Lamnhaj's

Guide to USABO

Second Edition

Written by



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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 160 additional subject specific practice questions modeled on real USABO exams.

Please note that ALL questions in sections 5 can be clicked to access their respective solutions, and all solutions in section 5 can be clicked to access their respective questions. The table of contents for this guide is clickable as well.

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 (IMDO).
  - **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, quizbowl 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.

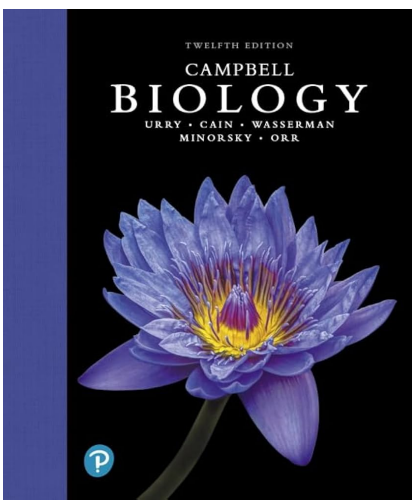
iii. Building intuition about what the question writers are looking to test. At some point, you will have become so accustomed to the style of USABO questions that you can get a large number of questions correct without even reading the question. This intuition can be extremely helpful when you are short on time, especially on Semis.

3. Study Resources

3.1 Textbook Recommendations

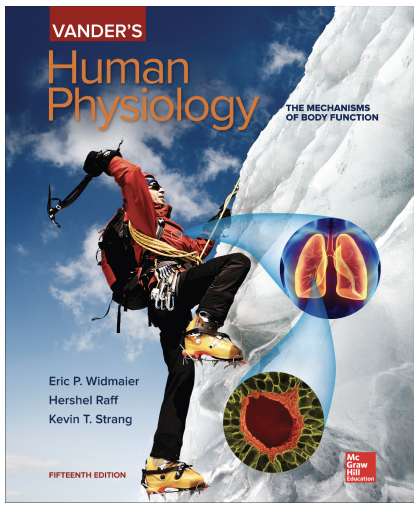
The following textbooks are our recommendations, and although there are alternatives, in our opinion, these are the most useful to study.

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

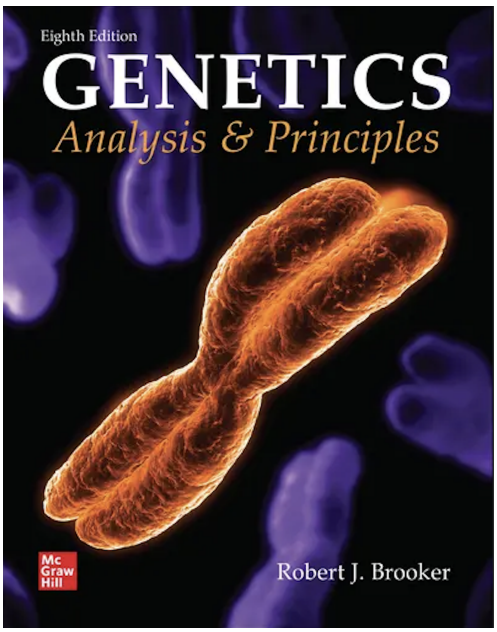
Vander's Human Physiology



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 you 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.

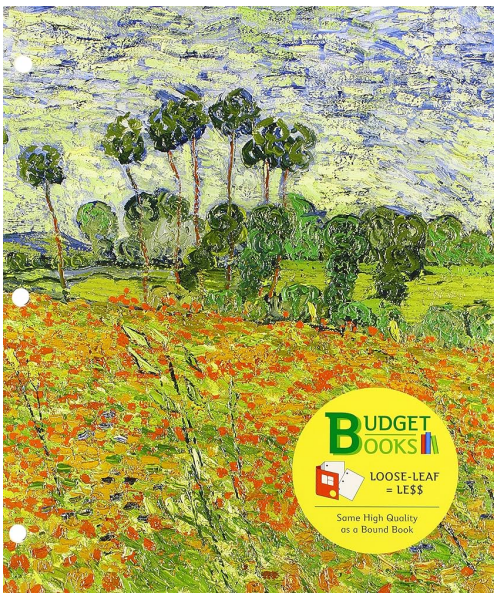
Brooker's Genetics: Analysis and Principles



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.

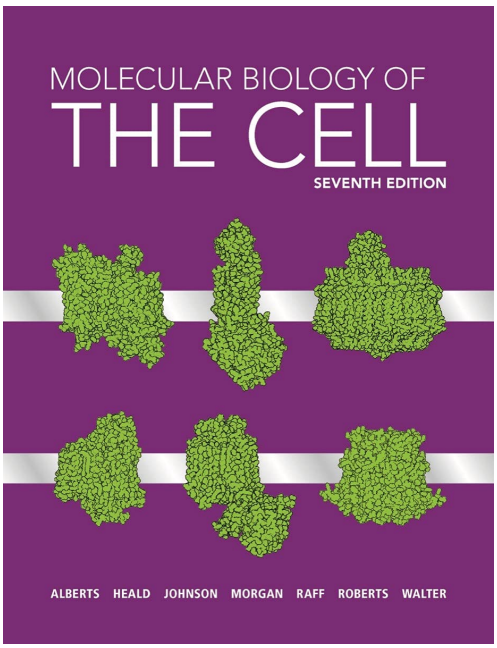
Raven's Plant Biology



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
  - 5/5*****
  - Campbell's 14
- **Non-Mendelian Inheritance**
  - Incomplete dominance, codominance, maternal effect
  - 4/5*****
  - Brooker's 5
- **Epistasis**
  - Dominant & Recessive epistasis ratios
  - 2/5
  - Scitable

Gene Linkage/Recombination

- **Recombination and Chromosomal Alterations**
  - Recombination Frequency, Deletions, Translocations, etc...
  - 4/5*****
  - Brooker's 6, 8
- **Complementation**
  - 3/5
  - MIT video part 1 & part 2
- **Transposition**
  - 2/5
  - Brooker's 10

Population Genetics

- **Hardy-Weinberg**
  - Equilibrium & Equations
  - 5/5*****
  - 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 50, 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 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

4.7 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

4.8 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 to 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

Solutions to Opens Exam 1

Solutions to Opens Exam 2

Subject Specific Questions
- Animal Anatomy & Physiology
- Cell Biology
- Genetics & Evolution
- Plant Biology
- Ecology
- Ethology
- Biosystematics

Solutions to Subject Specific Questions
- Animal Anatomy & Physiology Solutions
- Cell Biology Solutions
- Genetics & Evolution Solutions
- Plant Biology Solutions
- Ecology Solutions
- Ethology Solutions
- Biosystematics Solutions

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

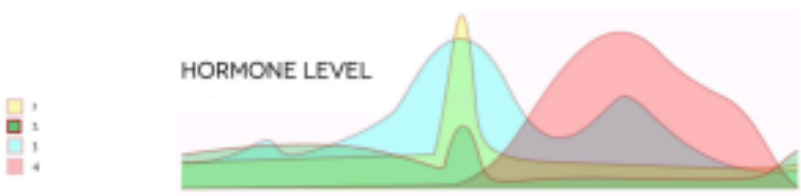
   (b) White pulp of the spleen

   (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 Ca2+ 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

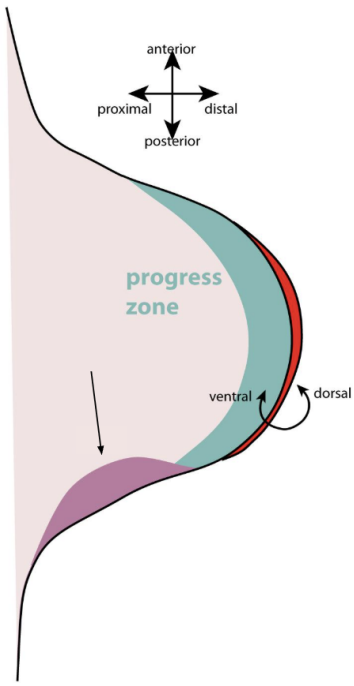
   (b) Phylloquinone

   (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-HT2a 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

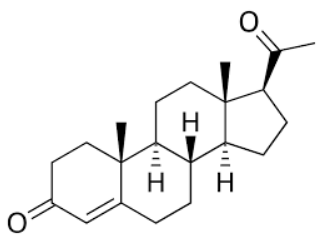
(b) KGCTRHSGGAAAKRHGG

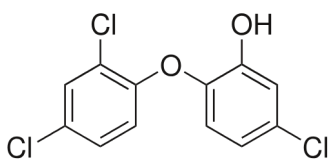
(c) DADEAEDEDGDEGDEAA

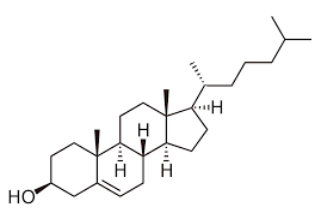
(d) KRHAAGVRHKKTKHRRR

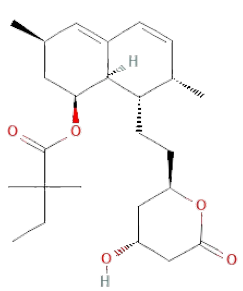
(e) GYRGYKYYFKCYRSAFAY

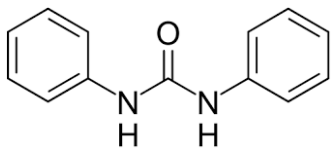
18. The newly discovered Rizz receptor was discovered on the surface of the nuclear membrane. Which of the following molecules would be the LEAST likely to target the receptor?

(a)


(b)


(c)


(d)


(e) 

19. Which of the following about signal transduction mechanisms is INCORRECT?

    (a) PIP2 is converted to DAG and IP3 by phospholipase C

    (b) DAG acts as a secondary messenger by activating protein kinase C and indirectly phosphorylating other proteins involved in signal transduction

    (c) In receptor tyrosine kinases, phosphorylation of the intracellular tyrosine residues attracts signaling molecules

    (d) IP3 acts by releasing additional calcium ions from the ER to act as secondary messengers

    (e) 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?
    I. TP53 (codes for p53)
    II. HRAS (codes for a Ras protein)
    III. BRCA1
    IV. EGF1

    (a) I only

    (b) II and III only

    (c) II and IV only

    (d) I, II, and IV only

    (e) 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?

    (a) miRNAs: Binding to mRNAs, targeting them for degradation and inhibiting translation.

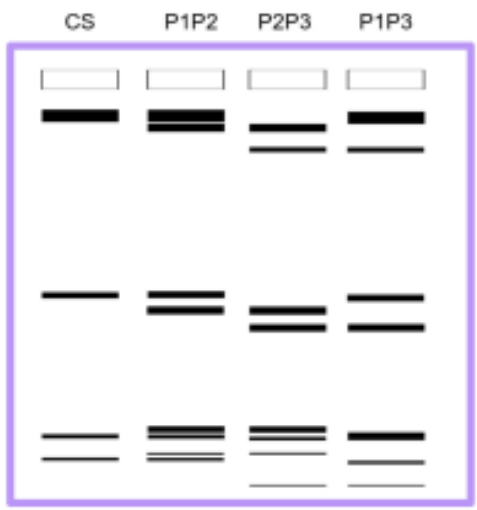
    (b) piRNAs: Protecting the germ cell line from transposable elements

(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 Nathaniels, 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

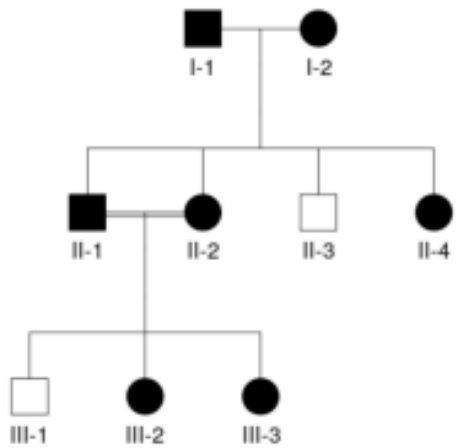
(b) Charles

(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^AX^A

(d) X^AX^a

(e) X^aX^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

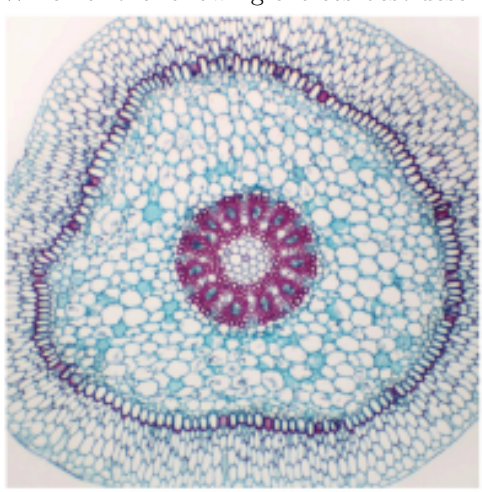
(d) Auxin

(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

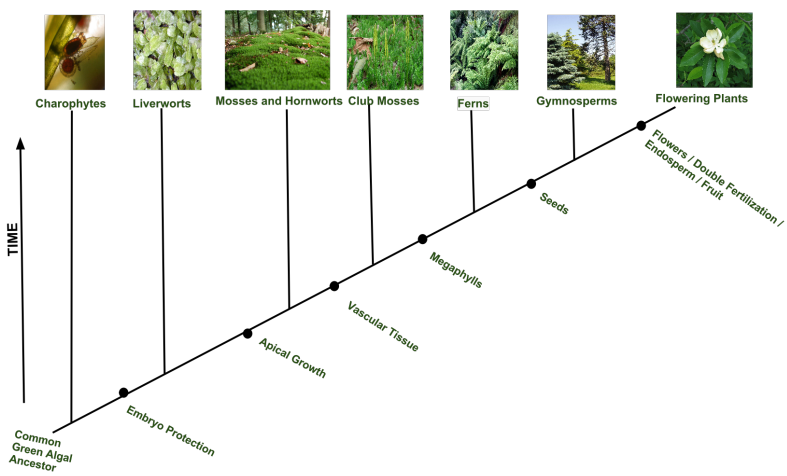
(b) Angiosperm stem

(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 megaspores

(e) A plant exhibiting genes A, B, E would be unable to produce megaspores

38. Which of the following statements regarding plant tissue is NOT true?

(a) Most parenchyma, sclerenchyma, and collenchyma are derived from the ground meristem.

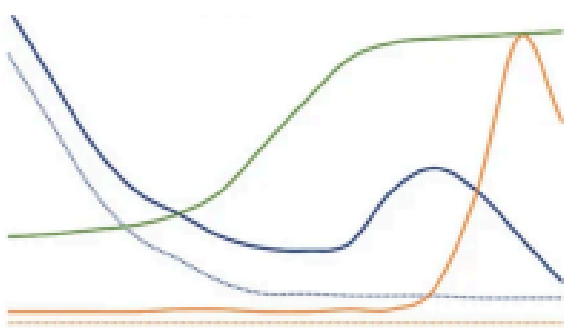
(b) Fibers' cell walls are rigid due to the presence of lignin, while collenchymas are pliable due to the presence of pectin.

(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; Accessory 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

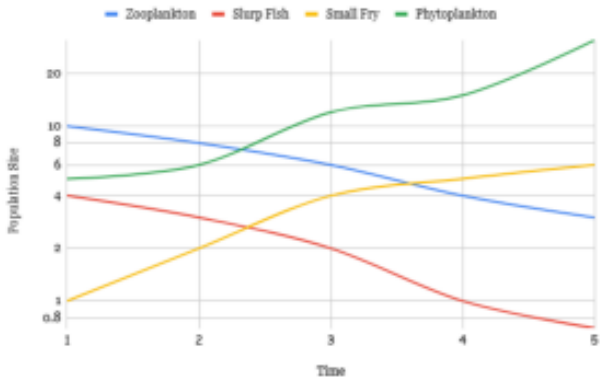
    (b) 28 individuals, uniform dispersion

    (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?

(a) Loot Lake is a bottom-up ecosystem, the increase in phytoplankton caused a decrease in small fry populations.

(b) Loot Lake is a top-down ecosystem, the decrease in slurp fish caused an increase in phytoplankton.

(c) Loot Lake is a bottom-up ecosystem, the increase in slurp fish caused an increase in small frys.

(d) Loot Lake is a bottom-up ecosystem, the decrease in small fry caused a decrease in zooplankton.

(e) 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

I. Using a machine to transform 5 Insular fish to Raven fish would increase the Shannon's diversity index
II. The Shannon's diversity index of this community is currently approximately 1.5
III. 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) Cryptomyectes 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

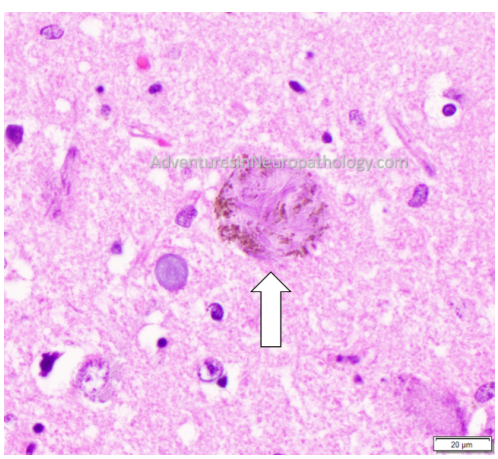
   (b) Levothyroxine - synthetic form of thyroxine

   (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

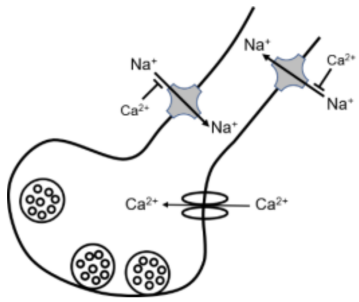
   (c) Schizophrenia

   (d) Huntington's

   (e) Creutzfelt-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

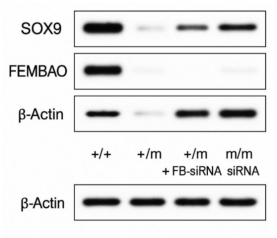
(b) I, II, V

(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?



(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.

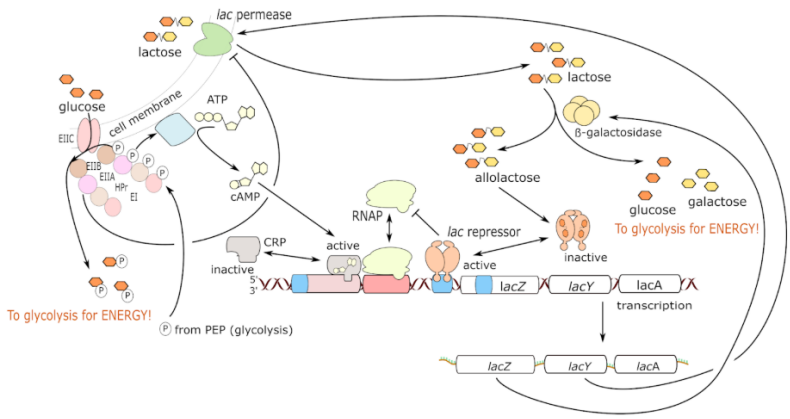
(b) Decrease because there'll be less NADH and FADH in the mitochondrion.

(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.

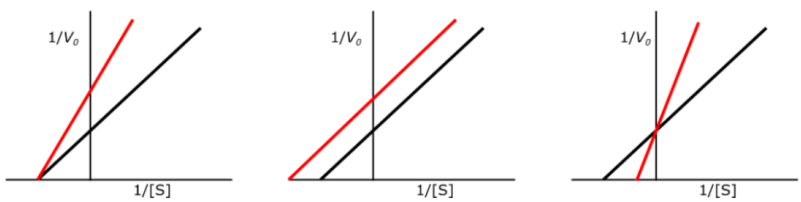
(b) The rough ER contains too many ribosomes, which results in an overproduction of the enzyme involved in lipid breakdown.

(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 $\frac{1}{S}$ versus $\frac{1}{V0}$ 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

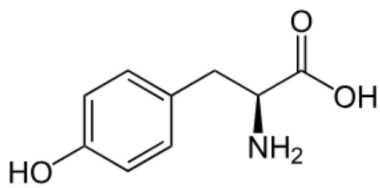
(d) Western Blot

(e) FRAP

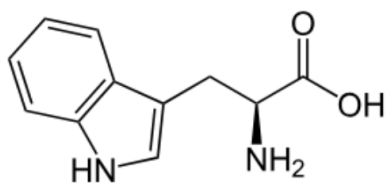
20. You are working at the Mitosisphere clinic when your patient reports symptoms of insomnia, anxiety, and impaired memory. Suspecting a

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

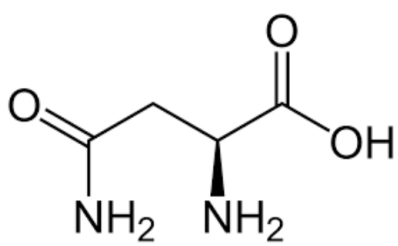
(a)



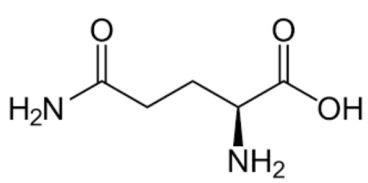
(b)



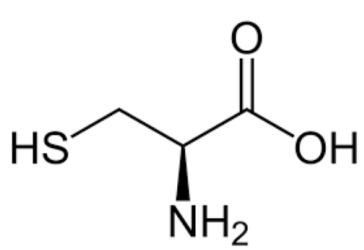
(c)



(d)



(e)



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	68	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%

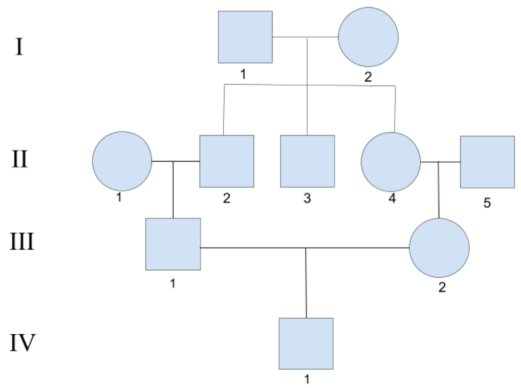
(b) 33%

(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. Which of the following is NOT a necessary condition for Hardy-Weinberg equilibrium?

