circulatory system), the correct answer is C.

12. Again, we go through each option.

A. If a loss-of-function genetic mutation is induced at the 11p15.5 locus, which codes for tyrosine hydroxylase, I. ntelligent will have trouble sleeping at night. This statement is false. Tyrosine hydroxylase is involved in the production of dopamine, norepinephrine, and epinephrine from tyrosine, while the main hormone involved in sleep is melatonin (which is derived from tryptophan).

B. In I. ntelligent, Na influx through the NMDA receptor causes the closing of AMPA channels in presynaptic neurons, allowing for LTP to occur. This statement is false. In LTP, calcium influx through the NMDA receptor causes the insertion of AMPA receptors.

C. Atropine, a chemical that dilates pupils by inhibiting metabotropic ACh channels, has the opposite effect of muscarine on the I. ntelligent nervous system. This statement is true. Metabolic ACh receptors are muscarinic, and atropine is a muscarinic antagonist; thus, atropine and muscarine have opposite effects.

D. If a genetic mutation is induced that causes loss of function in 5-HT2a receptors, LSD's hallucinogenic effects on members of I. ntelligent will be amplified. This statement is false. LSD is partially due to hyperstimulation of serotonin pathways.

E. Sarin, a potent inhibitor of acetylcholinesterase, can cause fatal muscle relaxation if administered to members of I. ntelligent. This statement is false. Sarin leads to pathological muscle contraction leading to spastic paralysis.

Therefore, the correct answer is C.

13. FRET is commonly used to observe protein-protein interactions. Thus, the answer is B.
14. Notice that B-cells and plasma cells likely have the lowest smooth ER:rough ER ratio, because they are specialized in protein secretion. Hepatocytes have the highest ratio since one of their main functions is detoxification, which is done by smooth ER. Thus, we narrow down the possible options to III, IV, I, II and III, IV, II, I. Only one of these options is an answer choice, option A.
15. Remember that the replication fork proceeds in both directions, so the total copying speed of the genome is 2000 nt/s. We compute  $\frac{4.6 \cdot 10^6 \text{ nt}}{2000 \text{ nt/s}} \cdot \frac{1 \text{ min}}{60 \text{ s}} = 38.3$ . This is closest to option B.

16. Hfr cells are named for their high frequency of recombination, due to their integrated F factor; they definitely do not lack conjugation. The answer is  E.
17. The interior of plasma membrane is hydrophobic, so a significant portion of residues in a transmembrane portion should be hydrophobic. However, option  C has almost all hydrophilic side chains.
18. Intracellular receptors bind to hydrophobic molecules. Option  E has two hydrophilic amine groups, so it is the most hydrophilic.
19. Cortisol is a steroid and thus binds to an intracellular receptor, without need for second messengers like cAMP. Therefore,  E is the false statement.
20. p53 (the "guardian angel of the genome") and BRCA1 (another protein involved in DNA repair) are both tumor-suppressor genes, while Ras (part of a signaling pathway that activates mitosis) and EGF (epidermal growth factor) are both proto-oncogenes. The option containing both of the proto-oncogenes is  C.
21. snRNAs ( E) are the RNAs in the spliceosome and crucial to its catalytic activity; they are not "scaffolds."
22. We want to find the person whose STR bands are those found in the crime scene. Note that P1P2 and P1P3 both share bands with CS. The common denominator is P1, or Euna (option  A).
23. The fact that the disease is not present equally in males and females suggests that it is X-linked. Since the affected I-1 and 1-2 have an unaffected child, the disease must be dominant (not recessive). For the same reason, 1-2 must have a wild-type allele, so her genotype must be  $X^A X^a$ , or option  D. Checking the pedigree more rigorously confirms this.
24. In HWE, the allele frequencies are fixed at p and q and the genotype frequencies are also fixed (*at*  $p^2$ ,  $2pq$ , and  $q^2$ ). Thus, option  E is the incorrect statement.
25. The scenario describes selection for an intermediate phenotype, which is stabilizing selection (option  C).
26. Consider the parental genotype bEC and the DCO genotype bEc (these can be identified by their frequencies). Notice that the allele for gene C is the difference between the two, so gene C is in between genes B and E. The only option that has this is option  B.
27. This question is just memorization of inheritance patterns. Through process of elimination, we can narrow down our options to choice  D.

Rett Syndrome is, in fact, often inherited through an X-linked dominant pattern.

28. Based on the descriptions of the groups, we're looking for a SNP with low occurrence in group 1, high occurrence in group 2, and roughly 50% occurrence in group 3. The SNP that matches this is Ch9 B922744 T, which denotes a thymine SNP on chromosome 9 (option C).
29. TUBA1A and XPB are most likely pleiotropic given that they affect "basic" cellular functions. PAH causes phenylketouria, a complex disease with symptoms in many different organ systems. LCT mutations cause a lactase deficiency, which only leads to lactose intolerance. Thus, the answer is B.
30. In option D, both parents have the same allele for all genes on each chromosome, so no recombination could have occurred.
31. The lowest level of pigmentation occurs when there are 0 dominant alleles, and the highest level of pigmentation occurs when there are  $2 \cdot 5 = 10$  dominant alleles. Thus, the number of possible phenotypes is  $10 - 0 + 1 = 11$ , or option B.
32. Observe that gg females have all golden children, while Gg or GG females have all black children. Thus, dragon color appears to be a maternal-effect gene. The F2 offspring of the F1  $Gg \times Gg$  cross will be in the ratio 1 GG: 2Gg: 1 gg. The only relevant factor in dragon color phenotype is the maternal genotype; dragons will only be golden if the mother has a gg genotype. Thus, the ratio between black F3 dragons to golden dragons is 3 (if the F2 mother is GG or Gg) to 1 (if the F2 mother is gg). This is option C.
33. Only options A and C are related to plant defense. Salicylic acid is more involved in pathogen defense, leaving jasmonic acid (option C) as the correct choice.
34. Vessel elements are not found in conifers; their xylem consists solely of tracheids. B is thus the answer.
35. The continuous ring of vascular tissue seen in the section is most characteristic of monocot roots (option A). Additionally, the multi-layer epidermis called the velamen is characteristic of epiphytic orchids, which are monocots.
36. We examine each answer option.
  - A. Double fertilization is an ancestral trait to all angiosperms. This statement is false. Double fertilization is a derived trait of angiosperms, according to the diagram.

- B. Seeds are a derived trait to all plants. This statement is false. Seeds are only found in gymnosperms and angiosperms, not all plants.
- C. Mosses and hornworts are direct descendants of liverworts. This statement is false. Although mosses, hornworts, and liverworts descended from a common ancestor, mosses and liverworts did not directly descend from liverworts.
- D. The length of the line segment is an exact measurement of time since divergence. This statement is false. There is no time scale given, and the points of divergence are too evenly spaced and linear to accurately represent divergence time.
- E. Embryonic protection is a derived trait to land plants. This statement is true.

Therefore, the correct answer is E.

37. According to the ABCDE hypothesis, gene A by itself produces sepals, genes A and B together produce petals, genes B and C together produce stamens, and gene C by itself produces carpels. Gene D is involved in the production of ovules and gene E is expressed in the whole flower. Therefore, a plant with genes B, C, D, and E (option D) would be able to produce carpels and thus megasporangia (it would only lack sepals).
38. Vascular rays are usually composed of parenchyma cells, not sclerenchyma cells. (Option E is thus the false statement.)
39. Ethylene, not brassinosteroids, is the hormone involved in fruit ripening. Thus, we can immediately eliminate options C and E. Furthermore, fruits are not photosynthetic, so we can eliminate option B. This leaves us with option A. By remembering that climacteric fruits are characterized by a rise/peak in ethylene and respiration rate after detachment from the parent plant (or by using word roots; note the similarity between "climax" and "climacteric"), we identify the solid lines as representing climacteric fruit and the dotted lines as representing non-climacteric fruit. Thus, the answer is D.
40. This is another memorization question; this time, one on the types of fruits. As a logical hint, notice that pomegranates (option E) have one pericarp that does not appear to be derived from fusion in any way, making them unlikely to be multiple fruits.
41. A fixed action pattern is defined as a behavior that is triggered by a sign stimulus and always runs to completion. Option D best describes this.
42. Flashy male displays are hypothesized to be a product of sexual selection; they indicate the high fitness of the male implied by the extra

energy that could have gone to survival instead spent on the display.  
This corresponds to option B.