    (a) Phenotypic frequencies remain constant throughout generations

    (b) Random mating

    (c) No flow of genes into the population

    (d) No natural selection of genes

    (e) Large population size

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

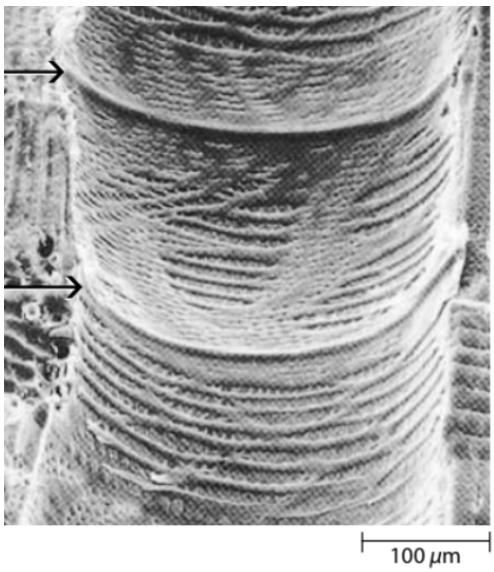
    (b) 1

    (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. 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. 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

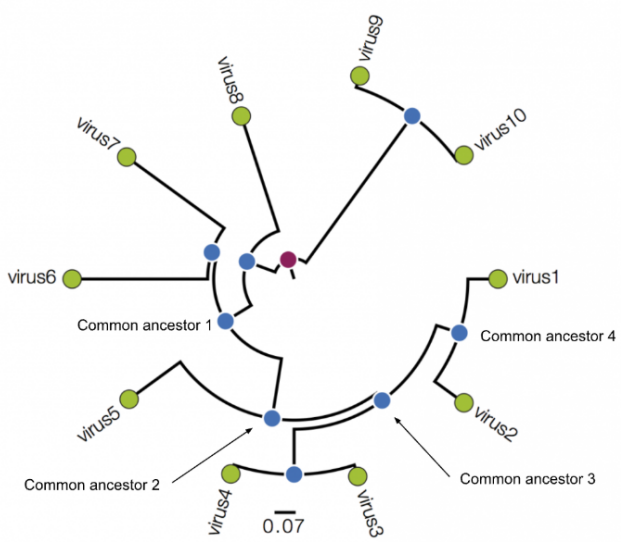
    (b) She still chooses the bright orange male due to strong innate preference

(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?



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

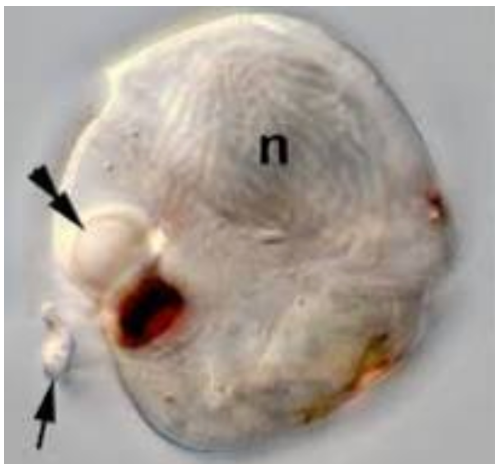
(b) I and II

(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 $\boxed{\text{B}}$.

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 steriod biosynthetic pathway than testosterone.

   D. LH is secreted from the bypothalamus 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 $\boxed{\text{E}}$.

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, analagous 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 $\boxed{\text{A}}$.

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 $\boxed{\text{B}}$.

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 $\boxed{\text{D}}$.

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 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 $\boxed{\text{D}}$.

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 $\boxed{\text{E}}$.

8. The primary effector cells against viral infections are T cells, corresponding to option $\boxed{\text{C}}$.

9. The vitamin primarily implicated in clotting is vitamin K, or phylloquinone (option $\boxed{\text{B}}$).

10. This question is just memorization of embryonic limb regions. The answer is $\boxed{\text{C}}$.

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 $\boxed{\text{C}}$.

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 $\boxed{\text{C}}$.

13. FRET is commonly used to observe protein-protein interactions. Thus, the answer is $\boxed{\text{B}}$.

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 $\boxed{\text{A}}$.

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 $\boxed{\text{B}}$.

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 $\boxed{\text{E}}$.

17. The interior of plasma membrane is hydrophobic, so a significant portion of residues in a transmembrane portion should be hydrophobic. However, option $\boxed{\text{C}}$ has almost all hydrophilic side chains.

18. Intracellular receptors bind to hydrophobic molecules. Option $\boxed{\text{E}}$ 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, $\boxed{\text{E}}$ 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 $\boxed{\text{C}}$.

21. snRNAs ($\boxed{\text{E}}$) 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 $\boxed{\text{A}}$).

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^AX^a, or option $\boxed{\text{D}}$. 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 $\boxed{\text{E}}$ is the incorrect statement.

25. The scenario describes selection for an intermediate phenotype, which is stabilizing selection (option $\boxed{\text{C}}$).

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 $\boxed{\text{B}}$.

27. This question is just memorization of inheritance patterns. Through process of elimination, we can narrow down our options to choice $\boxed{\text{D}}$.

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 $\boxed{\text{C}}$).

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 $\boxed{\text{B}}$.

30. In option $\boxed{\text{D}}$, both parents have the same allele for all genes on each chromosome, so no recombination could have occured.

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 $\boxed{\text{B}}$.

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 $\boxed{\text{C}}$.

33. Only options A and C are related to plant defense. Salicylic acid is more involved in pathogen defense, leaving jasmonic acid (option $\boxed{\text{C}}$) as the correct choice.

34. Vessel elements are not found in conifers; their xylem consists solely of tracheids. $\boxed{\text{B}}$ is thus the answer.

35. The continuous ring of vascular tissue seen in the section is most characteristic of monocot roots (option $\boxed{\text{A}}$). 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 $\boxed{\text{E}}$.

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 $\boxed{\text{D}}$) would be able to produce carpels and thus megaspores (it would only lack sepals).

38. Vascular rays are usually composed of parenchyma cells, not sclerenchyma cells. (Option $\boxed{\text{E}}$ 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 $\boxed{\text{D}}$.

40. This is another memorization question; this time, one on the types of fruits. As a logical hint, notice that pomegranates (option $\boxed{\text{E}}$) 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 $\boxed{\text{D}}$ 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: $H = -\frac{5}{43}ln(\frac{5}{43}) - \frac{3}{43}ln(\frac{3}{43}) - \frac{10}{43}ln(\frac{10}{43}) - \frac{25}{43}ln(\frac{25}{43}) = 1.09$. 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 $\boxed{\text{B}}$.

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 $\boxed{\text{B}}$.

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 $\boxed{\text{B}}$.

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 $\boxed{\text{C}}$ (II and III).

5. Metyrapone inhibits 11β-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 $\boxed{\text{C}}$.

6. Epinephrine exerts its effects by binding to α- and β-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 $\boxed{\text{A}}$.

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 $\boxed{\text{C}}$.

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 $\boxed{\text{E}}$.

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 $\boxed{\text{D}}$ 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 $\boxed{\text{B}}$.

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 $\boxed{\text{B}}$.

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 $\boxed{\text{E}}$.

13. Pleiotropy refers to a single gene influencing multiple distinct traits. Tubulin-α (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 $\boxed{\text{B}}$ (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 $\boxed{\text{A}}$ 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 $\boxed{\text{D}}$.

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 $\boxed{\text{A}}$.

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 $\boxed{\text{C}}$.

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 $\boxed{\text{E}}$.

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 $\boxed{\text{C}}$.

20. The molecule shown in option $\boxed{\text{B}}$ 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 $\boxed{\text{D}}$.

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 $\boxed{\text{C}}$.

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 $\boxed{\text{A}}$.

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 $\boxed{\text{B}}$.

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 $\boxed{\text{C}}$.

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 $\boxed{\text{D}}$.

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 $\boxed{\text{A}}$.

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 $\boxed{\text{B}}$ is incorrectly matched.

30. For tetrad analysis, the map distance between two genes is calculated using the formula $\frac{T+6NPD}{2(\text{Total Asci})} \cdot 100$. Here, the total number of asci 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 $\boxed{\text{A}}$.

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 $\boxed{\text{A}}$.

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 57/64, or $\boxed{\text{D}}$.

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 $\boxed{\text{D}}$.

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 $\boxed{\text{B}}$.

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 α-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 $\boxed{\text{C}}$.

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 megaspore 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 $\boxed{\text{D}}$ 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 $\boxed{\text{B}}$.

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 $\boxed{\text{A}}$.

39. Sieve-tube elements are living at functional maturity but lose many organelles during development to maximize space for phloem sap transport. They lack a nucleus, ribosomes, vacuoles, cytoskeleton, and other nonessential organelles, including the Golgi apparatus. However, they retain mitochondria for ATP production and a reduced form of smooth endoplasmic reticulum. Centrioles are not present in typical higher plant cells. Therefore, the correct answer is $\boxed{\text{B}}$.

40. Option $\boxed{\text{E}}$ 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 $\boxed{\text{C}}$.

42. $\boxed{\text{D}}$ 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 $\boxed{\text{C}}$.

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 $\boxed{\text{A}}$.

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 $\boxed{\text{C}}$ 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 $\boxed{\text{A}}$.

47. $\boxed{\text{A}}$ 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 $\boxed{\text{C}}$.

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 $\boxed{\text{C}}$ (I and III).

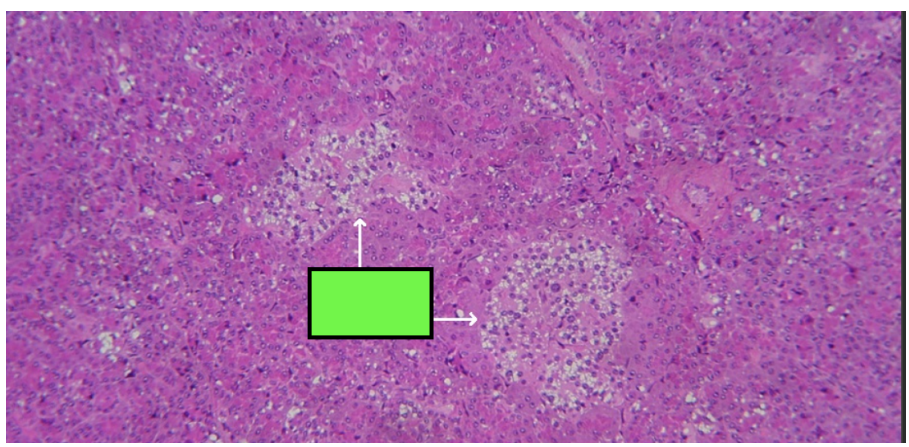
50. The structure described is the ocelloid, a highly complex, eye-like organelle found in certain dinoflagellates (e.g., family Warnowiaceae). It contains subcellular components analogous to a cornea, lens, iris, and retina, which are derived from mitochondria and plastids. This organelle functions in light perception and possibly prey detection. Therefore, the correct answer is $\boxed{\text{A}}$.

5.5 Subject Specific Questions

Section Links:
Animal Anatomy & Physiology
Cell Biology
Genetics & Evolution
Plant Biology
Ecology
Ethology
Biosystematics
Solutions to Subject Specific Questions

Anatomy & Physiology

1. Which of the following regions are the arrows in this image pointing to?



   (a) Islet of Langerhans; pancreas

   (b) Acinar tissue; pancreas

   (c) Ductal tissue; pancreas

   (d) Hepatic Lobule; liver

   (e) Crypt; small intestine

2. You are trying to develop a drug to target and destroy all extracellular cell membrane receptors (for no particular reason). Which of the following hormone receptors would likely be affected?

   I. Triiodothyronine (T3)
   II. Aldosterone
   III. Glucagon

IV. Cortisol
V. Epinephrine

(a) I, II

(b) II, III

(c) III, IV

(d) III, V

(e) IV, V

3. You are looking to develop a new medication that increases glomerular filtration rate(GFR). Which of the following actions would likely result in your desired effect?

   I. Afferent nephron constriction
   II. Afferent nephron dilation
   III. Efferent nephron constriction
   IV. Efferent nephron dilation
   V. Increased systemic blood pressure

   (a) I, II, III

   (b) I, II, IV

   (c) II, III, IV

   (d) II, III, V

   (e) III, IV, V

4. You are taking your USABO semis exam when you suddenly notice your sympathetic nervous system kicking in. Which of the following changes would you expect?

   I. Dilation of pupils
   II. Bronchi constriction
   III. Digestive system slowing down
   IV. Increased secretion of norepinephrine
   V. Increased heart rate

   (a) I, II

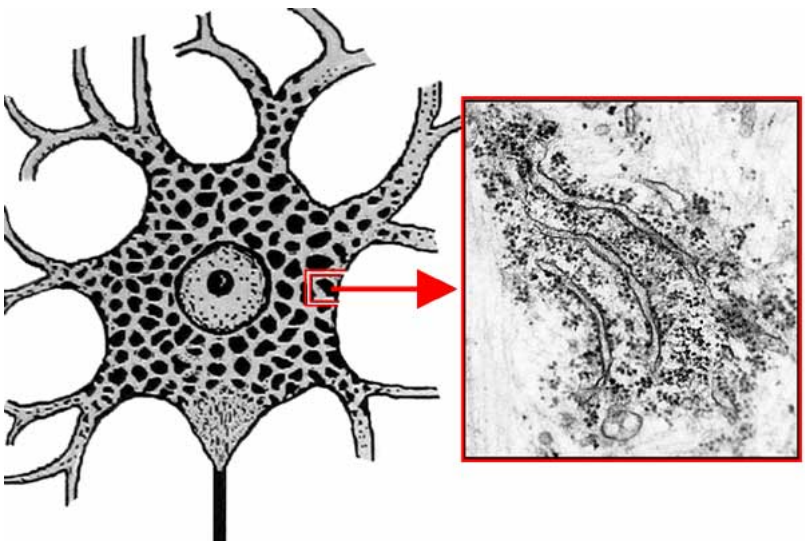
   (b) I, II, III

   (c) I, III, IV

   (d) I, II, IV, V

   (e) I, II, III, IV, V

5. Gopher was presenting to his neurobio class about the basal nuclei in the brain! He had brought up a microscope and a healthy sheep cerebrum, and was showing his students the wonders of the sheep basal nuclei. Suddenly, Nebulin crashed his class and took over the microscope, arbitrarily zooming it into a certain structure.



Which of the following structures is shown?

(a) Nuclei

(b) Nissl Bodies

(c) Lipofuscin Granules

(d) Lewy Bodies

(e) Beta-Amyloid Plaques

6. Swamp Izzo the tetanus virus sought to infect Playboi Carti's nervous system, and subsequently plague his music with his producer tag! F1lthy, an esteemed neuroscientist, is tasked with stopping Swamp from ruining Carti's music. Which of the following should he do to stop Swamp Izzo's spread throughout Carti's nervous system (disregarding any other negative side effects)?

(a) Inhibit all instances of neuronal kinesin

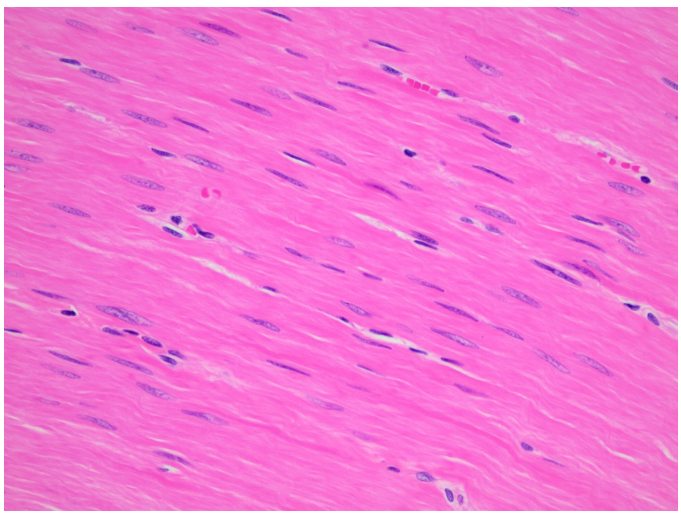
(b) Further activate all instances of neuronal dynactin

(c) Inhibit all instances of neuronal dynein

(d) Inhibit all instances of neuronal acetylcholinesterase

(e) Activate all instances of neuronal monoamine oxidase

7. You are looking through a microscope at some muscle tissues. Which of the following types of types of tissue is displayed in the image below?



   (a) Smooth Muscle

   (b) Cardiac Muscle

   (c) Skeletal Muscle

   (d) Adipose Tissue

   (e) Connective Tissue

8. Which of the following organs are derived from the mesoderm?

   I. Heart
   II. Thymus
   III. Kidneys
   IV. Adrenal cortex
   V. Adrenal Medulla

   (a) I, II, III

   (b) I, II, IV

   (c) I, III IV

   (d) II, III, IV

   (e) II, IV, V

9. Your lab is currently testing the effects of blocking beta 1 adrenergic receptors within the body. Which of the following is NOT one of the effects you would expect to observe?

(a) Decreased heart rate

(b) Decreased heart contractility

(c) Decreased renin release

(d) Decreased lipolysis

(e) Increased ghrelin secretion

10. Infrqtion decided to test his novel drug, ubiquitinab, on Tanish, a child he locked in his basement. Ubiquitinab has been found to cause increased excretion of bile salts based on prior testing on mice. Assuming that he was a healthy child prior to the administration of Ubiquitinab into his mouth and that any feedback loop mechanisms related to bile salts haven't been activated yet, which of the following molecules would be found to have been found at lower levels in Tanish's body?

    (a) Maltose

    (b) Cholesterol

    (c) Arginine

    (d) Blood plasma K+

    (e) $CaCl_2$

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

	Jerry	Healthy Range
Na+	132	135-145
TSH	3.4	.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

    (a) Cushing's disease

    (b) Addison's disease

    (c) Grave's disease

    (d) Hashimoto's disease

    (e) Congenital hyperplasia

12. Which of the following correctly traces the neural pathway of visual information from the retina to the brain, and identifies the first location where input from BOTH eyes is integrated together?

    (a) Photoreceptors → Bipolar cells → Ganglion cells → Optic chiasm → Lateral geniculate nucleus → Primary visual cortex; integration first occurs at the retina

    (b) Rods and cones → Optic nerve → Optic chiasm → Superior colliculus → Primary visual cortex; integration first occurs at the superior colliculus

    (c) Photoreceptors → Bipolar cells → Ganglion cells → Optic nerve → Optic chiasm → Lateral geniculate nucleus → Primary visual cortex; integration first occurs at the lateral geniculate nucleus

    (d) Photoreceptors → Ganglion cells → Optic chiasm → Occipital lobe → Primary visual cortex; integration first occurs at the occipital lobe

    (e) Primary visual cortex → Photoreceptors → Ganglion cells → Optic chiasm → Occipital lobe; integration first occurs at the occipital lobe

13. Given the following solutes, what would be the order of filtration speed from fastest to slowest (or not at all) in the glomerulus?

    (a) Na+, tryptophan, albumin

    (b) Na+, albumin, tryptophan

    (c) Albumin, Na+, tryptophan

    (d) Albumin, tryptophan, Na+

    (e) Tryptophan, Na+, albumin

14. You accidentally inhale a lethal dose of sarin. Which of the following reasons best explains how you would tragically die in a few minutes?

    (a) Inhibition of ACh receptors, causing muscular paralysis

    (b) Destruction of V-SNAREs, resulting in ACh signaling termination

    (c) Destruction of cholinergic fibers

    (d) Inhibition of acetylcholinesterase, causing buildup of ACh in the synaptic clefts

    (e) You would be totally fine

15. Dr. Khan is managing a trauma patient who suffered significant hemorrhage and is showing signs of cold, clammy skin and rapid pulse.

While explaining to a student, she lists expected physiological responses during this acute volume loss. Which of the following responses is NOT expected to occur as a direct result of baroreceptor-mediated sympathetic activation?

(a) Increased systemic vascular resistance

(b) Enhanced heart rate and myocardial contractility to support cardiac output

(c) Constriction of afferent renal arterioles to reduce glomerular filtration rate

(d) Increased atrial natriuretic peptide secretion

(e) Increased renin release to activate the renin-angiotensin-aldosterone system

16. Hamood is a sweaty 1st grader interested in immunology. One day, he decided to try his hand at performing coimmunoprecipitation on the protein TfR1 and proteins that it associates with. He inserted the TfR1 protein bound to a heavily beaded antibody into an unknown immune cell via electroporation, and performed co immunoprecipitation on the cell's lysate. To his surprise, the precipitate also contained a large amount of the protein lactoferrin, a protein that has a high affinity for free iron. Based on this information, which of the following cells did Hamood experiment on?

    (a) Monocytes

    (b) Eosinophils

    (c) NK Cells

    (d) Helper T-Cells

    (e) Neutrophils

17. The liver produces bile that is stored in the gall bladder and used in the small intestines. It contains bile salts that are amphipathic in nature and various other substances. Which of the following is not a direct function of bile?

    (a) Digestion of vitamin B5

    (b) Digestion of lipids

    (c) Excretion of unwanted substances

    (d) Regulating the pH level

    (e) Digestion of vitamins K and A

18. On a typical Thursday working as a doctor at the Mitosisphere clinic a patient comes in complaining about dizziness and fatigue due to having low blood pressure. Thinking back to your USABO days you decide to test for their MAP. After running a few tests you get the following data:

    End diastolic volume (EDV) = 110 mL
    End systolic volume (ESV) = 80 mL
    HR = 70 BPM
    Total peripheral resistance (TPR) = 0.03 mmHG·min/mL

    Which of the following is the closest to this patient's MAP and what could result in this change?

    (a) 63 mmHG, increased blood flow to lungs

    (b) 63 mmHG, inadequate perfusion to major organs

    (c) 67 mmHG, decreased blood flow to the brain

    (d) 67 mmHG, high levels of glucose in blood

    (e) 71 mmHG, decreased oxygenation to muscles

19. Donatello accidentally touches a hot pan and quickly withdraws his hand. Which of the following is true regarding the reflex involved?

    (a) It is monosynaptic and involves interneurons in the cerebellum

    (b) It is polysynaptic and uses both excitatory and inhibitory interneurons

    (c) It is monosynaptic and does not involve the spinal cord

    (d) It is voluntary and requires input from the motor cortex

    (e) It only activates extensor muscles

20. Ubiquia is a doctor at the BDNF Emergency Room. Right as she is about to go home for the night and enjoy her time watching Stranger Things, her long lost uncle Ubiquian comes in with chest pain, heart palpitations, and shortness of breath after overstudying for the p+q exam. Worried, she quickly runs an ECG on Ubiquian in an attempt to diagnose and treat their problem. Based on the ECG results, which of the following are true about Ubiquian?

    (a) He has a first-degree AV block

(b) He presents with a third-degree AV block

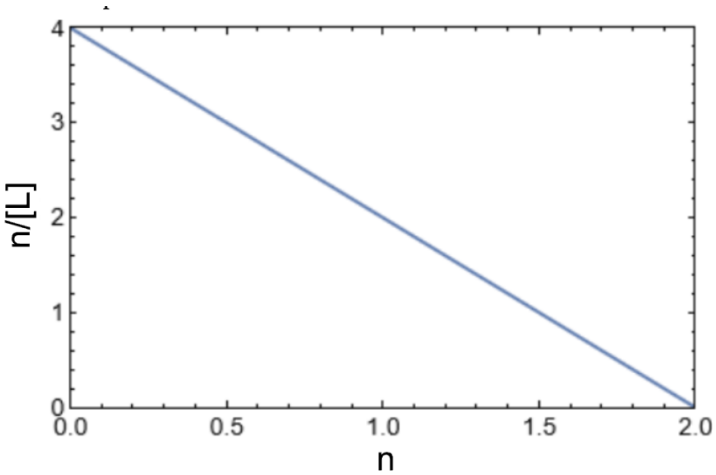
(c) He has a heart attack due to the presence of an elevated ST segment

(d) He has a second degree AV block

(e) Ubiquia didn't run the ECG correctly and should quit her job expeditiously

Cell Biology

1. Shown in the image is a plot of n vs $\frac{n}{[L]}$. n represents the average number of ligands bound to a receptor. Which of the following is the value of the number of binding sites on each receptor and the value of K_d respectively?



   (a) 1, $\frac{1}{2}$
   (b) 1, 2
   (c) 2, $\frac{1}{2}$
   (d) 2, 2
   (e) 4, 4

2. You are trying to direct a protein back into the cell via receptor mediated endocytosis. Which of the following coat proteins are necessary to accomplish this task?

   (a) COPI
   (b) COPII
   (c) Clathrin
   (d) ATP
   (e) Calcium

3. You are looking to study the surface structures of mitochondria in a monkey. Which of the following microscopy techniques would best accomplish this task?

   (a) Light microscopy

(b) Differential-contrast microscopy

(c) Phase-contrast microscopy

(d) Transmission electron microscopy

(e) Scanning electron microscopy

4. Old Mac Donald had a farm, and on that farm he had some maize. However, he also has many other crops which got him thinking, do all his crops function the same? Identify which of the following statements regarding photosynthesis is NOT true:

   (a) CAM plants are well adapted to xerophytic conditions due to temporal adaptations regarding stomatal opening and closure.

   (b) C4 Plants such as maize avoid the accumulation of oxygen by spatially separating the enzymes required for initial carbon fixation and ATP synthesis.

   (c) Carbon dioxide is fixed in the stroma, and ATP is synthesized across the thylakoid membranes.

   (d) In cyclic electron flow, ATP synthesis is skipped and electrons cycle through PS I , producing NADPH.

   (e) In linear electron flow, the energy required for ATP synthesis is provided by the movement of H+ ions down their concentration gradients into the stroma.

5. Histone H3 lysine 9 trimethylation (H3K9me3) is the most common form of constitutive repression in eukaryotes. In which of the following regions would you least expect to find H3K9me3 modifications?

   (a) Centromeric regions

   (b) Telomeres regions

   (c) Transposable elements

   (d) X-inactivation regions

   (e) Short tandem repeats

6. Which of the following glycolytic enzymes produce or use ATP?

   I. Hexokinase
   II. Phosphofructokinase-1
   III. G3P dehydrogenase
   IV. Phosphoglycerate kinase
   V. Pyruvate kinase

   (a) I, II, III

(b) I, II, IV

(c) I, II, IV, V

(d) I, II, III, IV, V

(e) I, II, III, IV

7. Which of the following are NOT rate-limiting enzymes in their respective pathways?

   (a) F 1,6-BPase, gluconeogenesis

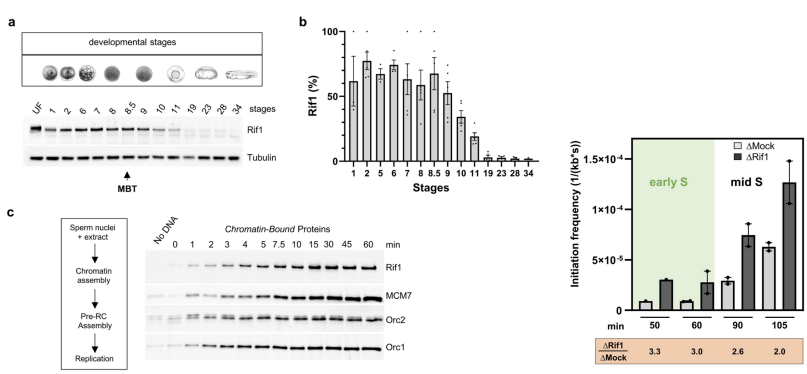
   (b) PFK-1, glycolysis

   (c) G6PD, pentose phosphate pathway

   (d) LPO, ornithine cycle

   (e) Isocitrate Dehydrogenase, Krebs Cycle

8. Rif1 is a key replication timing factor that has been studied in developing frogs of the species Xenopus laevis. Rif1 recruits protein phosphatase 1 (PP1) to chromatin, counteracting S phase kinases. Rif1 depletion increases the chromatin-binding of the S phase kinase Cdc7/Drf1, the firing factors Treslin and MTBP, Cdc45, RecQL4, and the phosphorylation of both Treslin and MTBP. Treslin is a protein crucial for DNA replication and cell cycle control. It plays a role in initiating DNA replication, working in conjunction with TopBP1 and Cdc45. Cdc45 plays a key role in the formation of the CMG complex. The CMG complex acts as a DNA helicase, unwinding the DNA double helix to allow replication to begin. Cdc45 also interacts with other proteins and is involved in double-strand break repair.



a) Time course analysis of Rif1 expression throughout development; whole embryo protein extracts were analyzed by western blotting against indicated proteins, tubulin was used as loading control; MBT (midblastula transition), UF (unfertilized egg).

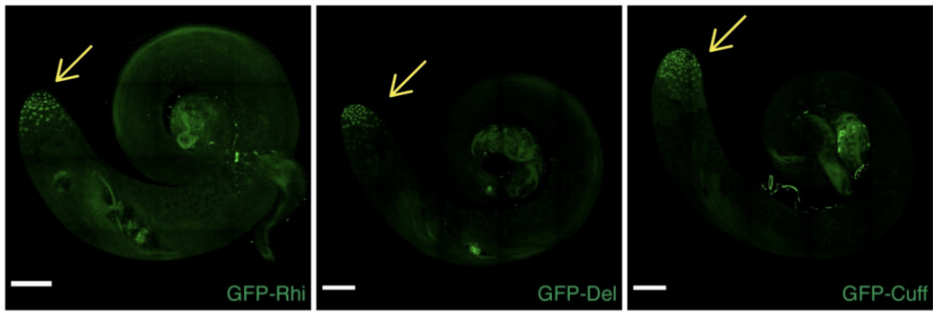
b) Quantification of Rif1 abundance in three biological replicates and two technical replicates of western blot series of embryonic whole cell extract, plotted as mean OD normalized to Tubulin, scaled using min and max: x scaled = (x - x min)/(x max - x min), Mean with SED, n = 5 (data points).

c) Time course analysis during the S phase; sperm nuclei were incubated in Xenopus egg extracts and chromatin was isolated for immunoblotting at indicated time points before and during DNA replication.

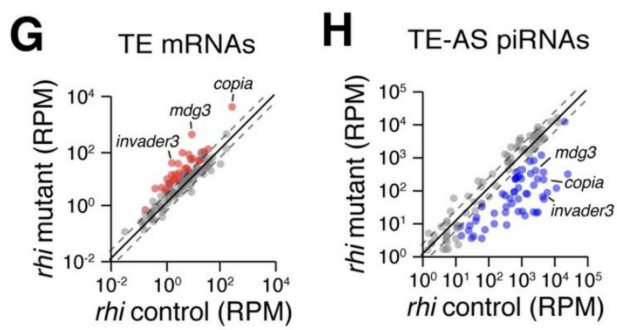
Mean initiation frequencies (I(t)) with standard error of mean with SEM, n = 2 (data points) and ratio ΔRif1/ΔMock (I(t)) were calculated. Indicate whether the following statements are true or false.

I. Rif1 expression accelerates the rate of replication firing in Xenopus Laevis
II. If a Xenopus Laevis zygote in the 4 cell stage was treated with siRNAs specific to Rif1, its cell's S-phase would likely be accelerated.
III. Rif1 disrupts cell cycle progression via perturbation of the cytoskeleton.
IV. A possible mechanism of Rif1 may be recruitment of initiation factors to chromatin.
V. Inhibition of Rif1 in cancerous cells may be effective in increasing the rate of double stranded break repair.

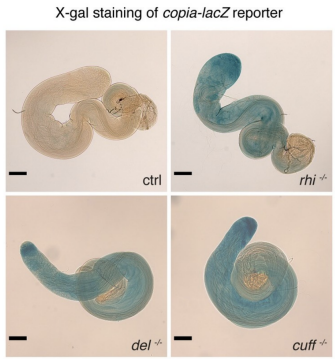
9. Piwi-interacting RNAs, or piRNAs are small non-coding RNAs which guard the germ line from transposons by silencing them. The Rhino-Deadlock-Cutoff (RDC) complex in the Drosophila line has been seen to be essential for expression of dual-strand piRNA clusters and transposon silencing in testis. RDC is critical to transposon repression in males, and males without RDC exhibit reduced fertility and loss of germ cells. Invader3, mdg3, and copia are three of the most highly active transposons in the rhi-mutants. Copia sits shortly upstream of the lacZ-gene, in order to monitor its expression, X-gal staining was utilized in control as well as mutants for all 3 genes rhi, del, and cut. Del has been seen to recruit the transcription initiation factor TFIIA-L and the protein Moonshiner (moon) to initiate transcription in hostile heterochromatin environments. Moon has been observed to be necessary only in ovaries, while not in testis. Moon expression in testis using a GFP-tagged Moon transgene was observed to be able to rescue the female sterility caused by moon mutation. In these moon mutants, Rhi localization was perturbed; however, in two other moon mutants, moonΔ1 and moonΔ28, Rhi localization was undisturbed.



Expression of GFP-tagged Rhi (left), Del (middle) and Cuff (right) transgenes driven by their respective regulatory regions. Scale bar: 100μm.



(G) De-repression of TEs in testes of rhi mutants measured by polyA+ RNA-seq. Scatter plot showing expression of TE mRNAs in rhi2/KG mutant versus heterozygous control testes. TEs that show 2-fold de-repression (FDR < 0.05) and 1 RPM averaged levels are marked red. The mean of two biological replicates is shown. (H) Loss of TEtargeting piRNAs in testes of rhi mutants. Scatter plot showing expression of TE-antisense piRNAs in rhi2/KG mutant versus heterozygous control testes. TE-antisense piRNAs that show 2-fold reduction (FDR < 0.05) and 10 RPM averaged levels are marked blue. Shown are averages of two biological replicates.



De-repression of copia reporter in testes of rhi mutants. Brightfield images showing heterozygous control and rhi2/KG, delHN/WK and cuffWM25/QQ37 mutant testes expressing copia-lacZ, after X-gal staining. copia LTR containing its promoter is fused upstream to lacZ gene. Note that part of copia LTR is transcribed as well. Scale bar: 100μm.

Indicate whether the following statements are true or false.
I. Rhi co-localizes with both del and cuff at the apical tip of the testes.
II. Moon acts genetically upstream of the RDC complex.
III. Rhi mutants show constitutively repressed transposition of copia.
IV. RDC mutant germline stem cells likely upregulate nucleotide excision repair.
V. Copia is a more active transposable element than Invader3.

10. Your new biology teacher Ms. Qin is the trickiest in the whole school. She purposely says false information so students who don't think critically fail. During a lesson on photosynthesis, she says the following:

    I. Photosynthesis produces ATP during the light dependent reactions.
    II. Rubisco is a key component in the light dependent reaction, transferring electrons onto the photosystems.
    III. The epidermis of the leaf contains a lot of chloroplast to perform photosynthesis.
    IV. Trees are good because they give us oxygen, a product from the Calvin cycle.

    (a) I

    (b) I, III

    (c) II, IV

    (d) III, IV

    (e) I, II, III, IV

11. Donelly has failed the swim test and thus has to take the swim gym

class. She's scared of drowning, so she decides to inject some hydrogen peroxide into her cells. Which of the following enzymes now has to work overtime for her mistake?

(a) Ubiquinone

(b) Ubiquitin

(c) Catalase

(d) PNMT

(e) StAR

12. Which of the following correctly describes the steps in the path of a glycoprotein from its formation to being secreted?

(a) Rough ER → COPII vesicle → Golgi → Clathrin-coated vesicle → Plasma membrane

(b) Free ribosome → Rough ER → Golgi trans → Golgi cis → Lysosome → Plasma membrane

(c) Rough ER → Golgi → COPI vesicle → Endosome → Plasma membrane

(d) Nucleus → Smooth ER → rough ER → Golgi → Secretory vesicle → Plasma membrane

(e) Rough ER → Golgi → Secretory vesicle → Nuclear pore → Extracellular space

13. Which of the following is incorrect regarding the organelles and their functions for a typical eukaryotic cell?

(a) Both the rough ER and smooth ER can synthesize phospholipids

(b) Free ribosomes can be found in the nuclear membrane, cytosol, mitochondrial matrix and chloroplast stroma; and unlike bound ribosomes which mainly make secretory proteins, free ribosomes are responsible for making proteins that are used inside the cell

(c) Both lysosomes and peroxisomes can help detoxify harmful substances in the cell, but the smooth ER and central vacuole (for plant/fungal cells) can not.

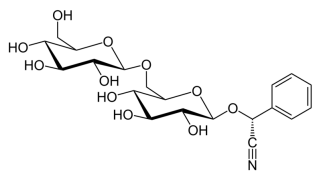
(d) Although both plant and animal cells have microtubules, most plant cells lack centrioles.

(e) According to the endosymbiont theory, the ancestors of mitochondria and chloroplasts were aerobic, non-photosynthetic and anaerobic, photosynthetic prokaryotes respectively. This is

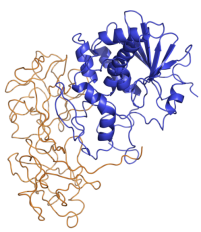
evidenced by the fact that they have double membranes, circular DNA and 70S ribosomes.

14. Dr. Orange was suddenly poisoned! Post-mortem analysis proved that the mysterious toxin targeted cellular respiration and blocked the functionality of Cytochrome C Oxidase. Which of the following compounds was most likely given to Dr. Orange, resulting in his poisoning?

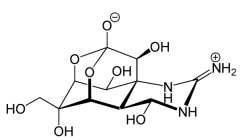
(a)



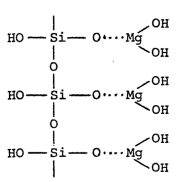
(b)



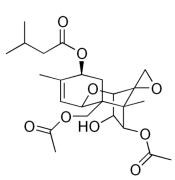
(c)



(d)



(e)



15. Identify which of the following statements about cancer cells is TRUE:

    (a) Cancerous cells utilize large amounts of glucose as they perform high amounts of oxidative phosphorylation.

(b) Cancerous cells often grow unchecked in suspended mediums despite not being anchored to anything.

(c) Cancer cells require the human body to survive, therefore they cannot survive ex vivo

(d) Most cancers are the result of gain-of-function mutations in tumor suppressor genes.

(e) Sarcomas, myelomas, and lymphomas are all white blood cell or white blood cell precursor related cancers.

16. Oh no! You accidentally stuck your head into a microwave (somehow) and your DNA has suffered severe UV damage. Which of the following repair mechanisms would most likely be used to repair this damage?

(a) Base excision repair

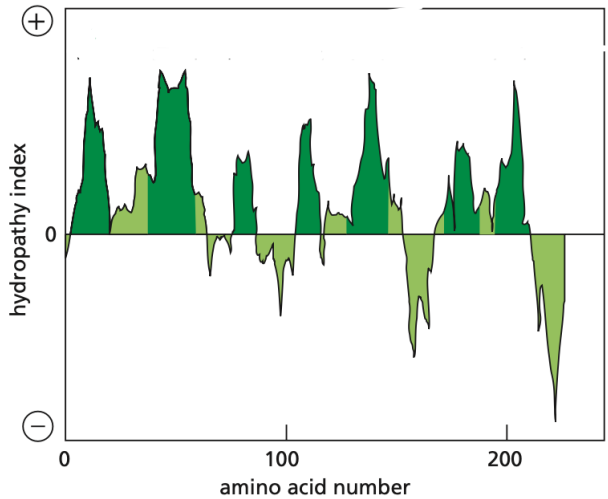
(b) Mismatch repair

(c) Direct repair

(d) Nonhomologous end joining

(e) Nucleotide excision repair

17. Jhriyan decided to run a hydropathy plot on his favorite protein isonebulin, a prominent transmembrane channel in Purkinje cells for the molecule FNDB. However, since he has a major skill issue, he cannot seem to analyze the plot even though he ran it perfectly. You, an expert biology researcher and a USABO sweat, decide to help him out in his analysis of isonebulin's hydropathy plot. Which of the following are valid assumptions that you can make about isonebulin given the following hydropathy plot?



(a) Isonebulin has 6 membrane-spanning beta-barrels.

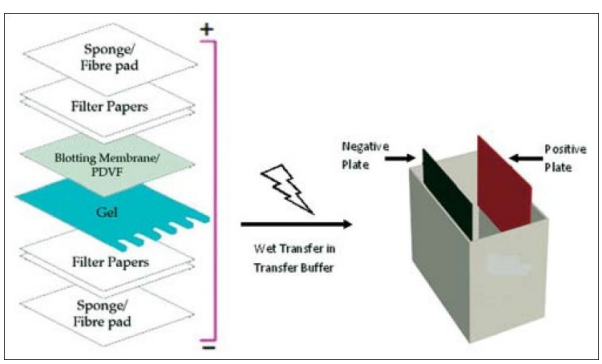
(b) Isonebulin unusually has 12 subunits.

(c) Isonebulin has 7 membrane-spanning alpha-helices.

(d) Isonebulin is a single-spanning membrane protein.

(e) Isonebulin has undergone N-linked glycosylation prior to integration into the membrane.

18. Western blotting is a lab technique used to detect a protein of interest in a sample of proteins or tissue. To detect the protein, gel electrophoresis is conducted to separate the proteins in the sample by size, and the proteins are then transferred to a membrane sheet. These membranes are washed over with primary antibodies that bind to the protein of interest, and the leftover antibodies are washed off; the process is repeated with secondary antibodies. What is the use of the secondary antibodies in Western blotting?