43. Pay attention to the double negative. It's asking for the correct answer, which happens to be D. Birds have larger cerebellums as compared to reptiles in order to accomodate the complex, 3-dimensional process of flight.
44. The description of highly territorial behavior among the animals suggests that they have an uniform distribution. We then perform the mark-and-recapture calculation:  $5/x = 3/17$  to approximate the population's size as 28. Combining these, we arrive at option B.
45. All of the options except choice B are inconsistent with the graph. Option A is incorrect because the small fry population actually increased, option C is incorrect because the slurp fish population actually decreased, option D is incorrect because the small fry population actually increased, and option E is incorrect because the phytoplankton population actually increased.
46. First, we compute the Shannon's diversity index:  
$$H = -\frac{5}{43} \ln\left(\frac{5}{43}\right) - \frac{3}{43} \ln\left(\frac{3}{43}\right) - \frac{10}{43} \ln\left(\frac{10}{43}\right) - \frac{25}{43} \ln\left(\frac{25}{43}\right) = 1.09.$$
 Thus, statement II is false. Statement I is true because the procedure would increase species evenness, while statement III is false because the procedure would decrease species evenness. Therefore, the answer is A.
47. C. This is a basic assessment of the definitions of primary/secondary succession and pioneer species. (Refer to Campbell's chapter 54).
48. The introduced species would decrease predator populations and thus increase herbivore populations, which would decrease algal populations. This corresponds to option B.
49. B. Chytrids also have flagella.
50. C. Invertebrates, despite being chordates, do not have a backbone.

## 5.4 Solutions to Practice Exam 2

1. The patient presents with rapid weight gain and cold intolerance, which are classic symptoms of hypothyroidism (insufficient thyroxine production). Levothyroxine is a synthetic form of thyroxine used to treat this condition. Options A and E relate to calcium homeostasis and the parathyroid gland, which are unrelated to the patient's specific metabolic symptoms. Options C and D are anti-inflammatory drugs that would not address the underlying hormonal deficiency. Therefore, the correct answer is **[B]**.
2. The histological image displays neurofibrillary tangles, which are intracellular aggregates of hyperphosphorylated tau proteins. These tangles are a hallmark pathological feature of Alzheimer's disease. Parkinson's disease (A) typically involves the loss of dopaminergic neurons in the substantia nigra. Huntington's disease (D) involves neuronal death in the striatum, while Creutzfeldt-Jakob disease (E) presents with spongiform encephalopathy. Therefore, the correct answer is **[B]**.
3. The diagram illustrates that high concentrations of calcium ions ( $Ca^{2+}$ ) inhibit the influx of sodium ions ( $Na^+$ ) through voltage-gated channels. Since  $Na^+$  influx is essential for the depolarization phase of the action potential, its inhibition prevents the nerve terminal from reaching the threshold required to trigger synaptic vesicle fusion and neurotransmitter release. Consequently, this leads to reduced muscle stimulation and function. Therefore, the correct answer is **[B]**.
4. A Bohr shift is characterized by a rightward shift of the oxygen-hemoglobin dissociation curve, indicating a decreased affinity of hemoglobin for oxygen. This effect is promoted by conditions such as low pH (acidosis), high  $P_{CO_2}$ , and increased temperature. Severe dehydration (II) can lead to metabolic acidosis due to poor tissue perfusion. Excessive consumption of carbonated drinks (III) introduces carbonic acid, potentially contributing to acidosis. In contrast, hypophosphatemia (IV) reduces 2,3-BPG levels, causing a leftward shift (increased affinity). Therefore, the correct answer is **[C]** (II and III).
5. Metyrapone inhibits  $11\beta$ -hydroxylase, the enzyme responsible for the final step of cortisol synthesis. This inhibition leads to a decrease in serum cortisol levels. The reduction in cortisol removes the negative feedback inhibition on the hypothalamus and anterior pituitary, resulting in a compensatory surge in ACTH secretion. Therefore, the correct answer is **[C]**.
6. Epinephrine exerts its effects by binding to  $\alpha$ - and  $\beta$ -adrenergic receptors, which are members of the G-protein coupled receptor (GPCR) superfamily. These receptors activate intracellular signaling cascades

involving second messengers. Receptor tyrosine kinases are typically activated by growth factors (e.g., insulin), not catecholamines. Ion-gated channels and nuclear receptors do not represent the primary signaling mechanism for epinephrine. Therefore, the correct answer is A.