(a) To degrade the remaining proteins that don't have a primary antibody bonded to their side chains, leaving only the target proteins on the membrane.

(b) To stabilize the proteins of interest because when bonded to primary antibodies, proteins become unstable, requiring secondary antibodies to bind and stabilize the complex.

(c) To make the proteins bonded to the primary antibodies gain extra weight, causing them to stay behind when examined in the dark room; this allows researchers to easily identify the proteins.

(d) To visualize the proteins of interest - the secondary antibodies bind to the primary antibodies, and are usually equipped with an enzyme or fluorescent tag; this allows researchers to easily identify the proteins.

(e) To stop the proteins of interest from moving as these proteins drift along the membrane after bonding to primary antibodies.

19. Plasma membranes are highly dynamic structures that allow for the compartmentalization of cells and organelles. Which of the following statements regarding plasma membranes is FALSE?

(a) Plasma membranes maintain fluidity through the incorporation of sterols and unsaturated fatty acids.

(b) Cytoplasmically synthesized phospholipids primarily move to the extracellular monolayer through random diffusion.

(c) Cells with shorter phospholipid chains remain fluid at lower temperatures.

(d) Both plants and bacteria do not contain cholesterol in their plasma membranes.

(e) Red blood cell membrane composition significantly differs from mitochondrial membrane composition.

20. Tom is interested in cell structure and shape, as well as the movement of cells. Help Tom identify which of the following statements regarding the cytoskeleton is INCORRECT.

(a) Actin filaments are the primary constituent of the cortex underlying the plasma membrane.

(b) In a cell with a very low concentration of tubulin subunits, microtubules will shrink from the plus end while grow from the minus end.

(c) Intermediate filaments are the primary constituent of the nuclear lamina underlying the nuclear envelope.

(d) In a cell with intermediate concentration of actin subunits, actin filaments may grow from the plus end while shortening from the minus end.

(e) Underlying the plasma membrane of red blood cells, spectrin helps aid in holding its concave structure.

Genetics

1. Which of the following statements about operons is correct?
   (a) The lac operon is an example of an inducible operon.
   (b) The CAP binding site requires binding of Cyclic AMP and decreases gene expression of the lac gene in low lactose conditions.
   (c) Using glucose then phosphatidylcholine to grow a bacterial culture would be an example of diauxic growth.
   (d) The trp operon uses a riboswitch as a mechanism of operon control.
   (e) A 3-4 stem loop is formed due to ribosome stalling in the trp operon and increases transcription levels.

2. Robert is interested in how bacteria evolve over time in order to confer resistance to certain antibiotics. He has two strains of the novel diploid bacterium Tree Coli, 1 strain from a year ago, and 1 strain from the present day. The year old strain is sensitive to both erythromycin and penicillin due to homozygosity at the erm- and pen- genes. The new strain however, is homozygous for the erm+ and pen+genes, and is thus resistant to both (Homozygosity of both erm+ and pen+ are needed to confer resistance). Robert crosses these two strains, and then self-crosses the F1 generation and plates them on a petri dish with both erythromycin and penicillin. To his surprise though, he notices a 17% survival rate on his dishes. He concludes the genes must be linked, in cM, how far apart are the erm and pen genes?
   (a) 35 cM
   (b) 34 cM
   (c) 18 cM
   (d) 9 cM
   (e) 16 cM

3. Eric is researching the KINDBEFRIENDER operon, which encodes for the three polypeptides Nice, Caring, and Helpful. These three genes are flanked by an operator (KbO) and a promoter (KbP). He decides to study the activity of the KINDBEFRIENDER operon under various conditions as shown in the tables below. "++" indicates significant transcription, "+" indicates baseline level transcription, "-" represents insignificant transcription.

	Nice	Caring	Helpful
KbO+, KbP+	+ +	+	+ +
KbO+, KbP-	+	-	+
KbO-, KbP+	+	-	+
KbO-, KbP-	-	-	-

Cells exposed to the protein "Mean".

	Nice	Caring	Helpful
KbO+, KbP+	-	+	-
KbO+, KbP-	-	-	-
KbO-, KbP+	+	-	+
KbO-, KbP-	-	-	-

Cells exposed to the protein "Nice".

Identify which of the following statements is not true.

(a) The protein Mean acts as a positive regulator for transcription of the Helpful gene.

(b) The KINDBEFRIENDER promoter increases expression of all three genes.

(c) The protein Nice acts as a negative regulator for transcription of the Caring gene.

(d) The protein Nice has a baseline level of expression under standard conditions.

(e) The KINDBEFRIENDER operon is repressible.

4. The choice between the lysogenic and lytic cycle depends on the relative levels of two proteins, cII and cro in bacteriophages. Identify all of the following statements that are true about the competition between the lysogenic and lytic cycle in these phages:

   I. The N protein is acts as an antiterminator before the selection is made
   II. If the lysogenic cycle is chosen, cII protein activates PRM, which leads to the formation of the repressor
   III. Binding of the repressor to OR inhibits the expression of cro, leading to the inactivation of PRM, but for the maintenance of the lysogenic cycle, PRE produces enough repressor to continue in the latent state

   (a) I only

   (b) II only

   (c) I, II

   (d) II, III

   (e) I, II, III

5. You are working in the Mitosisphere lab, studying the sex based difference in N.etflix gene expression, which is located on the X chromosome in a population of T.V individuals, a new species of marsupials. Strangely the expression of this gene is the same in both sexes; how could this be?

   (a) One of the X chromosomes is randomly activated

   (b) The paternally derived X chromosome is inactivated

   (c) The X chromosome in a female has halved expression

   (d) The X chromosome in ia male has doubled expression

   (e) You are tweaking - the expression of this gene is not the same in both sexes.

6. In the Great Huff Forest, there are birds of the same species that have different colors, including blue and grey. Early in the morning, a wildfire struck and most of the trees were reduced to ash, which settled to the ground. Most of the blue birds, losing their camouflage between the thick leaves in the trees, died in the following week, while the grey birds' population increased as they hid in the ash. What evolutionary principle is depicted in this event?

   (a) Stabilizing selection

   (b) Directional selection

   (c) Epistasis

   (d) Disruptive selection

   (e) Gene flow

7. Aarnav is studying *X. Rebidoptera*, a new fly species. On this organism's 9th chromosome, there are three genes *duck*, *on*, and *wheel*. Aarnav is trying to determine the coefficient of coincidence. The recessive mutations are *duck*, *on*, and *wheel* (mutant). He crosses a homozygous wt *X. Rebidoptera* with a *X. Rebidoptera* that has all 3 mutant phenotypes. He then testcrosses the progeny and gets the shown results:

Phenotype of Progeny	Number of Progeny
+ + +	156
- - -	91
- + -	18
+ - -	32
- - +	15
+ + -	14
- + +	64
+ - +	72

Note: In this diagram, + represents wild type and - represents mutant. Additionally, the phenotypes of the progeny are listed in the gene order duck, on, wheel.

What is the coefficient of coincidence?

(a) 0.62

(b) 0.68

(c) 0.76

(d) 0.81

(e) 0.90

8. Currently, there are more than 20 known blood group types. However, the ABO and Rhesus (Rh) systems are by far the most clinically relevant. The frequencies of the following blood group phenotypes in the Biolympiland (a small island on Mars) population are as follows: O+ = 38%, O– = 9%, A+ = 32%, A– = 6%, B+ = 9%, B- = 2%. Which of the following answers correctly predicts the approximate ratios of the frequency of AB+ to AB- (assuming it follows a similar trend as the previous blood groups)?

   (a) 2.45

   (b) 2.9

   (c) 3.85

   (d) 4.2

   (e) 4.65

9. Homeobox-containing genes, or Hox genes, are highly conserved genes that have remained very similar between distantly related species through millions of years of evolution. Considering that these genes are so similar in most animals' genomes, what is most likely the reason why these animals have such contrasting forms and structures?

   (a) Much of these animals experienced chromosomal duplications and recombination errors during meiosis, leading to changes in the proteins' structures.

   (b) Organisms may have similar development genes but the regulation sequences play a big role in the expression of these genes; each species has a different set of regulatory sequences.

   (c) Exon shuffling can influence the protein's functions as they change the gene's DNA sequence, which causes the proteins to have different properties.

(d) This information is incorrect because the Hox genes are greatly dissimilar when compared to distant related species.

(e) These genes are not related to animal development.

10. Which two individuals have differing coefficients of relatedness with you?

(a) Your mom and grandson

(b) Your dad and sister

(c) Your grandma and uncle

(d) Your mom's niece and your nephew's daughter

(e) Your grandpa and grandmother

11. Jake is trying to align the sequences inside of a protein. Sequence 1 reads GATTACA while sequence 2 reads GTCGACGCA. He decides to perform a Needleman-Wunsch Algorithm to determine the alignment. Given that a match score is +1, a mismatch score is -1, and a gap penalty is -2, identify all of the following statements that are true regarding the resulting alignment.

I. The total score for the best alignment will be -1.
II. There are many possible best alignments.
III. The first and last parts of the alignment are both matches.

(a) I only

(b) III only

(c) I, II

(d) II, III

(e) I, II, III

12. Bob and Angela, two individuals of the diploid B. nerd species, have 60 chromosomes each (i.e. 2n = 60). One day, they decide to have a child! Assuming independent assortment and no crossing over, what is the probability that their son, Darth Vader, will share all of his maternal chromosomes with his maternal grandfather, R2D2?

(a) 1

(b) $(\frac{1}{2})^{60}$

(c) $(\frac{1}{2})^{30}$

(d) $(\frac{1}{4})^{60}$

(e) $(\frac{1}{4})^{30}$

13. Which of the following deamination reactions are correct? Select all that apply.

    (a) Cytosine → Uracil

    (b) 5-methylcytosine → Inosine

    (c) Adenine → 8-oxoguanine

    (d) Guanine → Xanthine

    (e) Thymine → Cytosine

14. A diploid organism has two genes, A and B, located 10 centimorgans (cM) apart on the same chromosome. An individual heterozygous for both genes (genotype: Ab/aB) is testcrossed with an individual homozygous recessive for both genes (ab/ab). Assuming no interference, what is the expected percentage of offspring with the parental genotypes?

    (a) 5%

    (b) 10%

    (c) 45%

    (d) 80%

    (e) 90%

15. Scientists analyzed the genome of an unknown deep-sea organism and found that 35% of its nucleotides are Adenine (A) and 25% are Guanine (G). Assuming a standard double-helix structure and Chargaff's equivalence, what fraction of the genome comprises pyrimidine bases?

    (a) 40%

    (b) 60%

    (c) 50%

    (d) 45%

    (e) 55%

16. In a newly discovered bacterial species, Dr. Bob identified a gene cluster called the Qlr operon. Its expression is controlled by two regulatory proteins: An activator protein (P), which only binds to the promoter when it's attached to a small molecule ligand (L) and a repressor protein (R), which binds to a separate site to block transcription when L is absent. When L is present, it activates P, which then promotes high levels of transcription. In the absence of L, R binds and prevents even low-level expression of the operon. Based on this description, how would

you classify the Qlr operon's regulation, and how many key molecular interactions are required for full activation of its genes?

(a) Inducible operon; 3 interactions

(b) Repressible operon; 4 interactions

(c) Dual-regulated operon; 2 interactions

(d) Constitutive operon; 5 interactions

(e) Activatable operon; 3 interactions

17. Isoprene is studying the organism N.respenjoyer, a haploid fungal species in the Ascomycota phylum whose 3rd chromosome contains the genes skb and idi, both of which code for two transporter proteins used by N. respenjoyer. The diploid organism he is studying has the genotype skb+skb7 idi+idi7 , where skb7 and idi7 are nonfunctional mutants. From the analysis of 40 tetrads, the following results were obtained (refer to the table below). Which of the following gives the most accurate representation of the map distance between the genes skb and idi?

Number of Asci	Genotype Distribution
24	2 skb/idi, 2 skb7/idi7
12	1 skb/idi, 1 skb7/idi7, 1 skb/idi7, 1 skb7/idi
4	2 skb/idi7, 2 skb7/idi

(a) 45mu

(b) 30mu

(c) 23mu

(d) 15mu

(e) The genes are not linked.

18. Which of the following disorders are caused by trisomies?

I. Edward Syndrome
II. Turner Syndrome
III. Patau Syndrome

(a) I only

(b) II only

(c) III only

(d) I, III

(e) I, II, III

19. Butter Chicken. Ah, so yummy. However, some people are unable to taste butter chicken, a recessive phenotype. In the year 2091, butter chicken will become the only food people are allowed to eat. The fitness of nontasters is 0.5 relative to homozygous dominant tasters and that of heterozygous tasters is 0.8 relative to homozygous dominant tasters. Currently, in the year 2091, the population of generation I has a frequency of the tasting allele to be 0.6. In the next generation, what will be the frequency of the non tasting allele?

    (a) 0.14

    (b) 0.27

    (c) 0.33

    (d) 0.36

    (e) 0.40

20. (Continuing from question 19). Suddenly, in the next generation, all of the nontasters start to die and 15% of heterozygotes also die. What are the new frequencies of the taster and nontaster allele?

    (a) 0.23, 0.77

    (b) 0.34, 0.66

    (c) 0.67, 0.33

    (d) 0.77, 0.23

    (e) 0.90, 0.10

Plant Biology

1. Bob the bacteria had the sudden craving to eat a serving of PEP O's, one of the primary materials being PEP carboxylase, an enzyme in CO2 fixation. Unfortunately, he was completely out of his supply :(Which of the following plants would help him create his own PEP O's?

   I. Amaranth
   II. Sunflower
   III. Corn
   IV. Rice
   V. Pineapple

   (a) I, II, III

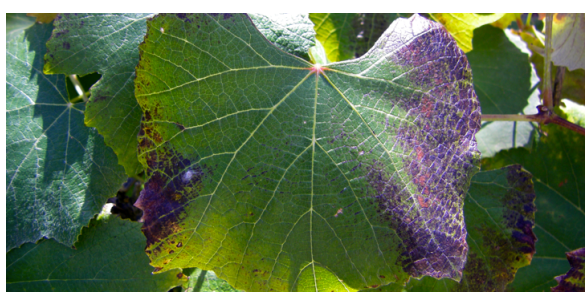
   (b) I, II, IV

   (c) I, III, V

   (d) I, II, V

   (e) I, IV, V

2. You observe an older leaf (shown below) with purple-ish edges. Interestingly, the younger leaves on this plant do not seem to show symptoms. Which of the following nutrients is this plant most likely deficient in?



   (a) Iron

   (b) Calcium

   (c) Potassium

   (d) Nitrogen

   (e) Phosphorus

3. Shown below is an image depicting the development of an angiosperm plant embryo. Which of the following choices accurately describes the order of the different stages of plant embryo development and also correctly states which stage the highlighted picture in the image is in?



I. Globular stage
II. Torpedo stage
III. Proembryo
IV. Heart stage

(a) III, I, II, IV; Torpedo stage

(b) II, I, IV, III; Torpedo stage

(c) II, I, IV, III; Heart stage

(d) III, I, IV, II; Torpedo stage

(e) III, I, II, IV; Heart stage

4. You are on a hike when you run into this absolutely mesmerizing plant (shown below). Looking at it, your friend says: "Wow! What a cool pattern." You, being the absolute USABO nerd that you are, instead say: "Actually, that plant observes _____ phylotaxis."



(a) Desucate

(b) Spiral

(c) Whorled

(d) Opposite

(e) Distichous

5. You are looking to locate a root hair cell to brew some root beer! Which of the following regions should you look to brew your delectable concoction?

   (a) Region of cell division

   (b) Quiescent center

   (c) Region of elongation

   (d) Region of maturation

   (e) Apical center

6. Oh no! The new plant that you just got your girlfriend is under attack! There are insects eating at the leaves of your beautiful new gift. Which of the following plant hormones is likely responsible for mediating the immediate response against this foreign invader?

   (a) Indole-3-acetic acid

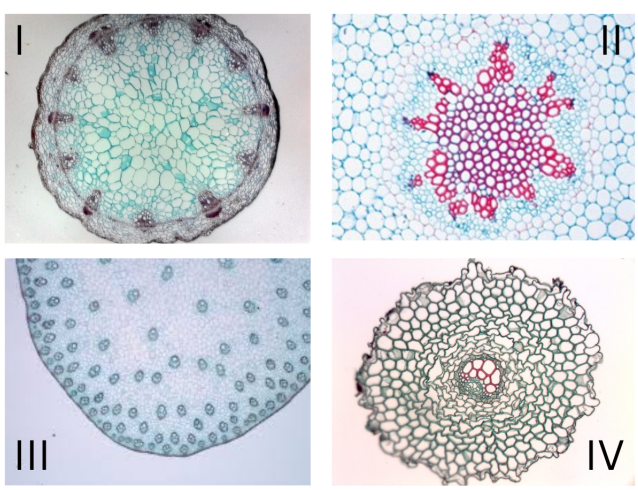
   (b) Systemin

   (c) Florigen

   (d) Salicylic acid

   (e) Jasmonic acid

7. Arrange the following steles from most primitive to most modern/evolved:



   (a) I, II, III, IV

   (b) III, I, IV, II

(c) IV, I, II, III

(d) II, IV, III, I

(e) IV, II, I, III

8. You have been studying the function of nutrients in plants that utilize different pathways of photosynthesis. In order to do so, you have deprived three different species (maize, rice, and pineapple) of different nutrients. The data may be found below. Identify all of the following statements that are TRUE.

	Unknown	Boron	Phosphate	Nitrogen	Mangaese
Maize	-	+ + +	+	+ + +	+
Rice	+ + +	+ + +	+ + +	+	+ + +
Pineapple	-	+ + +	+ + +	+ + +	+ + +

A "+++" indicates standard levels of photosynthesis, a "+" indicates downregulated levels, a "-" indicates insignificant levels of photosynthesis.

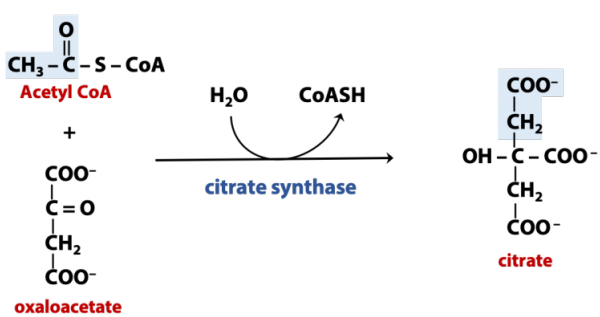
(a) The nutrient labeled "unknown" is sodium.

(b) C4 plants require more nitrogen than C3 plants for photosynthesis.

(c) If the experiment were repeated under high CO2 conditions, maize would have shown a single "+" under the unknown nutrient.

(d) If the experiment were repeated with calcium deprivation, all three plants would have shown a wilted appearance in older leaves relatively quickly.

9. Shown below is the reaction catalyzed by citrate synthase. Which of the following processes would be most directly affected with the inhibition of citrate synthase inside of root cells?



(a) Formation of mucilage

(b) Synthesis of casparian strip

(c) Aluminum resistance

(d) Uptake of water

(e) Synthesis of strigolactones

10. Attempting to get around pesky evolution, you would like to try and bypass plants' tendency towards self incompatibility. If you are trying to do this in a plant that displays sporophytic self incompatibility, which of the following experiments would lead to successful fertilization?

    (a) Transferring the nucleus from an S1 pollen grain to an S2 shell from an S2S3 flower, and then pollinating an S1S2 flower.

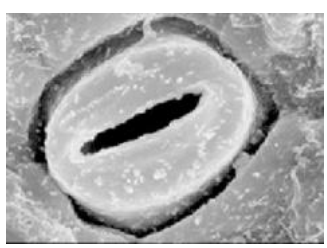
    (b) Transferring the nucleus from an S1 pollen grain to an S3 shell from an S3S3 flower, and then pollinating an S3S3 flower.

    (c) Pollinating an S1S2 flower with an S1 pollen grain from an S1S2 flower and inhibiting DNAses in the style of the flower being fertilized.

    (d) Pollinating an S2S3 flower with an S2 pollen grain from and S2S3 flower, but using a hummingbird as the vector for pollination.

    (e) None of the previous choices would result in successful fertilization.

11. Shown below is an SEM image taken of a certain plant. From which of the following groups of plants could this image NOT have been taken?



    (a) Mosses

    (b) Liverworts

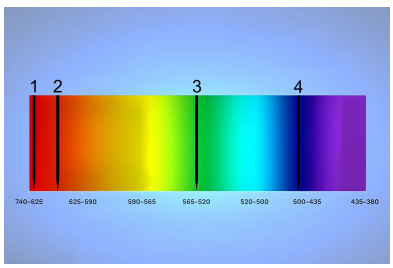
    (c) Hornworts

    (d) Club Mosses

    (e) Quillworts

12. Derrick is studying plants' responses to different wavelengths of light. In his experiment, he monitors the concentration of different receptors present in the plants that he is studying. He notices that some receptors are more prevalent during periods of dark, while others are more prevalent during periods of light. He also noticed that some receptors' concentration seemed to change rapidly after emerging from the soil.

Refer to the image provided below. Which of the following answer choices best describes the concentrations of different receptors that he was monitoring?