7. The clinical presentation of a "cherry-red spot" on the macula and progressive loss of motor skills is characteristic of Tay-Sachs disease. This autosomal recessive disorder is caused by a deficiency in the enzyme hexosaminidase A, leading to the accumulation of GM2 gangliosides in neuronal lysosomes. While Sandhoff disease involves hexosaminidases, it affects both A and B isozymes, whereas the prompt specifies hexosaminidase A. Therefore, the correct answer is C.
8. Vitamin K is essential for the synthesis of clotting factors; deficiency results in coagulopathy and excessive bleeding (B). Vitamin B3 (niacin) deficiency causes pellagra, characterized by dermatitis, diarrhea, and dementia (fatigue/coordination). Vitamin B5 (pantothenic acid) is a component of Coenzyme A; deficiency impairs energy metabolism, leading to fatigue and muscle cramps. Impaired immune function is more typically associated with deficiencies in Zinc or Vitamin C, rather than the specific B/K vitamins listed. Therefore, John is least likely to experience E.
9. Lipid nanoparticles (LNPs) encapsulate mRNA, protecting it from nuclease degradation and facilitating cellular uptake. While effective, unmodified LNPs are rapidly cleared from the circulation by the reticuloendothelial system (primarily the liver and spleen) as foreign particulates. Therefore, they do not inherently provide a long circulation period without specific surface modifications like PEGylation. Option D is the false statement.
10. The patient presents with elevated ACTH levels alongside low cortisol and aldosterone. High ACTH suggests the pituitary is functioning normally and attempting to stimulate the adrenal cortex. The failure of the adrenals to produce hormones despite this stimulation indicates primary adrenal insufficiency, also known as Addison's disease. This explains the hyponatremia (low aldosterone) and hypoglycemia/fatigue (low cortisol). Therefore, the correct answer is B.
11. During the cardiac cycle, ventricular systole begins with contraction, causing a rapid rise in intraventricular pressure. When ventricular pressure exceeds atrial pressure, the atrioventricular (mitral and tricuspid) valves close to prevent backflow. This event marks the onset of isovolumetric contraction, where pressure increases without a change in ventricular volume. Therefore, the correct answer is B.
12. Leukocytes are classified into granulocytes and agranulocytes. Neutrophils are granulocytes and are the most abundant type of white

blood cell in the peripheral blood, typically comprising 50-70% of the total leukocyte count. They function as the primary responders to bacterial infections. Therefore, the correct answer is **E**.

13. Pleiotropy refers to a single gene influencing multiple distinct traits. Tubulin- $\alpha$  (I) is a core component of the cytoskeleton and is required for cell division, intracellular transport, and development across many tissues. Thus, it affects numerous phenotypes and is pleiotropic. SLC45A2 (II) regulates melanin production and transport, influencing pigmentation of the skin, hair, and eyes, making it pleiotropic as well. PAH (V) mutations cause phenylketonuria, which produces multiple systemic effects including metabolic, neurological, and developmental abnormalities, demonstrating pleiotropy. In contrast, OCA2 (III) primarily affects eye pigmentation, and 9q34 (IV) determines blood type only, so neither is pleiotropic. Therefore, the correct answer is **B** (I, II, V).
14. The Western blot data demonstrates that siRNA-mediated knockdown of FEMBAO results in a concomitant decrease in SOX9 protein levels. This indicates that FEMBAO is required for SOX9 expression, placing FEMBAO upstream of SOX9 in the regulatory pathway. If FEMBAO were downstream, its depletion would not affect the levels of the upstream regulator SOX9. Therefore, statement **A** is the correct interpretation.
15. The cristae of the inner mitochondrial membrane serve to significantly increase the surface area available for the electron transport chain (ETC) complexes and ATP synthase. If the cristae were "unflattened" (reducing the folding), the surface area would decrease, limiting the number of ETC units and thereby reducing the efficiency of cellular respiration and ATP production. Therefore, the correct answer is **D**.
16. The lac operon is maximally expressed when glucose is low (leading to high cAMP) and lactose is present (removing the repressor). The addition of a cAMP phosphodiesterase (PDE) inhibitor would prevent cAMP degradation, further elevating intracellular cAMP levels. This would enhance the binding of the cAMP-CRP complex to the promoter, potentially increasing transcription beyond normal maximal levels. In the second scenario (high glucose), basal cAMP is low; the inhibitor would raise cAMP levels, increasing transcription compared to the uninhibited state. Thus, expression levels would be higher in both cases compared to their respective controls. Therefore, the correct answer is **A**.
17. Gaucher's disease is a lysosomal storage disorder caused by a hereditary deficiency of the enzyme glucocerebrosidase. This defect impairs the catabolism of glucocerebroside, leading to the accumulation of lipids

within the lysosomes of macrophages. Therefore, the pathology is localized to the lysosomes, corresponding to option C.

18. Analyzing the Lineweaver-Burk plots relative to the uninhibited control (black line): Mixture 1 (DESTROYER) shows an increase in the y-intercept ( $1/V_{max}$ ) with an unchanged x-intercept, characteristic of \*\*Noncompetitive\*\* inhibition. Mixture 2 (BETA) shows parallel lines (decreases in both  $K_m$  and  $V_{max}$ ), characteristic of \*\*Uncompetitive\*\* inhibition. Mixture 3 (BOMB) shows an increase in the x-intercept ( $-1/K_m$ ) with an unchanged y-intercept, characteristic of \*\*Competitive\*\* inhibition. Therefore, the correct answer is E.
19. Fluorescence Resonance Energy Transfer (FRET) is a technique used to detect physical interactions between two proteins in living cells. Energy transfer only occurs if the fluorophores attached to the proteins are in extremely close proximity (typically within 10 nm), indicating direct affinity. Other techniques listed do not directly measure dynamic protein-protein interactions in this manner. Therefore, the correct answer is C.
20. The molecule shown in option B is Tryptophan. Tryptophan is an essential amino acid that serves as the biochemical precursor for serotonin (a neurotransmitter regulating mood and anxiety) and melatonin (a hormone regulating sleep-wake cycles). A deficiency in tryptophan would impair the synthesis of these molecules, explaining the patient's symptoms of insomnia, anxiety, and memory impairment.
21. This experiment utilizes a competitive binding assay format. The patient's antibodies and the fluorophore-labeled antibodies compete for binding sites on the fixed peanut antigen. A high concentration of peanut-specific antibodies in the patient's blood will block the binding of the labeled antibodies, resulting in a decrease in the fluorescence signal. Conversely, a low concentration of patient antibodies allows more labeled antibodies to bind, yielding a higher signal. Therefore, the correct answer is D.
22. NEP55 and L68 are proteins associated with the inner nuclear membrane and nuclear lamina. During the onset of mitosis, phosphorylation of the nuclear lamina induces its depolymerization. This process triggers the disassembly of the nuclear envelope, which is necessary to allow spindle microtubules to access the chromosomes. Therefore, the correct answer is C.
23. Negative frequency-dependent selection occurs when the fitness of a phenotype decreases as it becomes more common. The scale-eating fish *Perissodus microlepis* demonstrates this: when the "left-mouthed" morph becomes abundant, prey species learn to guard their right side, conferring a selective advantage to the rare "right-mouthed" morph.

This leads to oscillation in the frequency of the two phenotypes.  
Therefore, the correct answer is **A**.