(a) In the dark, receptors that absorb wavelengths labeled "2" were most prevalent, while receptors that absorb wavelengths labeled "1" decreased. In response to seedlings emerging from soil, receptors that recognize wavelengths labeled "4" rapidly increased.

(b) In the dark, receptors that absorb wavelengths labeled "1" were most prevalent, while receptors that absorb wavelengths labeled "2" decreased. In response to seedlings emerging from soil, receptors that recognize wavelengths labeled "3" rapidly increased.

(c) In the dark, receptors that absorb wavelengths labeled "4" were most prevalent, while receptors that absorb wavelengths labeled "1" decreased. In response to seedlings emerging from soil, receptors that recognize wavelengths labeled "2" rapidly increased.

(d) In the dark, receptors that absorb wavelengths labeled "2" were most prevalent, while receptors that absorb wavelengths labeled "1" decreased. In response to seedlings emerging from soil, receptors that recognize wavelengths labeled "3" rapidly increased.

(e) In the dark, receptors that absorb wavelengths labeled "3" were most prevalent, while receptors that absorb wavelengths labeled "1" decreased. In response to seedlings emerging from soil, receptors that recognize wavelengths labeled "4" rapidly increased.

13. Suzuko 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 Suzuko 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.

14. Kendrick Lamar, after his stellar performance at the Super Bowl Halftime Show, decided to go home an do some experiments on his personal houseplant D.rake. He discovered that, when genes responsible for gravitropism are knocked out of D.rake, it has a strong hydrotropic response. Which of the following, if removed from the plant, would most likely diminish this hydrotropic response?

(a) Starch sheath

(b) Root hairs

(c) Hydathodes

(d) Rootcap

(e) Marginal Meristems

15. Identify whether the following statements regarding ground tissue are true or false:

(a) Some parenchyma cells often have ingrowths, and are termed as transfer cells.

(b) Collenchyma has a characteristically unevenly thickened cell wall due to uneven deposition of polysaccharides like cellulose.

(c) Sclereids are found in the flesh of pears, as well as the seed coats of legumes.

(d) Bundle sheath cells are an example of specialized parenchyma cells.

16. Identify whether the following pairs correctly or incorrectly match features commonly associated with respective types of photosynthesis:

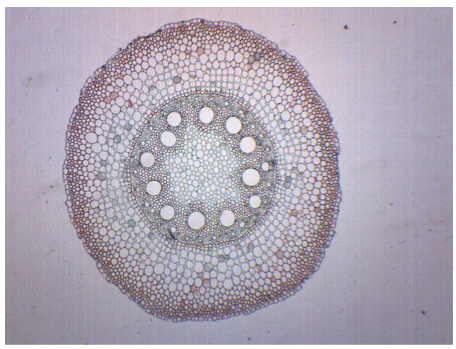
(a) Kranz anatomy: C3 plants

(b) Mestome sheath: C4 plants

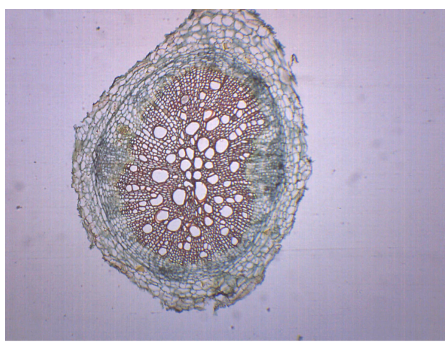
(c) 2-4 cells between adjacent veins: C4 plants

(d) 4-12 cells between adjacent veins: C3 plants

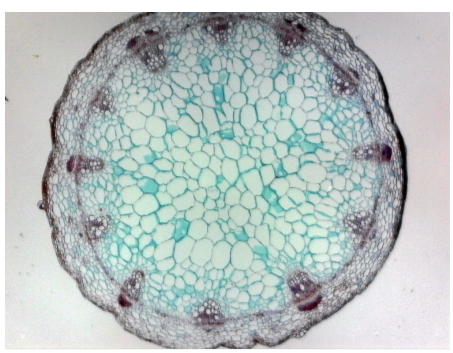
17. Identify whether the following cross sections are correctly or incorrectly matched with the type of stele present and where the cross section is from; select the answer choices that are correctly matched:



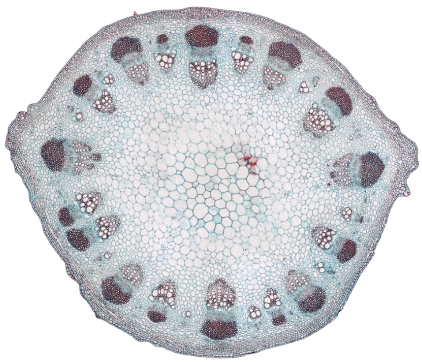
(a) Actinostele, monocot root



(b) Atactostele, dicot stem

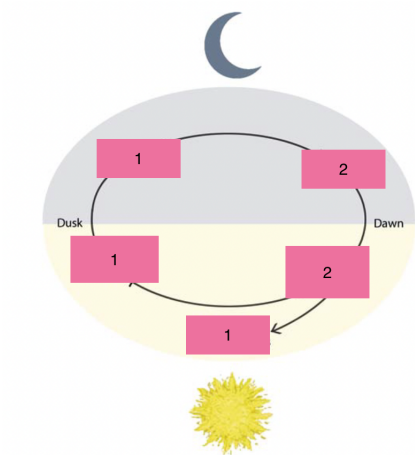


(c) Eustele, monocot root



(d) Eustele, dicot root

18. Let's talk about different proteins in Arabidopsis that help with the regulation of circadian rhythms. There are three major genes involved in this pathway, TOC1, LHY, and CCA1. Identify whether the following statements about the regulation of circadian rhythms in Arabidopsis plants are true or false; select the answer choices that are true.



(a) All of the genes (TOC1, LHY, and CCA1) regulate transcription

(b) The TOC1 protein is a positive regulator of LHY only

(c) LHY and CCA1 are at minimum levels during noon

(d) TOC1 reaches maximum when CCA1 reaches its minimum

19. Indicate whether the following pairings are correct; select the options that are.

(a) Pomes: Simple fruit, develop from compound inferior ovule, mostly derived from non carpellary tissue, e.g. Coconut

(b) Follicles: Dehiscent simple fruit, two carpels split on halves, e.g. Magnolia

(c) Achene: Indehiscent simple fruit, small one seeded fruit, e.g. Buckwheat

(d) Capsule: Dehiscent simple fruit, from compound ovary, e.g. Okra

20. Scientists have recently been working on creating a modified version of rice that utilizes C4 photosynthesis instead of C3. Which of the following accurately describes an advantage of this GMO:

(a) C4 plants do not use RuBisCO.

(b) C4 plants require more resources.

(c) C4 plants do not need the Calvin Cycle.

(d) RuBisCO in C4 plants is more reliable.

(e) RuBisCO in C4 plants can utilize oxygen the same as CO2.

Ecology

1. Which of the following species is incorrectly matched to the zone where it is predominantly found?

   (a) Zooplankton in the Limnetic Zone

   (b) Rooted Cattails in the Littoral Zone

   (c) Catfish in the Benthic Zone

   (d) Anglerfish in the Abyssal Zone

   (e) Rooted Emergent Plants in the Profundal Zone

2. A venomous coral snake mimics a harmless garter snake. This is an example of which type of mimicry?

   (a) Batesian

   (b) Mullerian

   (c) Emsleyan

   (d) Wasmannian

   (e) Vavilovian

3. A forest ecologist surveys a small section of woodland and counts four different tree species with the following numbers of individual trees. Which of the following is the Shannon's Diversity Index?

   Species A: 10
   Species B: 30
   Species C: 60
   Species D: 100

   (a) 1.12

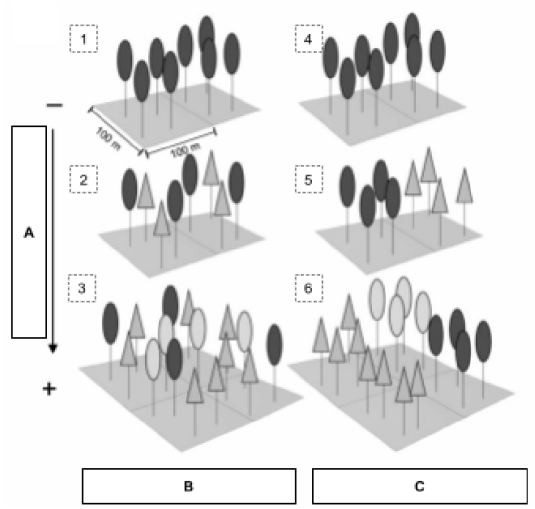
   (b) 1.13

   (c) 1.14

   (d) 1.15

   (e) 1.16

4. In the diagram below, what combination of axes labels of diversity types is accurate for the forests?



(a) A: Alpha, B: Beta, C: Gamma

(b) A: Alpha, B: Gamma, C: Beta

(c) A: Beta, B: Gamma, C: Alpha

(d) A: Gamma, B: Alpha, C: Beta

(e) A: Gamma, B: Beta, C: Alpha

5. You are watching anime when suddenly you question the real life applicability of the word harem within nature. Which of the following relationships best describes a harem of multiple females with a single male?

   (a) Polyandry

   (b) Polygyny

   (c) Polymorphy

   (d) Monogamy

   (e) Promiscuity

6. 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

7. Which of the following most clearly incorrectly describes a species and its reproductive strategy?

   (a) Human, K selected

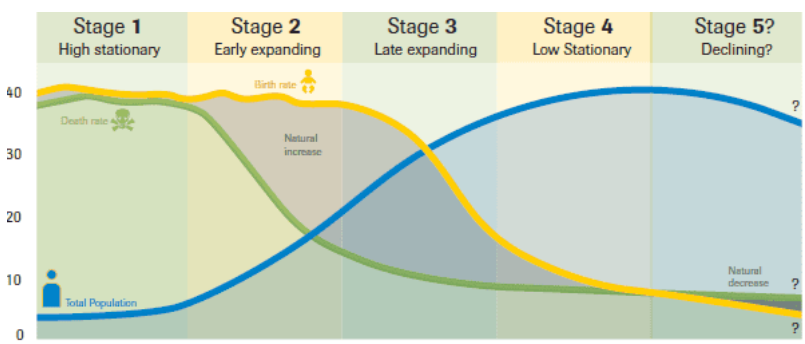
   (b) Crab, R selected

   (c) Lizard, type 2 survivorship curve

   (d) Salmon, type 1 survivorship curve

   (e) Shark, K selected

8. Below is a model of the demographic transition model stages. What can you infer about a country that is in Stage 5 of the Demographic Transition Model?



   (a) High Birth Rates, Low Death Rates, Developed

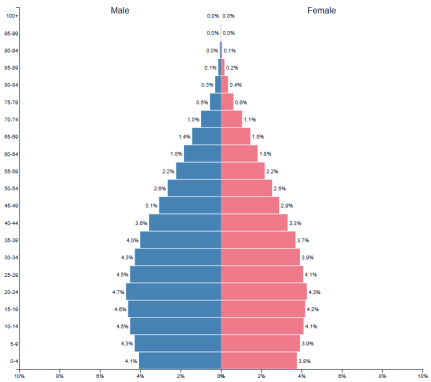
   (b) Advanced Healthcare, Declining Population Rates, Aging Population

   (c) Poor Healthcare, Industrialized, Declining Population Rates

   (d) Low Birth Rates, High Death Rates, Poor Healthcare

   (e) Large Youth Population, High Birth Rates, Advanced Healthcare

9. What country exhibits this population pyramid shown below?



(a) India

(b) Kenya

(c) Japan

(d) United States

(e) Argentina

10. What 2 acids contribute most to acid rain?

(a) Crassulacean acid and Sulfuric Acid

(b) Hydrochloric Acid and Aspartic Acid

(c) Acetic Acid and Citric Acid

(d) Sulfuric Acid and Nitric Acid

(e) Carbonic Acid and Hydrochloric Acid

11. An environmental disaster has occurred and 1,400 tons of molasses spilled into Honolulu Harbor. Based on your knowledge on eutrophication (algae does thrive in molasses), which of the following is most likely, immediate reaction?

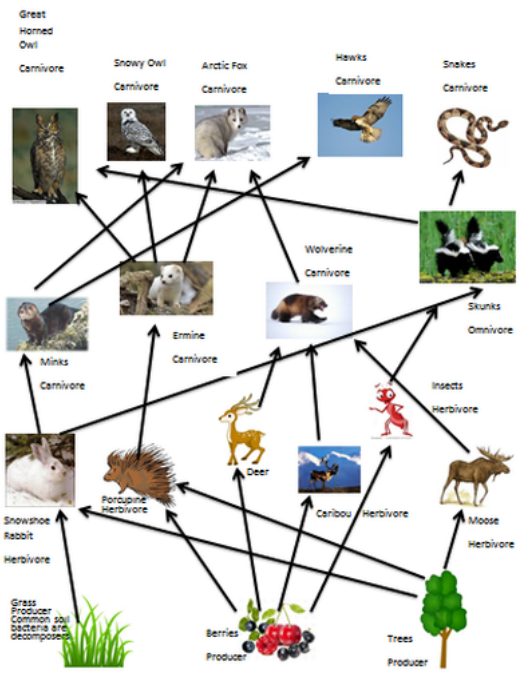
(a) Just like fertilizer runoff, the spill caused a huge loss of marine life due to hypoxic waters.

(b) Marine life near the harbor are mostly from the domain Archaea and thrive in the extreme conditions the spill has made.

(c) There is a massive build up of algae preventing producers in the water to photosynthesize.

(d) Marine life loves the algae build up and use that as a food source.

12. Below is a food web of a mystery biome. This biome gets 30-85 cm of rain per year and has dramatic changes in temperature throughout the seasons. Indicate which of the following statements are true.



(a) This biome is most likely the tundra.

(b) Assuming that the 10% tropic level rule is exact, that snakes need to eat 100 calories per day, and that each animal eats an equal portion of its prey (e.g. porcupines, deer, caribou, and insects each eat $\frac{1}{4}$th of berries), 400,000 calories worth of berries must be produced for the snakes to live.

(c) Berries can be considered a dominant species in this food chain.

(d) Given that the common alder is a deadly species within the tundra, the non-venomous smooth snake which displays similar coloration to the common alder is displaying Batesian mimicry.

13. Uh oh! In a population all of the producers were killed off by a mysterious alien invasion. This sparked a chain reaction causing primary consumers to die due to no food, secondary consumers, and so on! What term describes this phenomenon?

(a) Mesopredator Release

(b) Top Down Control

(c) Lotka-Volterra Dynamics

(d) Bottom Up Cascade

14. Which are methods to mitigate the effects of climate change?

    I. Create more sequestration sinks to store more greenhouse gases in the ground
    II. Anthropogenic ways that implement negative feedback loops to regulate the average temperature of the Earth
    III. Reduce sources of gasses that store heat in the atmosphere
    IV. Investment in renewable resources to promote renewable energy

    (a) I

    (b) I, II

    (c) I, II, III

    (d) I, II, III, IV

    (e) I, II, IV

15. What letter of the alphabet is typically used to define a population curve that has no limits and has infinite resources?

    (a) H

    (b) S

    (c) J

    (d) L

    (e) I

16. Indicate whether the following statements about population estimate methods are true or false.

    (a) You are studying the population of a rare species of turtle in a river. An effective method to estimate the population size would be Mark-Recapture.

    (b) You are studying the distribution of plant species along a coastal habitat. An effective method to estimate the population size would be Transect Sampling.

    (c) You are estimating the population density of ferns in a forest ecosystem. An effective method to estimate the population size would be Point-Count.

    (d) You are counting bird species in a forest during a specific time frame. An effective method to estimate the population size would be Quadrat Sampling.

17. Indicate whether the following statements about geological cycles are true or false.

    (a) About 20% of Earth's water is contained ice, 70% in oceans, and the remaining 10% in lakes and other sources.

    (b) Nitrification, which converts NH3 to NO3, is a oxidizing process .

    (c) Sulfur released from volcanic eruptions typically comes in the form of SO4.

    (d) The greatest three CO2 sinks, in order, are: the oceans, terrestrial forests, and soils.

18. A population with an annual growth rate of 0.35 has a population in the year 1000 of 2000. What is the population in 8 years?

    (a) 8000

    (b) 12000

    (c) 16000

    (d) 24000

    (e) 33000

19. Bobby is trying to learn about different types of ecological indices. He discovers Menhinick's Index which is calculated by the following equation: $\frac{s}{\sqrt{n}}$ where $s = \#$ of species and $n =$ total $\#$ of individuals. Calculate the Menhinick's Index of the following population to 3 significant figures:

Species	Number of Organisms
A	156
B	123
C	91
D	991
E	911

    (a) 0.55

    (b) 0.75

    (c) 0.105

    (d) 0.125

    (e) 0.15

20. Identify all of the following that are true:

(a) Kleiber's Law states that the metabolic rate of plants and animals scales to the 4/5th power of their mass

(b) Rapoport's rule states that the latitudinal ranges of plants and animals are generally larger at lower latitudes than at higher latitudes

(c) Schmalhausen's law states that a population at the extreme limit of its tolerance in any one aspect is more vulnerable to large differences in any other aspect

(d) Thorson's rule states that benthic marine invertebrates at low latitudes tend to produce large numbers of eggs developing to pelagic and widely dispersing larvae, whereas at high latitudes such organisms tend to produce fewer and larger lecithotrophic eggs and larger offspring

(e) Bergmann's rule states that species that live in colder climates (higher latitudes) have smaller limb and appendage sizes

Ethology

1. Tired of reading Lamhaj's Guide to USABO for hours on end, you instead choose to invent a memory linking device to your dog so that you can passively absorb the information within its long pages. The USABO semis exam is rapidly approaching and you need your dog to flip through the pages at a rate of exactly 2 pages/min to maximize efficiency. Which of the following operant conditioning reinforcement schedules would be the most effective given that you do not care at all if your dog forgets how to flip the pages efficiently after the exam?

   (a) Fixed interval

   (b) Variable interval

   (c) Fixed ratio

   (d) Variable ratio

   (e) Classical conditioning

2. During their road trip through Eastern Canada, Anish observed that one of the male prairie voles he took began grooming and staying close to the female after mating. Curious about what hormone might be driving this behavior, he researched several possibilities. Which hormone is most directly responsible for this male post-mating attachment behavior in prairie voles?

   (a) Oxytocin

   (b) Dopamine

   (c) Cortisol

   (d) Vasopressin

   (e) Growth Hormone

3. Kevin was observing fiddler crabs and noticed that males only performed their claw-waving courtship displays during certain times of the month. After tracking their behavior, he realized it always occurred around the new and full moons. Which of the following explain why fiddler crabs time their mating this way?

   I. New and full moons cause the strongest tidal movements.
   II. Female fiddler crabs are most fertile during the new and full moons.
   III. The moonlight helps females spot the males more easily.
   IV. Offspring can return to shore more effectively during strong tidal cycles

   (a) I, II, III

   (b) I, II, IV

(c) II, III, IV

(d) I, IV

(e) I, II, III, IV

4. Graysen Everet Hyunho Lee was in a heated voice-channel discussion with his partner, Evan, when he began comparing the song development of white-crowned sparrows and canaries. Which statement best explains a key difference in how these two bird species learn their songs?

   (a) Both species have a fixed song from birth and do not require learning or exposure.

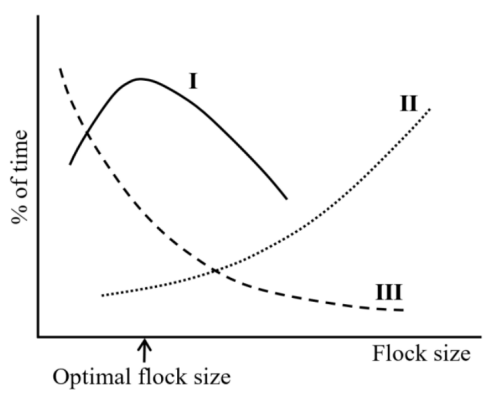
   (b) White-crowned sparrows can crystallize a song without ever hearing their species' song.

   (c) White-crowned sparrows have a fixed sensitive period for song memorization, while canaries continue modifying their songs each year.

   (d) Canaries crystallize their songs permanently after the first breeding season, just like white-crowned sparrows.

   (e) There is no difference.

5. A group of scientists were studying the factors influencing winter flocks of small birds. The survival of birds in a flock is considered to be dependent on two main risks namely starvation and predation. The bird's time budget is divided into three types of behaviors associated with these risks: scanning (for predators), feeding, and fighting (for food). A graph depicting the three behaviours is shown in three curves I, II and III.



   (a) Fighting, feeding and scanning

   (b) Scanning feeding and fighting

(c) Fighting, scanning and feeding

(d) Feeding, fighting and scanning

(e) None of the above

6. Which of the following is an example of a fixed action pattern?

   (a) A stickleback fish attacks a wood block with a red bottom.

   (b) A hamster becomes active at the same time each evening.

   (c) A wolf always tracks its prey.

   (d) A person gets bitten by a poison snake during a hike and never wants to go out in the woods anymore.

   (e) A blackback gull returns to the same island breeding grounds each year.