24. The recombination frequency is calculated by dividing the number of recombinant offspring by the total number of offspring. The recombinant phenotypes are Gray/Vestigial (68) and Black/Normal (74).  
Calculation:  $\frac{68+74}{653+68+628+74} = \frac{142}{1423} \approx 0.0998$ . Since 1% recombination frequency equals 1 map unit (centimorgan), the distance is approximately 9.98 map units. Therefore, the correct answer is **B**.
25. For an X-linked recessive trait, the frequency of affected males corresponds directly to the allele frequency  $q$ , as males are hemizygous. Given  $q = 0.26$ , the frequency of the wild-type allele is  $p = 1 - 0.26 = 0.74$ . The frequency of female carriers (heterozygotes) is calculated as  $2pq = 2(0.74)(0.26) \approx 0.3848$ , or 38%. Therefore, the correct answer is **C**.
26. To find the probability that IV-1 is affected by the autosomal recessive trait, consider all possible carrier statuses of II-2 and II-4. If both II-2 and II-4 are heterozygous carriers, the probability is  $\frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{2} \cdot \frac{1}{4} = \frac{1}{64}$ . If one of II-2 or II-4 is homozygous recessive and the other is heterozygous (two symmetric cases), the combined probability is  $2 \cdot (\frac{1}{4} \cdot \frac{1}{2} \cdot 1 \cdot \frac{1}{2} \cdot \frac{1}{4}) = \frac{1}{32}$ . If both II-2 and II-4 are homozygous recessive, the probability is  $\frac{1}{4} \cdot \frac{1}{4} \cdot 1 \cdot 1 \cdot \frac{1}{4} = \frac{1}{64}$ . Summing all valid scenarios gives  $\frac{1}{64} + \frac{1}{32} + \frac{1}{64} = \frac{1}{16}$ . Therefore, the correct answer is **D**.
27. Hardy-Weinberg equilibrium describes a theoretical state where a population's allele and genotype frequencies remain constant from generation to generation. The conditions for this state are random mating, no migration (gene flow), large population size, no mutations, no natural selection. The phenotypic variations are not controlled for in Hardy Weinberg equilibrium so A is correct.
28. In a case of overdominance (heterozygote advantage), the equilibrium frequency of the dominant allele ( $\hat{p}$ ) is determined by the selection coefficients against the homozygotes.  
Selection against AA ( $s_{AA}$ ) =  $1 - 0.7 = 0.3$ .  
Selection against aa ( $s_{aa}$ ) =  $1 - 0.4 = 0.6$ .  
 $\hat{p} = \frac{s_{aa}}{s_{AA} + s_{aa}} = \frac{0.6}{0.3+0.6} = \frac{0.6}{0.9} = \frac{2}{3}$ .  
Therefore, the correct answer is **A**.
29. Topoisomerases are enzymes that regulate the topological state of DNA. During replication, helicase unwinds the DNA, creating positive supercoils ahead of the replication fork. Topoisomerase functions to \*relieve\* this torsional strain by introducing transient breaks in the DNA backbone, not to promote supercoiling. Therefore, the function listed in option **B** is incorrectly matched.

30. For tetrad analysis, the map distance between two genes is calculated using the formula  $\frac{T+6NPD}{2(\text{Total Ascii})} \cdot 100$ . Here, the total number of ascii is  $200 + 42 + 33 = 275$ . Substituting the given values gives  $\frac{33+6(42)}{2(275)} \cdot 100 = \frac{285}{550} \cdot 100 = 51.8$  map units. Therefore, the correct answer is A.
31. For a new neutral mutation in a diploid population of size  $N$ , the initial frequency is  $1/(2N)$ . This represents the probability of fixation. The probability of elimination is therefore  $1 - 1/(2N)$ . For  $N = 125$ , fixation probability is  $1/250 = 0.004$ , so elimination probability is  $0.996$  (99.6%). The average time to fixation for a neutral allele that becomes fixed is  $4N$  generations, which is  $4 \times 125 = 500$  generations. Therefore, the correct answer is A.
32. For additive quantitative traits controlled by three genes, the distribution of phenotypes follows the sixth row of Pascal's triangle (since pointiness ranges from 0 to 6), giving counts of 1, 6, 15, 20, 15, 6, and 1 out of 64. Offspring with fewer than 5 points correspond to the categories with 0 through 4 points, so their probabilities sum to  $1 + 6 + 15 + 20 + 15 = 57$  out of 64. Therefore, the correct answer is D.
33. The image depicts interveinal chlorosis on an older leaf. Magnesium is a central component of the chlorophyll molecule and is a phloem-mobile nutrient. During a deficiency, plants translocate magnesium from older leaves to support younger, developing tissues, resulting in the characteristic yellowing of older leaves while veins remain green. Therefore, the correct answer is C.
34. Uncoupling proteins dissipate the mitochondrial proton gradient by allowing protons to leak back into the matrix, bypassing ATP synthase. This drastically reduces ATP production. Root cation exchange relies on proton pumps ( $H^+$ -ATPases) that actively transport protons out of the root cells into the soil to displace cations. These pumps are ATP-dependent. A lack of ATP due to uncoupling would therefore directly inhibit cation exchange. Therefore, the correct answer is B.
35. During the germination of grass seeds (like barley), the embryo secretes gibberellins (GA), which signal the aleurone layer to synthesize hydrolytic enzymes such as  $\alpha$ -amylase. These enzymes degrade the starch stored in the endosperm into sugars. The solubilized nutrients are then absorbed by the scutellum (a modified cotyledon) and transported to the growing embryo. Therefore, the correct answer is C.
36. This question is testing total DNA yield after meiosis and subsequent gametophyte development, not the number of meiotic divisions. A microsporocyte undergoes meiosis to form four viable haploid microspores, each of which develops into a pollen grain, so the total final

DNA derived from the microsporocyte is proportional to  $4 \times (S/2) = 2S$ . A megasporocyte also undergoes meiosis to form four haploid megaspores, but three degenerate, leaving only one functional megasporule that develops into the female gametophyte, giving a total final DNA of  $S/2$ . Therefore, the ratio of final DNA from the microsporocyte to that from the megasporocyte is  $2S : (S/2) = 4$ , making **[D]** the correct answer.

37. This is secondary xylem from an angiosperm, so the conducting cells are vessel elements rather than tracheids. The arrows indicate perforation plates which are the open end walls between vessel elements that allow efficient water flow. Thus, the correct answer is **[B]**.
38. Removing A allows C to expand into whorl 1, producing carpels, while B does not expand. In whorl 2, A is absent so B remains and C invades, giving B + C and producing stamens. Whorls 3 and 4 are unaffected and develop normally as stamens and carpels. The final pattern is carpel, stamen, stamen, carpel, which maximizes fruit yield because it produces two carpels and two stamens. Therefore, the correct answer is **[A]**.
39. Mature sieve-tube elements are specialized for translocation and undergo selective autophagy to remove nuclei, ribosomes, and vacuoles, thereby reducing resistance to phloem flow. However, they remain metabolically active and retain specific organelles, notably mitochondria and a modified smooth endoplasmic reticulum (ER). Therefore, the correct answer is **[D]**.
40. Option **[E]** is the correct answer because the fluorescent markers are specific to the vascular tissue (xylem and phloem). Option E describes fluorescence percolating into the cortex (tissue surrounding the vascular cambium) and the pith (inner part of the stem), which are ground tissues, not vascular tissues. It is important to note that fusiform initial cells are elongated, vertically oriented cells that give rise to the axial vascular system, while ray initial cells are rectangular and grow horizontally to form vascular rays; this distinction supports answer choice B. All other answer choices correctly describe either the functions of the vascular tissue (C) or the expected localization of the markers within the vascular tissue (A, D).
41. An indicator species is an organism whose presence, absence, or physiological condition serves as a proxy for the overall health or environmental integrity of an ecosystem. In this scenario, the jackrabbit's color change in response to pollution acts as a visible bio-indicator. The reversion to normal color upon environmental cleanup confirms its role as an indicator of ecosystem recovery. Therefore, the correct answer is **[C]**.

42. D is correct because Wasmannian mimicry involves organisms mimicking their host's behavior or appearance to integrate into the same colony, rather than avoiding predators or deceiving prey. To keep them straight: Batesian is harmless mimicking harmful, Müllerian is harmful mimicking harmful, Vavilovian is a weed mimicking a crop, Wasmannian is mimicking a host within a colony, and Emsleyan is deadly mimicking harmless.
43. The scenario calls for a forest management strategy that balances economic resource extraction (timber) with ecological preservation (preventing erosion and fragmentation). Selective cutting involves the removal of specific mature or defective trees while leaving the majority of the forest canopy and soil structure intact. This method minimizes soil erosion and maintains habitat continuity, unlike clear-cutting. Therefore, the correct answer is C.
44. K-selected species are characterized by traits that maximize competitive ability in stable environments near carrying capacity. These traits typically include large body size, long lifespan, late maturity, and production of few offspring with high parental investment. Among the choices, the elephant exemplifies this life history strategy. The other options (mosquito, salmon, frog, mouse) exhibit r-selected traits. Therefore, the correct answer is A.
45. Negative reinforcement describes a process where a behavior is strengthened (increased in frequency) because it results in the removal or avoidance of an aversive stimulus. Scenario C describes a rat pressing a lever to terminate an electric shock. The removal of the shock reinforces the lever-pressing behavior. Scenario A is punishment, while scenarios B and E represent positive reinforcement.
46. To establish a new behavior rapidly, a reinforcement schedule that provides a clear and predictable contingency is most effective. A Fixed Ratio (FR) schedule delivers reinforcement after a set number of responses, generating a high response rate and rapid acquisition. While continuous reinforcement is fastest, among the intermittent options provided, Fixed Ratio typically produces higher response rates than interval schedules. Given the goal of rapid learning without concern for long-term persistence, the correct answer is A.
47. A is correct because the bird's warning call increases the risk to itself by potentially attracting the predator while providing a benefit to others by alerting them to danger, which fits the definition of altruism. The other choices either directly increase the individual's own reproductive success, are unrelated to altruistic behavior, or are unrealistic.
48. Mate choice copying is a form of social learning where an individual's mate preference is influenced by the observed choices of conspecifics. In