7. Everyday after school, you walk to the park near the train station and feed the squirrels. After close observation, you start to wonder why they sometimes act so oddly — they are chasing and biting each other's tails. How would you ask a question about the proximate cause of this behavior to your ethology teacher?

   (a) Is this biting behavior a form of courtship?

   (b) Does biting help keep other squirrels from stealing food?

   (c) Does the presence of a tail close-by cause a squirrel to bite?

   (d) Was the squirrel defending a mate from an intruder?

   (e) Are the squirrels being aggressive to each other or are they just playful?

8. An aquaculture facility hatched salmon eggs and released young fish into a river leading to the ocean. The fish fed and grew in the ocean, and in a few years they returned to the facility. Because the number of returning fish was low, a scientist suggested that adding a chemical to the river would _____.

   (a) provide an opportunity for associative learning

   (b) enhance social learning

   (c) allow them to form a cognitive map

   (d) enable them to imprint on the facility

   (e) increase their capacity for spatial learning

9. When mice were exposed to a particular odor and electric shock at the same time, they started to avoid the odor. This is an example of _____.

   (a) imprinting

   (b) operant conditioning

   (c) cognitive mapping

   (d) social learning

   (e) classical conditioning

10. In the famous experiment conducted by Pavlov, he was able to condition dogs to salivate to the sound of a bell. Food alone will cause dogs to salivate, but when the food is paired with a bell, eventually, the food alone would cause salivation. Bob took this experiment further and decided to pair some Drake music to the bell, and eventually the dog started to salivate to the Drake music also. The sound of the bell that elicits the dog to salivate would be considered what?

    (a) Unconditioned Stimulus

    (b) Conditioned Response

    (c) Neutral Stimulus

    (d) Conditioned Stimulus

    (e) Higher Order Conditioning

11. The Century Plant grows vegetatively for many years, blooms its flowers, and finally gets fertilized and disperses its seeds. After all of this however, because of the large amount of energy needed to produce these seeds, the plant dies. What type of reproductive episode is shown in this scenario?

    (a) Polyandry

    (b) Semelparity

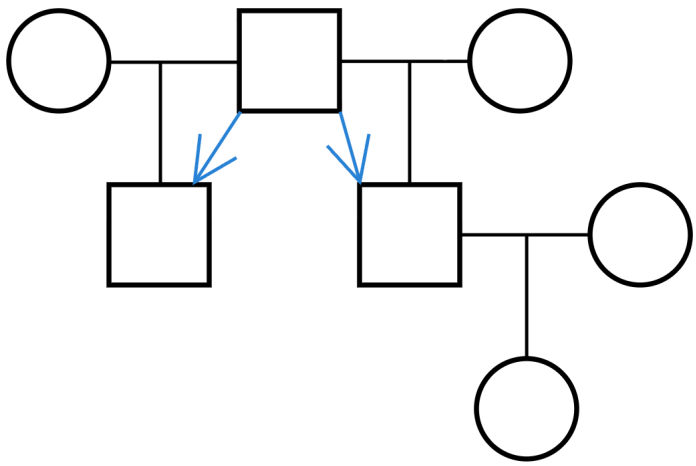
    (c) Iteroparity

    (d) Monogamy

    (e) Sexual Dimorphism

12. Bob and his half-sibling's daughter, Amy, decide to go surfing at the beach. Unfortunately, Amy toppled over, and started drowning. You are thinking about saving her, but it could cost you your life as well, with a 75% chance of you drowning. Hypothetically, Amy has a reproductive potential of generating 3 offspring, and Bob has a reproductive potential

of generating 2. Based on Hamilton's rule and not morality, what should be the best thing for him to do, save or not? Here is a pedigree to help.



(a) R = 0.125, Bob should not save her

(b) R = 0.125, Bob should save her

(c) R = 0.25, Bob should not save her

(d) R = 0.25, Bob should save her

(e) R = 0.5, Bob should not save her

13. While reviewing the footage of a zoo during a flood in Florida, police saw that Billy the monkey had gone out of his way to sacrifice his own life in order to save his first cousin, Pablo, who was stuck in the water. What is the minimum number of offspring Pablo must produce for Billy's risk to be evolutionarily more favorably than if he did not save Pablo, assuming Billy would have produced 2 offspring himself?

    (a) 4

    (b) 5

    (c) 16

    (d) 17

    (e) 32

14. In an experiment, a Dr. Sengupta trains a rat to press a lever to receive a little bit of sugar. Initially, the rat presses the lever randomly, but after several trials, it learns to press the lever more frequently because it gets food as a reward. What type of learning is best demonstrated in this situation?

(a) Classical conditioning

(b) Habituation

(c) Operant conditioning

(d) Imprinting

(e) Insight learning

15. Which of the following species is known for a polygynous mating system?

(a) Wolves

(b) Swans

(c) Bald Eagles

(d) Penguins

(e) Lions

16. Aarav was investigating different species' parental strategies of K-selection and r-selection. K-selection refers to the reproductive strategy of producing few offspring but giving each one maximum resources, whereas r-selection refers to producing large amounts of offspring without high investment. Which of the following species is most likely an r-strategist?

(a) Chimpanzees

(b) Kangaroos

(c) Sea turtles

(d) Wolves

(e) Elephants

17. Certain non-toxic butterfly species, like Papilio polytes, have evolved wing patterns nearly identical to toxic species such as Heliconius erato. Predators avoid both types after bad experiences with the toxic ones. The behavior of Papilio polytes is an example of:

(a) Batesian mimicry

(b) Cryptic coloration

(c) Aggressive mimicry

(d) Automimicry

(e) Müllerian mimicry

18. Jack the kangaroo is having a boxing showdown with John, what type of behavior are they exhibiting?

    (a) Parasitism

    (b) Mutualism

    (c) Antagonistic

    (d) Altruistic

    (e) Malicious

19. A baby elephant learns to follow its mother around, and shortly after the elephants mother's death, it follows another, similar-looking mother elephant. Which type of animal behavior is exhibited by this elephant?

    (a) Imprinting

    (b) Operant conditioning

    (c) Habituation

    (d) Classical conditioning

    (e) Insight learning

20. Sexual dimorphism refers to the extent to which the different sexes of an organism differ in appearance. You observe a female organism of the newly discovered COSMOS organism that is highly decorated surrounded by many male. Which of the following observations makes the most sense?

    (a) The COSMOS species is polyandrous: the female must be more heavily decorated to attract many males.

    (b) The COSMOS species is polyandrous: the female must be more heavily decorated to get access into female harems.

    (c) The COSMOS species is polygynous: the female must be more heavily decorated to attract many males.

    (d) The COSMOS species is polygynous: the female must be more heavily decorated to get access into male harems.

    (e) None of the above conclusions can be made.

Biosystematics

1. Colchicine is a microtubule inhibitor that works by binding to tubulin and inhibiting its polymerization. If you were to inject a sponge (phylum porifera) with colchicine, which of the following functions would be least disrupted?

   (a) Phagocytosis

   (b) Formation of spicules

   (c) Drawing in of water

   (d) Maintenance of mesohyl

   (e) Movement of nutrients

2. Which of the following are traits of all mammals?

   I. Produce milk
   II. Have pharyngeal slits and a post-anal tail during embryonic stages
   III. Contain a single temporal fenestra through which jaw muscles pass through
   IV. All have an amniotic egg
   V. Contain a placenta during embryonic development

   (a) I, II, III

   (b) I, II, III, IV

   (c) I, II, III, IV, V

   (d) II, III, IV

   (e) II, III, IV, V

3. Which of the following animals are most closely related to birds?

   (a) Cyclostomes

   (b) Humans

   (c) Crocodiles

   (d) Eagles

   (e) Grasshoppers

4. Which of the following clades of echinoderms are not matched to the species they contain?

   (a) Asteroidea - Sea Stars

   (b) Opiuroidea - Brittle Stars

   (c) Echinoidea - Sea Urchins

(d) Holothuroidea - Sand Dollars

(e) Crinoidea - Sea lilies

5. Which of the following statements are true regarding insect systematics?

   I. Insects that undergo incomplete metamorphosis contain larval stages specialized for feeding
   II. Insects of the order lepidoptera are more closely related to diptera than to hymenoptera
   III. The ability to suck blood, seen in both fleas and mosquitoes, which are distantly related, is due to convergent evolution

   (a) I only

   (b) I and II

   (c) II and III

   (d) II only

   (e) I, II, and III

6. Which statement below is false regarding protostome and deuterostome development?

   (a) In the eight-cell stage of development, the cells of organisms with protostome development have their developmental fates determined already

   (b) All molluscs exhibit a protostome development pattern

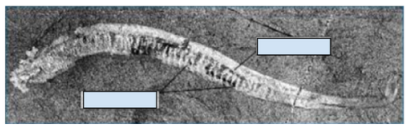
   (c) Deuterostome development patterns seen in many different lineages arose due to homology

   (d) The coelom forms from the mesoderm in protostome development

   (e) The clade Deuterostomia consists of Chordates, Echinochordates, and Hemichordates, all with a deuterostome developmental pattern

7. You recently went looking at a dig site and have found the following fossils. Based on what you know about the fossil record, choose the correct phylogenetic tree that shows the evolutionary relationships between them.

1.



2.



3.



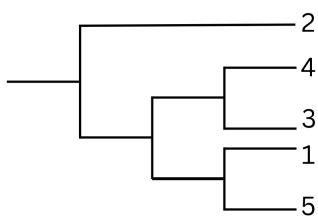
4.



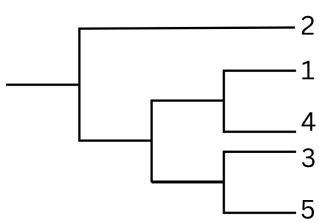
5.



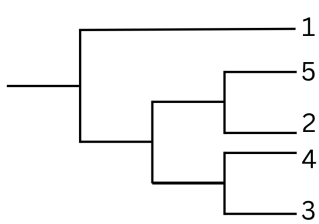
(a)



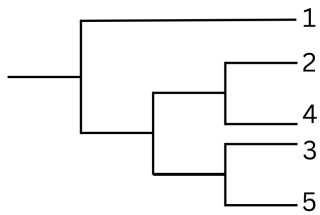
(b)



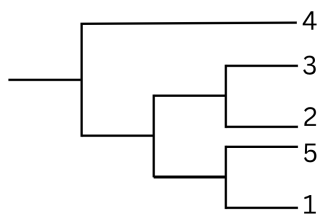
(c)



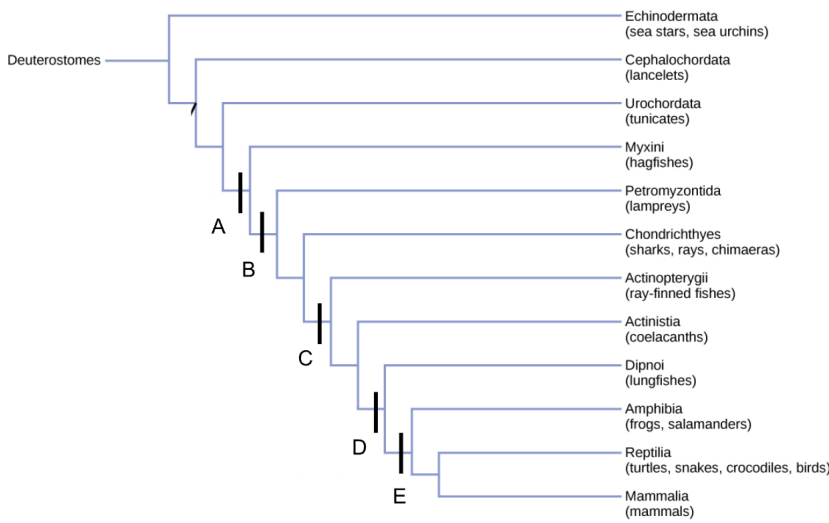
(d)



(e)



8. Using the following image of vertebrate phylogeny, at which hatch would lungs have evolved first?



(a) A

(b) B

(c) C

(d) D

(e) E

9. Which of the following are vertebrates?

I. Sea Urchins

II. Lampreys
III. Lancelets
IV. Lobe-finned fishes
V. Salamanders

(a) I, III, V

(b) I, II, V

(c) I, II, IV

(d) II, III, IV

(e) II, IV, V

10. Which group of protists is known for creating genetic variation from the exchange of tiny micronuclei and larger macronuclei?

(a) Ciliates

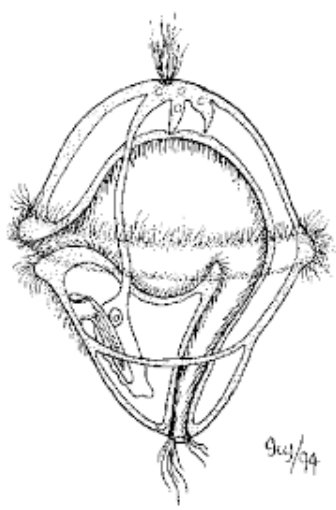
(b) Oomycetes

(c) Parabasalids

(d) Entamoebas

(e) Cercozoans

11. After culturing and growing a random embryo you found, you notice the following structure forming its larval stage. Based on this distinctive developmental stage, the embryo (and subsequent organism) would best be classified as which of the following?



(a) Ecdysozoan

(b) Cnidarian

(c) Echinodermate

(d) Nematode

(e) Lophotrochozoan

12. Which phyla of fungi includes species with a short heterokaryotic stage contained in a zygosporangium?

(a) Basidiomycetes

(b) Ascomycetes

(c) Chytrids

(d) Mucoromycetes

(e) Zoopagomycetes

13. Which of the following would be an example of exaptation?

(a) Giraffe necks used for feeding on taller trees

(b) The incus and malleus bones of the middle ear

(c) Webbed feet involved in swimming for aquatic birds

(d) The alpha and beta subunit genes for hemoglobin

(e) Vision in a squid compared to a human

14. You identify an unknown microorganism in a sample of water that you collected. You decide to run some tests on it to try and identify what it is. You use a French press to try and disrupt the plasma membrane and lyse the cell with 1000 psi, but find that the microorganism withstands the intense pressure! Intrigued, you do some more research and see that this strength is partly due to a glass-like cell wall made of silicon dioxide, along with organic materials. Based on this, which type of microorganism did you most likely find?

(a) Dinoflagellate

(b) Kinetoplastid

(c) Diatom

(d) Apicomplexan

(e) Foram

15. What is the only living group of mammals that lay eggs?

(a) Monotremes

(b) Marsupials

(c) Rodents

(d) Ungulates

(e) Primates

16. Farmer John is planting tomatoes and maize, however his soil is very depleted and has lost its fertility due to repeated harvests of the same crop. Luckily for him though, the fungus *Claroideoglomus Claroideum* has been introduced to his soil. *Claroideoglomus Claroideum* is known for helping plants acquire nutrients such as nitrogen and phosphate, which unfortunately is scarce on John's farm. *Claroideoglomus Claroideum* infiltrates the roots of John's maize and tomatoes, exchanging nutrients with them. Identify which of the following statements is most likely FALSE regarding *Claroideoglomus Claroideum*.

    (a) *Claroideoglomus Claroideum*is an example of an arbuscular mycorrhizal fungi (AMF).

    (b) *Claroideoglomus Claroideum* is a coenocytic fungus.

    (c) *Claroideoglomus Claroideum*'s hyphae consist of many cells separated by septa with pores, in which nutrients can pass through.

    (d) *Claroideoglomus Claroideum* will colonize farmer John's soil by producing spores which will grow and form mycelia.

    (e) *Claroideoglomus Claroideum* may grow by forming thin walled endospores, germinating directly through the spore wall.

17. While on a hike through the Costa Rican jungle, you notice a colony of ants all traveling together towards their ant hill. Fascinated by their behavior, your tour guide tells you these ants can carry tens of times their body weight and that these ants are all bringing these leaves to their queen within the ant hill. Which of the following orders of insects are these ants a part of?



(a) Archeagnatha

(b) Zygentoma

(c) Orthoptera

(d) Hymenoptera

(e) Himenptera

18. You are looking for a protist that uses paramylon as a form of polysaccharide storage, contains pellicles, and a contractile vacuole. Which of the following protist groups best fits this description?

(a) Dinoflagellate

(b) Cryptomonads

(c) Diatoms

(d) Red Algae

(e) Euglenoids

19. Which of the following clades are NOT part of the tracheophytes?

(a) Gnetum

(b) Marchantia

(c) Welwitschia

(d) Poaceae

(e) Pteridophyta

20. Which of the structures are NOT found in pteridophytes?

(a) Sorii

(b) Independent Gametophytes

(c) Fiddleheads

(d) Microphylls

(e) Roots

5.6 Solutions to Subject Specific Questions

Section Links:
Subject Specific Questions
Animal Anatomy & Physiology Solutions
Cell Biology Solutions
Genetics & Evolution Solutions
Plant Biology Solutions
Ecology Solutions
Ethology Solutions
Biosystematics Solutions

Anatomy & Physiology Solutions

1. **Difficulty:** Medium Opens
   Topic: Histology
   The arrows point to a cluster of lighter colored cells within a darker cluster of cells with round nuclei. The morphology of the surrounding tissue is characteristic of the pancreas, and these lighter colored clusters are characteristic of the Islets of Langerhans, making $\boxed{\text{A}}$ the correct choice.

2. **Difficulty:** Easy Opens
   Topic: Hormones
   T3 (I) is derived from tyrosine and is interestingly a hydrophobic hormone; similarly, aldosterone (II) and cortisol (IV) are steroid-derived and hydrophobic. Since glucagon (III) and epinephrine (V) are hydrophilic, they cannot cross the cell membrane and are the only ones with an extracellular receptor. Thus, $\boxed{\text{D}}$ is correct.

3. **Difficulty:** Medium Opens
   Topic: Excretory System
   Glomerular filtration rate (GFR) increases when the pressure inside the glomerulus rises. Dilation of the afferent arteriole (II), constriction of the efferent arteriole (III), and increased systemic blood pressure (V) all serve to raise filtration pressure. Because I and IV would have the opposite effect, $\boxed{\text{D}}$ is the correct answer.

4. **Difficulty:** Easy Opens
   Topic: Nervous System
   During sympathetic activation, we expect pupil dilation (I), digestive slowdown (III), increased norepinephrine secretion (IV), and an increased heart rate (V). Option II is incorrect because the "fight or flight" response triggers bronchodilation rather than constriction, leading us to $\boxed{\text{C}}$ as the correct answer.

5. **Difficulty:** Easy Semis
Topic: Nervous System
The characteristic granular structure shown here represents Nissl bodies, $\boxed{\text{B}}$, which consist of rough endoplasmic reticulum studded with polyribosomes. Nuclei (A) are not the focus as only one is present per neuron, while lipofuscin (C), Lewy bodies (D), and Beta-amyloid plaques (E) have distinct morphologies not observed in this image.

6. **Difficulty:** Hard Opens
Topic: Nervous System
Retrograde transport (axon to cell body) is most involved in viral transport. While kinesin (A) handles anterograde transport and dynactin (B) assists retrograde movement, $\boxed{\text{C}}$ is correct because inhibiting neuronal dynein would effectively block the virus's movement toward the cell body.

7. **Difficulty:** Easy Opens
Topic: Histology
The image features cells with centrally located nuclei and no visible striations, which confirms that $\boxed{\text{A}}$ smooth muscle is the tissue shown. This distinguishes it from cardiac muscle (B) and skeletal muscle (C), which both feature striations, and adipose (D) or connective tissue (E), which have entirely different extracellular matrices.

8. **Difficulty:** Easy Opens
Topic: Embryo Development
The heart (I), kidneys (III), and adrenal cortex (IV) are all derived from the mesoderm. Because the thymus (II) and adrenal medulla (V) arise from the endoderm and ectoderm respectively, the correct answer is $\boxed{\text{C}}$.

9. **Difficulty:** Medium Opens
Topic: Nervous System
β_1 adrenergic receptors are located mainly in the heart, kidney, and adipose tissue; blocking them decreases heart rate (A), contractility (B), renin release (C), and lipolysis (D). Since ghrelin secretion (E) is not regulated by these receptors, $\boxed{\text{E}}$ is the correct answer.

10. **Difficulty:** Medium Opens
Topic: Metabolism
Because $\boxed{\text{B}}$ cholesterol serves as the primary precursor for bile salt synthesis in the liver, its levels will likely decrease during this process. Other substances like maltose (A), arginine (C), and various electrolytes (D, E) are not directly consumed or significantly affected by bile salt production.

11. **Difficulty:** Hard Opens
Topic: Biomedical Sciences
The lab results showing low sodium, low glucose, and low cortisol

alongside markedly elevated ACTH point to primary adrenal insufficiency (Addison's disease). This indicates the pituitary is attempting to stimulate the adrenals to no avail, confirming that $\boxed{\text{B}}$ is the correct diagnosis.

12. **Difficulty:** Medium Opens
Topic: Visual System
Visual signals travel from photoreceptors to the LGN and finally the primary visual cortex. $\boxed{\text{C}}$ is correct because it accurately describes this pathway and identifies the lateral geniculate nucleus as the first site where information from both eyes is integrated.

13. **Difficulty:** Medium Opens
Topic: Excretory System
Filtration speed in the glomerulus is determined by size and charge. Small, freely filtered sodium ions pass through the barrier fastest, followed by the amino acid tryptophan. Large, negatively charged albumin molecules are filtered last, making $\boxed{\text{A}}$ the correct sequence.