this scenario, the female guppy overrides her innate preference for orange males after observing another female select a yellow male. She copies this behavior, inferring that the yellow male possesses superior quality based on the social cue. Therefore, the correct answer is C.

49. Analysis of the phylogenetic tree reveals: Statement I is correct because the group containing Common Ancestor 1 and viruses 1-5 excludes the lineage leading to viruses 6-10, making it paraphyletic. Statement II is incorrect; separate nodes imply distinct ancestral populations with genetic differences. Statement III is correct because Virus 8 and the clade stemming from Common Ancestor 1 branch from the same node, making them sister taxa. Therefore, the correct answer is C (I and III).
50. The structure described is the ocelloid, a highly complex, eye-like organelle found in certain dinoflagellates (e.g., family Warnowiaceae). It contains subcellular components analogous to a cornea, lens, iris, and retina, which are derived from mitochondria and plastids. This organelle functions in light perception and possibly prey detection. Therefore, the correct answer is A.

## 6. Conclusion

### 6.1 Concluding Thoughts

As you begin your USABO preparation, we wish you luck. That being said, here are some final tips to help you prepare:

- Keep a consistent study schedule – USABO is a marathon, not a sprint.
- Explore the subjects that interest you, many of the Semis FRQs require knowledge outside of the textbooks.
- In the final weeks before the exam, practice active recall and hone problem solving through previous year exam problems.
- The night before the exam, get a good night of sleep, and have a clear idea of exactly how you want to approach the exam.

We hope you enjoy your USABO journey!

### 6.2 About Us

We are Mitosisphere, a student-led nonprofit that creates advanced biology materials. Besides Lamnhaj's Guide to USABO, we have some other initiatives as well.

- **P + Q = 1 Exam Series:** Each year, we host two Opens exams, with the top competitors qualifying to the Semifinals exam.
- **BioBlitz:** A MathDash-style game where players can compete to climb the ranked leaderboards while practicing biology! Check it out here: [bioblitz.net](http://bioblitz.net)
- **Problem of the Day:** On Discord and BioBlitz, we host a Problem of the Day to sharpen your biology skills daily!
- **Mentorship:** A free, personalized 1:1 tutoring program that connects experienced USABO, ISEF, and Research mentors with mentees. You can receive mentorship in anything biology related.

More details about all of our initiatives can be found on our website: [mitosisphere.org](http://mitosisphere.org)

Join our Discord server here: [Discord](#)

If you are interested in what we do, you can apply to join our staff as well! You can help with creating new content, help with outreach, join our technology team, join our community engagement team and help with mentorship, or

become a branch head and expand our reach across international borders! We offer volunteer hours for all work done for Mitosisphere. There is also potential for leadership positions as older members of the nonprofit step down. To apply, visit our website and scroll to the bottom for the staff application form.

### **6.3 Authors and Contributors**

Ethan Guo - Writing - Class of 2026

Jake Rosenblum - Writing - Class of 2027

Shriyan Junnuthulla - Writing - Class of 2027

Srikanth Reddy - Review - Class of 2027

Aarnav Suwal - Writing, Editing, LaTeX - Class of 2028

Abdus-Samad Shaik - Writing - Class of 2027

Vedanth Reddyvari - Writing - Class of 2027

Donelly Qin - Writing - Class of 2027

Brian Lu - Writing - Class of 2028

Aryan Adappa - Writing - Class of 2028

Kedar Sukharamwala - Writing - Class of 2026

Aniketh Gudi - Writing - Class of 2027

Lawrence Sun - Review - Class of 2027

Yuva Gade - LaTeX - Class of 2029

#### **Expert Reviewers:**

Monica Zhang - IBO qualifier - Class of 2024