14. **Difficulty:** Medium Opens
Topic: Nervous System
Sarin acts as a potent acetylcholinesterase inhibitor. This leads to a dangerous buildup of ACh in the synaptic clefts, causing continuous receptor stimulation and spastic paralysis; therefore, $\boxed{\text{D}}$ is the correct answer.

15. **Difficulty:** Medium Semis
Topic: Cardiovascular System
During a hemorrhage, the body triggers vasoconstriction (A), increased heart rate (B), and reduced GFR (C) via the RAAS pathway (E). However, ANP secretion—which promotes vasodilation—would not increase during volume loss, so $\boxed{\text{D}}$ is the correct choice.

16. **Difficulty:** Medium Semis
Topic: Immune System
The presence of TfR1 and high levels of lactoferrin (an iron-sequestering protein) in the precipitate suggests the cell type is $\boxed{\text{E}}$ neutrophils. Other leukocytes like monocytes or T cells do not produce lactoferrin in such high abundance.

17. **Difficulty:** Medium Opens
Topic: Digestive System
Bile functions to emulsify lipids (B), excrete bilirubin (C), neutralize stomach acid (D), and facilitate fat-soluble vitamin absorption (E). Because Vitamin B5 is water-soluble and does not require bile for absorption, $\boxed{\text{A}}$ is the incorrect statement.

18. **Difficulty:** Medium Semis

Topic: Cardiovascular System
By calculating stroke volume ($110 - 80 = 30$ mL) and cardiac output ($30 \times 70 = 2.1$ L/min), we find a Mean Arterial Pressure (MAP) of 63 mmHg (2100×0.03). This low pressure risks organ dysfunction, so $\boxed{\text{B}}$ is correct.

19. **Difficulty:** Medium Semis
Topic: Nervous System
The withdrawal reflex is a protective, polysynaptic spinal mechanism that simultaneously activates flexor muscles and inhibits extensor muscles. Thus, $\boxed{\text{B}}$ is the correct description of this response.

20. **Difficulty:** Medium Semis
Topic: Biomedical Sciences
The ECG reveals a consistent prolongation of the PR interval followed by a skipped QRS complex. This specific pattern is the hallmark of a second-degree atrioventricular (AV) block, confirming that $\boxed{\text{D}}$ is the correct answer.

Cell Biology Solutions

1. **Difficulty:** Hard Semis
   Topic: Biochemistry
   This plot is known as a Scatchard plot and follows the Scatchard equation:
   $$\frac{\bar{n}}{[L]} = \frac{n}{K_d} - \frac{\bar{n}}{K_d}$$
   The x-intercept represents the number of binding sites (n), narrowing the answer to (c) or (d). Since the slope is $-\frac{1}{K_d}$ and the slope of the graph is -2, the value of K_d is $1/2$. Thus, the answer is $\boxed{\text{C}}$.

2. **Difficulty:** Medium Opens
   Topic: Cell Transport
   Receptor-mediated endocytosis involves selective uptake via receptor binding and vesicle formation. This specific process relies on the coat protein clathrin to form the pits that pinch off from the plasma membrane. While COPI and COPII handle Golgi-ER transport, and ATP/calcium provide energy or signaling, none act as the primary vesicle coat protein here. Thus, the correct answer is $\boxed{\text{C}}$.

3. **Difficulty:** Medium Opens
   Topic: Biotechnology
   Light microscopy is restricted by a diffraction limit of approximately 200 nm, ruling out choices (A), (B), and (C). While TEM is optimized for viewing internal structures, scanning electron microscopy (SEM) is the superior choice for producing high-resolution images of external morphology, such as the outer surface of a mitochondrion. Therefore, the correct answer is $\boxed{\text{E}}$.

4. **Difficulty:** Medium Opens
   Topic: Metabolism
   In photosynthesis, CAM plants separate carbon fixation temporally to conserve water, and C_4 plants separate it spatially to avoid oxygen accumulation. While linear electron flow generates both ATP and NADPH, cyclic electron flow only produces ATP because electrons do not reach $NADP^+$ reductase. Consequently, statement (D) is false, making $\boxed{\text{D}}$ the correct choice.

5. **Difficulty:** Medium Opens
   Topic: Chromatin Regulation
   Centromeres (A), telomeres (B), transposable elements (C), and short tandem repeats (E) are generally associated with constitutive heterochromatin to ensure structural stability. X-inactivation regions (D), however, are categorized as facultative heterochromatin because this state is reversible and developmental. Thus, the answer is $\boxed{\text{D}}$.

6. **Difficulty:** Medium Opens

Topic: Metabolism
Kinases are the specific enzymes responsible for transferring phosphate groups to consume or generate ATP. In the glycolytic pathway, these include hexokinase (I), phosphofructokinase-1 (II), phosphoglycerate kinase (III), and pyruvate kinase (IV). Because dehydrogenases facilitate redox reactions instead, the correct answer is $\boxed{\text{C}}$.

7. **Difficulty:** Medium Semis
Category: Molecular Pathways / Metabolism
Enzymes (A), (B), (C), and (E) serve as the primary rate-limiting steps in their respective metabolic pathways. However, the rate-limiting enzyme in the ornithine (urea) cycle is carbamoyl-phosphate synthetase I (CPS-I). Since LPO is involved in leukotriene synthesis within the immune response rather than the direct urea cycle, $\boxed{\text{D}}$ is the correct answer.

8. **Difficulty:** Hard Semis
Topic: Biotechnology
Data analysis reveals that Rif1 depletion increases the binding of firing factors like Treslin, which initiates DNA replication; thus, Rif1 normally acts as a repressor. Inhibiting Rif1 via siRNAs would accelerate S-phase (II), and its inhibition also leads to the binding of Cdc45 for DNA repair (V). Since statements II and V are accurate, the answer is $\boxed{\text{II and V}}$.

9. **Difficulty:** Hard Semis
Topic: Biotechnology
Images confirm that rhi, del, and cuff colocalize at the apical tip of the testis (I). Furthermore, scatterplots show that *copia* transposons are more active than *Invader*3 (V). Because the moon mutation acts downstream of rhi and Rhi mutants show increased transposon activity, only statements I and V are supported. Thus, the answer is $\boxed{\text{I and V}}$.

10. **Difficulty:** Medium Opens
Topic: Metabolism
Statement I is true because a proton gradient exists across the thylakoid membrane to power ATP synthase. However, Rubisco is involved in the light-independent reactions, not electron transfer, and oxygen is a byproduct of the light-dependent reactions, not the Calvin cycle. Thus, only (I) is correct, making the answer $\boxed{\text{A}}$.

11. **Difficulty:** Easy Opens
Topic: Metabolism
Ubiquinone, ubiquitin, PNMT, and StAR serve roles in electron transport, protein degradation, and hormone synthesis that are unrelated to the detoxification of reactive oxygen species. Catalase is the primary enzyme responsible for breaking down hydrogen peroxide within peroxisomes. Therefore, $\boxed{\text{C}}$ is the correct answer.

12. **Difficulty:** Medium Opens
Topic: Cell Transport
The secretion pathway follows a specific order: synthesis in the Rough ER, transport via COPII vesicles to the cis-Golgi, modification and sorting through the Golgi stacks, and finally, delivery to the plasma membrane via clathrin-coated or secretory vesicles for exocytosis. This sequence is correctly represented by choice $\boxed{\text{A}}$.

13. **Difficulty:** Hard Opens
Topic: Organelles
While lysosomes and peroxisomes are central to detoxification, the smooth ER is also a major site for this process, particularly in the liver. Statements (A), (B), (D), and (E) correctly describe phospholipid synthesis, ribosome function, and evolutionary origins. Therefore, the incorrect statement is $\boxed{\text{C}}$.

14. **Difficulty:** Medium Semis
Topic: Biochemistry
Amygdalin (A) contains a cyanide group ($\text{C} \equiv \text{N}$) that is released during digestion as hydrogen cyanide. This substance is a lethal inhibitor of Cytochrome C Oxidase in the mitochondrial electron transport chain. Thus, choice $\boxed{\text{A}}$ is the correct answer.

15. **Difficulty:** Medium Opens
Topic: Cancer
Cancer cells frequently exhibit the Warburg Effect (favoring glycolysis) and lose their need for physical attachment to a surface to grow. This lack of anchorage dependence is a hallmark of malignancy. Because oncogenes usually involve gain-of-function and sarcomas are not derived from white blood cells, the true statement is $\boxed{\text{B}}$.

16. **Difficulty:** Easy Opens
Topic: DNA Repair
Nucleotide excision repair (NER) is the specific mechanism responsible for removing bulky, helix-distorting lesions, such as those caused by UV radiation. Other mechanisms like base excision or mismatch repair handle smaller or different types of errors. Therefore, $\boxed{\text{E}}$ is the correct answer.

17. **Difficulty:** Medium Semis
Topic: Biotechnology
A hydropathy plot showing seven distinct positive peaks is strongly indicative of seven membrane-spanning α-helices. The plot cannot provide information on quaternary structure (subunits) or glycosylation timing. Therefore, statement $\boxed{\text{C}}$ is the only correct inference.

18. **Difficulty:** Medium Opens
Topic: Biotechnology

In immunohistochemistry or similar assays, secondary antibodies are utilized to bind to the primary antibody. This serves to "fluorescently label" the primary antibody, thereby allowing the visualization of the target protein. Thus, $\boxed{\text{D}}$ is the correct answer.

19. **Difficulty:** Medium Semis
Topic: Organelles
Membrane fluidity is influenced by chain length, saturation, and sterol content. However, the movement of phospholipids between the inner and outer leaflets is not a random process; it is tightly regulated by specific enzymes like flippases and floppases. Therefore, statement (B) is false, making $\boxed{\text{B}}$ the correct answer.

20. **Difficulty:** Hard Opens
Topic: Cell Biology
Actin and intermediate filaments provide essential structural support for the cell cortex and nuclear lamina. While actin treadmilling is a known behavior, statement (B) is incorrect because microtubules will shrink from both ends when the tubulin concentration falls below a critical threshold. Thus, $\boxed{\text{B}}$ is the answer.

Genetics & Evolution Solutions

1. **Difficulty:** Easy Opens
   Topic: Operons
   $\boxed{\text{A}}$ is correct because the lac operon is the most common example of an inducible operon—the binding of allolactose, the inducer, triggers inactivation of the lac repressor. (B) is incorrect as the cAMP-CAP complex increases lac operon transcription, while (C) is incorrect as diauxic refers specifically to the sequential use of two sugars. (D) is incorrect as the operon mechanism does not involve direct binding to trp, and (E) is incorrect as the 3-4 stem loop is involved in attenuation. Thus, the answer is (A).

2. **Difficulty:** Hard Semis
   Topic: Recombination Frequency
   If the *erm* and *pen* genes were unlinked, we would expect a 1/16 survival rate from non-recombinant $erm^+erm^+pen^+pen^+$ offspring. However, the 17% survival rate indicates linkage.

   Let r be the chance of recombination; thus, $1 - r$ represents the frequency of parental gametes. We need two parental gametes to survive, and we must divide by 2 because only half of the parental gametes are erm^+pen^+.

   We can solve using the equation $\left(\frac{1-r}{2}\right)^2 = 0.17$. After calculation, we find $r = 17.6\%$, or approximately 18 cM. Thus, the answer is $\boxed{\text{C}}$.

3. **Difficulty:** Medium Semis
   Topic: Operons
   (A) and (B) are true as the $Helpful$ gene undergoes increased translation under the $KINDBEFRIENDER$ promoter. (D) and (E) are true because KbO knockouts reveal basal transcription, indicating the $Nice$ protein acts as a repressor. (C) is false because the expression of "Caring" remains at baseline regardless of exposure to $Nice$ or $Mean$, meaning no correlation can be concluded. Thus, the answer is $\boxed{\text{C}}$.

4. **Difficulty:** Hard Semis
   Topic: Microbiology
   Examining each statement: I is true as the N protein is an antiterminator. II is false because cII activates P_{re}, not P_{rm}. III is false because while the repressor inhibits *cro* expression, it activates P_{rm} through positive autoregulation, and lysogeny maintenance relies on P_{rm}. Therefore, the answer is $\boxed{\text{B}}$.

5. **Difficulty:** Easy-Medium Opens
   Topic: Gene Expression
   In marsupials, paternal X chromosomes are specifically inactivated. Choices (A), (C), (D), and (E) serve as distractions regarding the

mechanisms of X-inactivation found in other taxa. Thus, $\boxed{\text{B}}$ is the correct answer.

6. **Difficulty:** Easy Opens
Topic: Selection
Following the environmental change, grey birds were better camouflaged while blue birds were targeted by predators. This shift in population frequency toward a single extreme phenotype—grey coloration—is a classic example of $\boxed{\text{B}}$ directional selection. Choices (A), (C), (D), and (E) are incorrect as they describe different selective pressures.

7. **Difficulty:** Medium Semis
Topic: Recombination
The Coefficient of Coincidence (CoC) is defined as:

$$CoC = \frac{\text{observed \# of double crossovers}}{\text{expected \# of double crossovers}}$$

Based on the provided data, $--+$ and $++-$ are the double crossovers because they have the lowest frequency, establishing the gene order as $duck - wheel - on$.

The $duck - wheel$ recombination frequency is $\frac{32+15+14+64}{462} = \frac{125}{462}$.

The $wheel - on$ recombination frequency is $\frac{18+15+14+72}{462} = \frac{119}{462}$.

To find the expected number of double crossovers, we calculate:

$$\frac{125}{462} \cdot \frac{119}{462} \cdot 462 \approx 32.197$$

With the observed double crossovers being $15 + 14$, the final calculation is $CoC = \frac{29}{32.197} \approx 0.9$. Therefore, $\boxed{0.9}$ is the correct answer.

8. **Difficulty:** Easy Opens
Topic: Population Genetics
Given the frequencies, we can calculate the ratio of Rh^+ to Rh^- phenotypes:

$$\frac{(0.38 + 0.32 + 0.09)}{(0.09 + 0.06 + 0.02)} = 4.647$$

This should be roughly equal to the ratio of AB^+ to AB^- (as stated by the assumption in the last sentence of the question), indicating the answer is $\boxed{\text{E}}$.

9. **Difficulty:** Medium Opens
Topic: Evo-Devo
Hox genes are highly conserved or very similar across many animal species. While organisms share these developmental genes, each species has a unique set of regulatory sequences that control their expression. For example, a fruit fly and a mouse share similar Hox genes, but

differences in gene regulation lead to vastly different body structures. Thus, the answer is $\boxed{\text{B}}$.

10. **Difficulty:** Easy Opens
Topic: Relatedness and Altruism
The relatedness coefficient (r) between a child and their mother is 0.5, representing the 50% of genetic material shared directly. In contrast, the relatedness with grandparents is 0.25 (25%). Thus, the answer is $\boxed{\text{A}}$.

11. **Difficulty:** Medium Semis
Topic: Sequence Analysis
This is an application of the Needleman-Wunsch algorithm. I is false because Sequence 2 is two nucleotides longer; the -4 gap penalty cannot be compensated for by matches in any orientation. II is false because the best alignment score is -5, achieved by aligning the start of Sequence 1 with Sequence 2. III is true as the sequences share the same start (G) and end (CA) motifs. Thus, the correct answer is $\boxed{\text{B}}$.

12. **Difficulty:** Medium Opens
Topic: Meiosis
Given independent assortment, the probability that a gamete inherits a specific parental chromosome at any given position is 1/2. Since Angela has 30 chromosome pairs (derived from 60 chromatids), the probability that Bob inherits all 30 specific chromosomes from R2D2 is $(1/2)^{30}$. Thus, the answer is $\boxed{\text{C}}$.

13. **Difficulty:** Hard Opens
Topic: Nucleotide Modifications
Naturally occurring deamination reactions include: Adenine $\rightarrow$ Hypoxanthine, Guanine $\rightarrow$ Xanthine, Cytosine $\rightarrow$ Uracil, and 5-Methylcytosine $\rightarrow$ Thymine. Thymine does not undergo deamination as it lacks an amine group. Consequently, the only correct answer choices are $\boxed{\text{A and D}}$.

14. **Difficulty:** Medium Opens
Topic: Recombination
A distance of 10 cM corresponds to a recombination frequency of 10%. This implies that 90% of the offspring will possess a parental genotype. Since there are two possible parental genotypes, the probability for any specific one is $90\%/2 = 45\%$. Thus, the correct answer is $\boxed{\text{C}}$.

15. **Difficulty:** Easy Opens
Topic: Chargaff's Rules
If 35% of the genome is Adenine (A) and 25% is Guanine (G), then 60% of the genome consists of purine bases ($35\% + 25\% = 60\%$). Since the total must be 100%, the remaining 40% must comprise pyrimidine bases. Thus, the correct answer is $\boxed{\text{A}}$.

16. **Difficulty:** Easy Opens
Topic: Chargaff's Rules
If 35% of the genome is Adenine (A) and 25% is Guanine (G), the total purine content is 60%. Therefore, the pyrimidine content must be 40% (100% − 60%). Thus, the correct answer is $\boxed{\text{A}}$.

17. **Difficulty:** Hard Semis
Topic: Recombination Frequency
Given the genotype distributions of asci from an ascomycete, the following formula can be used to calculate recombination frequency (map distance):
$$\frac{T + 6NPD}{\text{Total number of asci}} \times 0.5 \times 100$$
Plugging our values into this formula:
$$\frac{(12 + 6 \cdot 4)}{40} \cdot 0.5 \cdot 100 = 45$$
Thus, the answer is $\boxed{\text{A}}$.

18. **Difficulty:** Easy Opens
Topic: Genetic Disorders
Edward syndrome and Patau syndrome are caused by trisomies in chromosomes 18 and 13, respectively. Turner's syndrome doesn't result from a trisomy, rather a monosomy. Thus, the correct answers are I and III, or $\boxed{\text{D}}$.

19. **Difficulty:** Hard Semis
Topic: Population Genetics
The formula to calculate the allele frequency in the next generation is:
$$q_{next} = \frac{2pqw_{Aa} + 2q^2w_{aa}}{2(p^2w_{AA} + 2pqw_{Aa} + q^2w_{aa})}$$
Assuming $p = 0.6$, $q = 0.4$, $w_{AA} = 1$, $w_{Aa} = 0.8$, and $w_{aa} = 0.5$, we plug these values in:
$$\frac{1}{2}\frac{((2 \cdot 0.6 \cdot 0.4 \cdot 0.8) + (2 \cdot 0.4 \cdot 0.4 \cdot 0.5))}{((0.6 \cdot 0.6 \cdot 1) + (2 \cdot 0.6 \cdot 0.4 \cdot 0.8) + (0.4 \cdot 0.4 \cdot 0.5))}$$
This yields 0.33, meaning the correct answer is $\boxed{\text{C}}$.

20. **Difficulty:** Hard Semis
Topic: Population Genetics
In the next generation, $q = 0.33$ and $p = 1 - 0.33 = 0.66$. Using the modified equation to account for deaths (all q^2 die, and 15% of $2pq$ die):
$$0.66^2 + 2 \cdot 0.85 \cdot 0.33 \cdot 0.66 = 0.82$$

Because the total no longer equals 1, we divide by 0.82 to find $f(AA) = 0.54$ and $f(Aa) = 0.46$. The new allele frequency q is calculated as $f(aa) + \frac{1}{2}f(Aa) = 0 + 0.5(0.46) = 0.23$. Thus, the answer is $\boxed{\text{D}}$.

Plant Biology Solutions

1. **Difficulty:** Hard Opens
   Topic: Plant Phylogeny
   PEP carboxylase is the CO_2-fixing enzyme used in the mesophyll cells of C_4 and CAM plants. Amaranth (I) and corn (II) are C_4 plants, and pineapple (V) is a CAM plant. In contrast, sunflower (III) and rice (IV) are C_3 plants that do not utilize PEP carboxylase for initial fixation. Since we are looking for C_4/CAM species, (I), (II), and (V) are true, making $\boxed{\text{C}}$ the correct answer.

2. **Difficulty:** Medium Opens
   Topic: Plant Nutrition
   Purplish leaf edges are a classic sign of phosphorus deficiency. Because phosphorus is a phloem-mobile element, the plant prioritizes younger, growing leaves during a shortage. This results in the localization of deficiency symptoms to the older leaves, as described in the problem. Therefore, $\boxed{\text{E}}$ is correct.

3. **Difficulty:** Medium Semis
   Topic: Plant Development
   The stages of angiosperm embryogenesis proceed in the following sequence: Proembryo (III) $\rightarrow$ Globular (I) $\rightarrow$ Heart (IV) $\rightarrow$ Torpedo (II). Morphologically, the torpedo stage is characterized by the elongation of the split cotyledons established during the heart stage. Therefore, the correct choice is $\boxed{\text{D}}$.

4. **Difficulty:** Medium Opens
   Topic: Phyllotaxis
   In spiral phyllotaxis, each successive leaf emerges at a fixed angle (the golden angle), resulting in a spiral pattern that maximizes light capture and minimizes self-shading. The plant in the image exhibits this classic spiral arrangement. Thus, $\boxed{\text{B}}$ is the correct answer.

5. **Difficulty:** Medium Opens
   Topic: Roots
   Root hairs are tubular extensions of individual epidermal cells that significantly increase the surface area for water and mineral absorption. These structures specifically form in the region of maturation, also known as the differentiation zone. Therefore, $\boxed{\text{D}}$ is correct.

6. **Difficulty:** Medium Opens
   Topic: Plant Hormones
   While jasmonic acid (E) and salicylic acid (D) are involved in defense, systemin (B) is a peptide hormone released at wound sites that acts as the most immediate responder to insect attack. It activates jasmonic acid signaling to trigger the release of volatile compounds. Thus, $\boxed{\text{B}}$ is the best answer.

7. **Difficulty:** Medium Semis
Topic: Plant Histology
The evolution of the stele proceeds from the most primitive to the most modern: Protostele (IV) → Actinostele (II) → Eustele (I) → Atactostele (III). This progression moves from a solid vascular core to discrete rings and finally scattered bundles. In the order IV-II-I-III, the answer is $\boxed{\text{E}}$.

8. **Difficulty:** Medium Semis
Topic: Plant Nutrients
Statement I is true as sodium is an essential micronutrient for C_4 and CAM plants to regenerate PEP. Statement II is false as rice (C_3) is significantly affected by nitrogen depletion. Statement III is false because sodium is required for the regeneration of the CO_2 acceptor PEP, not for the carboxylase directly. Statement IV is false because calcium is phloem-immobile, meaning younger leaves show symptoms first. Thus, only I is true, leading to $\boxed{\text{A}}$.

9. **Difficulty:** Medium Opens
Topic: Plant Nutrients
To survive in acidic soils with high aluminum toxicity, certain plants exude organic acids like citrate into the rhizosphere. The citrate chelates the aluminum ions, preventing them from entering the root and causing poisoning. Thus, $\boxed{\text{C}}$ is correct.

10. **Difficulty:** Medium Opens
Topic: Self Incompatibility
In gametophytic self-incompatibility, the S-allele of the haploid pollen grain determines the reaction. In sporophytic self-incompatibility, the phenotype is determined by the diploid parental sporophyte (the "shell"). Therefore, $\boxed{\text{E}}$ is correct.

11. **Difficulty:** Medium Opens
Topic: Plant Evolution
The SEM shows a functional stomate with guard cells. Liverworts are unique among land plants because they lack true stomata, possessing only fixed air pores that cannot be closed. Because the image contains a regulated stomate, it cannot be a liverwort. Thus, $\boxed{\text{B}}$ is correct.

12. **Difficulty:** Medium Semis
Topic: Plant Response to External Stimuli
P_r absorbs red light (2) and is most prevalent in the dark, while P_{fr} absorbs far-red light (1). Blue light receptors like cryptochromes handle de-etiolation. Green light (3) is largely reflected, contributing to the plant's appearance but not these specific light responses. Thus, $\boxed{\text{A}}$ is correct.

13. **Difficulty:** Medium Semis
Topic: Plant Cross Sections

Vascular rays (A) extend into both secondary xylem and phloem, serving as conduits for nutrient transfer (D) and storage (C). The vascular cambium produces tissues inward and outward; however, these derivatives do not "invade" the primary cortex or pith. Therefore, the incorrect statement is $\boxed{\text{E}}$.

14. **Difficulty:** Easy Semis
Topic: Plant Anatomy
The root cap is the primary site for sensing environmental gradients. It is responsible for hydrotropism, establishing the auxin and abscisic acid (ABA) signaling required for the root to curve toward moisture. Thus, $\boxed{\text{D}}$ is correct.

15. **Difficulty:** Medium Semis
Topic: Plant Anatomy
All statements are correct: (A) transfer cells have wall ingrowths for transport; (B) collenchyma provides flexible support; (C) sclereids provide grainy protection in pears; and (D) bundle sheath cells are specialized parenchyma for transport or carbon fixation. Thus, the answer is $\boxed{\text{E}}$.

16. **Difficulty:** Medium Semis
Topic: Plant Anatomy
Kranz anatomy is a hallmark of C_4 plants, not C_3. Furthermore, C_4 plants typically have a mestome sheath and higher vein density (2–4 cells between veins), while C_3 plants have wider spacing (4–12 cells). Thus, B, C, and D are correct, making $\boxed{\text{D}}$ the answer.

17. **Difficulty:** Medium Semis
Topic: Plant Cross Sections
Actinosteles (A) are found in primitive vascular plants, Atactosteles (B) are typical of monocot stems, and Eusteles (C) are typical of dicot stems. Siphonosteles are characteristic of certain seedless vascular plants like ferns, making $\boxed{\text{D}}$ the correct match.

18. **Difficulty:** Hard Semis
Topic: Plant Cell Bio
TOC1, LHY, and CCA1 are central to the plant circadian clock. TOC1 levels peak in the evening when CCA1/LHY levels are low, acting as a positive regulator of their transcription to restart the cycle the following morning. Thus, (A) and (D) are true, making $\boxed{\text{E}}$ the correct answer.

19. **Difficulty:** Medium Semis
Topic: Plant Anatomy
Pomes like apples are accessory fruits, and follicles consist of a single carpel. Achenes (buckwheat) and capsules (poppy) are correctly described as indehiscent and dehiscent dry fruits, respectively. Thus, C and D are correct, making $\boxed{\text{D}}$ the answer.

20. **Difficulty:** Medium Opens
Topic: Plant Anatomy
In C_4 plants, the concentration of CO_2 around RuBisCO in the bundle sheath cells effectively suppresses photorespiration. This allows the enzyme to function with much higher efficiency compared to C_3 plants. Thus, $\boxed{\text{D}}$ is correct.

Ecology Solutions

1. **Difficulty:** Hard Opens
   Topic: Aquatic Ecology / Zonation
   The Limnetic (open water), Littoral (shoreline), Benthic (substrate), and Abyssal (deep ocean) zones are all correctly described. However, the $\boxed{\text{E}}$ Profundal zone is incorrectly matched; it is located below the photic zone where light is insufficient for photosynthesis, meaning rooted emergent plants cannot survive there.

2. **Difficulty:** Easy Opens
   Topic: Behavioral Ecology
   Mimicry types are distinguished by the relationship between the model and the mimic. While Batesian involves a harmless mimic and Müllerian involves two harmful species, $\boxed{\text{C}}$ Emsleyan (or Mertensian) mimicry occurs when a deadly species mimics a less harmful one. This is distinct from Wasmannian (commensal) or Vavilovian (crop) mimicry.

3. **Difficulty:** Medium Opens
   Topic: Biodiversity
   To find the biodiversity of the community, we use Shannon's Diversity Index (H):
   $$H = -\sum_{i=1}^{s} p_i \ln p_i$$
   With a total population of 200 and species counts of $10, 30, 60$, and 100, the proportions (p_i) are $0.05, 0.15, 0.30$, and 0.50.

   Substituting these into the formula:
   $H = -[0.05 \ln 0.05 + 0.15 \ln 0.15 + 0.30 \ln 0.30 + 0.50 \ln 0.50] \approx 1.14$.
   Thus, the answer is $\boxed{\text{C}}$.

4. **Difficulty:** Medium Opens
   Topic: Biodiversity
   Biodiversity can be measured at different scales: Alpha diversity refers to the richness within a specific site, and Gamma diversity is the total richness of a large region. $\boxed{\text{D}}$ Beta diversity represents the "species turnover" or the difference in species composition between two distinct sites.

5. **Difficulty:** Easy Opens
   Topic: Mating System
   Mating systems are defined by the number of partners involved. A harem, where one male mates with and defends multiple females, is a classic example of $\boxed{\text{B}}$ polygyny. This is the opposite of polyandry (one female, many males) and distinct from monogamy or promiscuity.

6. **Difficulty:** Medium Opens
   Topic: Species Roles

Species that show a measurable change in their physiology or population size in response to environmental shifts (like Johnny's color change due to pollution) are known as $\boxed{\text{C}}$ indicator species. They serve as biological alarms for ecosystem health, unlike keystone or flagship species.

7. **Difficulty:** Medium Opens
   Topic: Population Ecology
   Survivorship curves describe the pattern of mortality in a population. Humans (Type I) and birds (Type II) have relatively high adult survival. However, $\boxed{\text{D}}$ Salmon are r-selected species that undergo mass spawning with high early-life mortality, meaning they exhibit a Type III curve rather than Type I.

8. **Difficulty:** Medium Opens
   Topic: Population Ecology
   In the Demographic Transition Model, Stage 5 represents the "post-industrial" phase. It is characterized by advanced healthcare, birth rates that fall below death rates, and an aging population, leading to an overall population decline. Thus, the correct description is $\boxed{\text{B}}$.

9. **Difficulty:** Medium Opens
   Topic: Human Demography
   An age-structure pyramid with a medium-level base and a large middle-age cohort indicates a slowing but still substantial growth rate. This profile most closely matches $\boxed{\text{A}}$ India, where increased contraception use is stabilizing the base compared to the much wider pyramids seen in developing nations like Kenya.

10. **Difficulty:** Easy Opens
    Topic: Environmental Science
    Acid rain is the result of atmospheric pollutants reacting with water. The primary contributors are sulfur dioxide (SO_2), which forms sulfuric acid (H_2SO_4), and nitrogen oxides (NO_x), which form nitric acid (HNO_3). Therefore, $\boxed{\text{C}}$ is the correct answer.

11. **Difficulty:** Hard Opens
    Topic: Ecosystem Ecology
    A sudden pulse of organic carbon (like a molasses spill) fuels explosive microbial growth. The decomposition process consumes the available dissolved oxygen, creating $\boxed{\text{A}}$ hypoxic or anoxic conditions. This is a classic "dead zone" outcome similar to eutrophication, leading to mass mortality of fish and invertebrates.

12. **Difficulty:** Hard Opens
    Topic: Ecosystem Ecology
    The presence of deer and snakes identifies this biome as a temperate deciduous forest rather than a tundra. Applying the 10% energy rule, snakes at the tertiary level would indeed require a massive primary

production base (400,000 calories). Thus, statements $\boxed{\text{B and C}}$ are correct.

13. **Difficulty:** Hard Opens
Topic: Community Ecology
When the base of the food chain is removed, the entire energy supply to higher trophic levels is severed. This causes a sequential collapse of herbivores and carnivores known as a $\boxed{\text{D}}$ bottom-up cascade. This is the opposite of top-down control, where changes propagate from apex predators downward.

14. **Difficulty:** Hard Opens
Topic: Global Ecology
Mitigating climate change requires multiple strategies: reducing greenhouse gases (III), shifting from fossil fuels (IV), and utilizing negative feedback mechanisms (II) to stabilize temperatures. Because these all act to slow warming or allow ecosystems to adapt, the correct answer is $\boxed{\text{D}}$ (I, II, III, and IV).

15. **Difficulty:** Easy Opens
Topic: Population Ecology
In an environment with abundant resources and no competition, a population will grow without limits. This is represented by a $\boxed{\text{C}}$ J-shaped curve, or exponential growth. This differs from the S-shaped logistic curve, which levels off as it reaches the environment's carrying capacity (K).

16. **Difficulty:** Hard Opens
Topic: Population Ecology
Ecological sampling methods must match the mobility of the species. Mark-recapture is ideal for mobile turtles, and transects are perfect for coastal plant gradients. However, point-counts are designed for mobile birds, not stationary ferns, and quadrats are for sessile organisms, not birds. Thus, $\boxed{\text{A and B}}$ are true.

17. **Difficulty:** Hard Opens
Topic: Ecosystem Ecology
Approximately 97% of Earth's water is in oceans, while 70% of freshwater is locked in ice. Additionally, nitrification is an oxidizing process that converts NH_3 to NO_3^-. Since volcanic sulfur is released as SO_2 and not SO_4^{2-}, the correct statements are $\boxed{\text{B and D}}$.

18. **Difficulty:** Hard Opens
Topic: Population Ecology
Using the exponential growth formula $P(t) = P_0 e^{rt}$:

$$P(8) = 2000 \cdot e^{2.8}$$

Calculating this yields approximately 32,889. Rounding to the nearest

significant value, the population is approximately $\boxed{33{,}000}$, which corresponds to choice $\boxed{\text{E}}$.

19. **Difficulty:** Hard Opens
Topic: Community Ecology
With a total population of 2272, we apply the standard error or density calculation provided. The calculation $5/\sqrt{2272} \approx 0.105$ aligns with the value in $\boxed{\text{C}}$, which is the correct answer.

20. **Difficulty:** Hard Opens
Topic: Global Ecology
Ecological rules describe biological patterns: Bergmann's rule refers to body size, not appendages. Kleiber's law scales metabolism to the 3/4 power. $\boxed{\text{D}}$ is the correct statement, as it accurately describes Thorson's rule regarding the developmental patterns of marine invertebrates relative to latitude.

Ethology Solutions

1. **Difficulty:** Medium Opens
   Topic: Reinforcement Schedules
   To achieve a precise and high response rate without concern for long-term persistence, a fixed-ratio schedule is ideal. Unlike variable schedules which offer predictability or fixed-interval schedules which create "scalloping" bursts near the deadline, the fixed-ratio schedule ensures steady pacing. Thus, $\boxed{\text{C}}$ is the best option.

2. **Difficulty:** Medium Opens
   Topic: Neuroethology
   In prairie voles, pair-bonding and mate-guarding behaviors are mediated by specific neuropeptides. While oxytocin is the dominant modulator in females, vasopressin serves this role in males. Although dopamine influences the reward circuitry, $\boxed{\text{D}}$ vasopressin is the hallmark hormone for male bonding in this species.

3. **Difficulty:** Medium Opens
   Topic: Biological Rhythms
   Fiddler crabs synchronize reproduction with spring tides (new and full moons) because these phases generate the strongest tidal currents (I), which facilitate the effective dispersal and return of larvae (IV). Since fertility is not strictly lunar-locked (II) and the sky is dark during new moons (III), only statements I and IV are valid. Thus, $\boxed{\text{D}}$ is the answer.

4. **Difficulty:** Easy Opens
   Topic: Behavioral Development
   Birdsong learning styles vary by species: white-crowned sparrows are closed-ended learners that must memorize songs during a juvenile sensitive period. In contrast, canaries are open-ended learners that remain seasonally plastic, updating and modifying their songs annually. Therefore, $\boxed{\text{C}}$ is the correct description.

5. **Difficulty:** Hard Opens
   Topic: Social Foraging Models
   As flock size increases, specific behaviors shift: feeding (I) typically peaks at an optimal size, while internal aggression/fighting (II) increases due to heightened resource competition. Conversely, the time spent scanning for predators (III) decreases as individuals benefit from the "many eyes" effect. Thus, the correct mapping is $\boxed{\text{D}}$.

6. **Difficulty:** Easy Opens
   Topic: Neuroethology
   A Fixed Action Pattern (FAP) is often triggered by a specific sign stimulus. In male three-spined sticklebacks, the red underside of an intruder acts as the sign stimulus that provokes instinctive aggressive behavior. Therefore, $\boxed{\text{A}}$ is the correct choice.

7. **Difficulty:** Easy Opens
   Topic: Ethological Methodology
   Tinbergen's four questions distinguish between proximate and ultimate causes. Proximate causes address the immediate "how" (mechanism/development), while ultimate causes address the evolutionary "why" (function/phylogeny). Only choice $\boxed{\text{C}}$ focuses on a proximate cause, whereas A, B, and D deal with ultimate fitness.

8. **Difficulty:** Easy Opens
   Topic: Behavioral Development
   Salmon utilize olfactory imprinting during a critical period to recognize the unique chemical signature of their natal stream. This allows them to navigate back to their hatching grounds for spawning later in life. Spatial cognitive maps or social learning are not the primary mechanisms for this homing behavior. Thus, $\boxed{\text{D}}$ is correct.

9. **Difficulty:** Medium Opens
   Topic: Associative Learning
   Classical conditioning (E) involves associating a neutral stimulus with an involuntary response or an unconditioned stimulus. This differs from operant conditioning (B), where an animal associates its own voluntary behavior with a reward or punishment. Because the stimulus here is arbitrary and external, $\boxed{\text{E}}$ is the correct classification.

10. **Difficulty:** Medium Opens
    Topic: Learning & Cognition
    In this setup, the bell is the conditioned stimulus (CS). When a second neutral stimulus (music) is paired with the already established CS to elicit the same response, it is termed higher-order conditioning. However, the specific identity of the bell in this context is the $\boxed{\text{B}}$ conditioned stimulus.

11. **Difficulty:** Easy Opens
    Topic: Reproductve Strategies
    Organisms that invest all their energy into a single, massive reproductive event followed by death are described as semelparous. The Century Plant (*Agave*), which blooms once after decades of growth and then dies, is a perfect example of this strategy. Thus, $\boxed{\text{D}}$ is correct.

12. **Difficulty:** Medium Opens
    Topic: Evolutionary Biology
    Hamilton's Rule states that altruism is favored when $rB > C$. The cost (C) is Bob's risk multiplied by his potential offspring ($0.75 \times 2 = 1.5$). Amy's relatedness (r) to Bob is 0.125 (cousin's daughter). The benefit (B) is her 3 offspring. Since $0.125 \times 3 = 0.375$, which is less than 1.5, Bob should not save her. Thus, the answer is $\boxed{\text{A}}$.

13. **Difficulty:** Hard Opens

Topic: Evolutionary Biology
Using Hamilton's Rule ($rB > C$), the cost of Billy's life is his 2 potential offspring ($C = 2$). The relatedness of Billy to his nephew Pablo is $r = 0.125$. To favor altruism, $0.125 \times B > 2$, which means $B > 16$. Therefore, Pablo must have at least $\boxed{17}$ offspring for the act to be evolutionarily favorable. Thus, $\boxed{\text{D}}$ is correct.

14. **Difficulty:** Easy Opens
Topic: Learning & Cognition
This is a case of operant conditioning because the subject performs a voluntary action (pressing a lever) that is reinforced by a reward (sugar). This association between a specific behavior and a positive stimulus reinforces the frequency of that behavior. Thus, $\boxed{\text{C}}$ is the correct answer.

15. **Difficulty:** Easy Opens
Topic: Mating Systems
Polygynous mating systems are defined by a single male mating with multiple females. Lion prides are a classic biological example of this, as a dominant male (or small coalition) mates with the various females within the group. Therefore, $\boxed{\text{E}}$ is correct.

16. **Difficulty:** Easy Opens
Topic: Reproductive Strategies
Sea turtles are r-selected species; they produce a vast number of offspring and provide zero parental care, relying on high numbers to ensure some survive. This contrasts with the K-selected strategies of the other choices, which involve few offspring and high parental investment. Thus, $\boxed{\text{C}}$ is correct.

17. **Difficulty:** Easy Opens
Topic: Mimicry
Batesian mimicry occurs when a harmless species evolves to imitate the warning signals of a harmful or unpalatable one. The harmless *Papilio polytes* mimicking the unpalatable *Heliconius erato* is a definitive example of this evolutionary strategy. Therefore, $\boxed{\text{A}}$ is the correct answer.

18. **Difficulty:** Easy Opens
Topic: Social Behavior
Agonistic behavior encompasses a range of social interactions related to fighting, such as threats, displays, and physical combat over resources or mates. Kangaroos engaged in a "boxing" match are exhibiting clear agonistic behavior. Thus, $\boxed{\text{C}}$ is correct.

19. **Difficulty:** Easy Opens
Topic: Behavioral Development
The baby elephant's irreversible attachment and behavioral replication from birth is a result of imprinting. This form of learning occurs during

a critical period and persists even in the absence of the mother, as seen after her death. Thus, $\boxed{\text{A}}$ is the correct answer.

20. **Difficulty:** Easy Opens
Topic: Mating Systems
A mating system where a single female is surrounded by and mates with multiple males is termed polyandry. In such systems, females are often more heavily decorated or aggressive to attract mates and compete with other females, which is the pattern described here. Thus, $\boxed{\text{C}}$ is the answer.

Biosystematics Solutions

1. **Difficulty:** Medium Opens
   Topic: Animals
   The mesohyl of a sponge is an extracellular gelatinous matrix composed of collagen and glycoproteins. Unlike the cellular components of the sponge, its structural maintenance does not depend on a microtubule-based cytoskeleton, making it the least impacted by microtubule-disrupting agents. Thus, the answer is $\boxed{\text{D}}$.

2. **Difficulty:** Hard Opens
   Topic: Animals
   While shared characters like hair and mammary glands define the group, statement (B) is a broader trait of all chordates. The only false statement is (E), as monotremes (like the platypus) are an extant lineage of mammals that lay eggs and lack a placenta. Therefore, the correct option is $\boxed{\text{B}}$.

3. **Difficulty:** Easy Opens
   Topic: Animals
   Crocodiles and birds are both members of the class Reptilia and together form the clade Archosauria. This reflects their shared ancestry, which is more recent than their ancestry with other extant reptiles like lizards or snakes. The correct answer is $\boxed{\text{C}}$.

4. **Difficulty:** Medium Opens
   Topic: Animals
   Echinoderms are divided into several distinct clades. Sea cucumbers belong to the clade Holothuroidea (D), while sand dollars and sea urchins are members of the clade Echinoidea. Thus, $\boxed{\text{D}}$ is the correct classification.

5. **Difficulty:** Hard Semis
   Topic: Animals
   Phylogenetic analysis shows that Lepidoptera and Diptera form a sister taxon, indicating they are each other's closest relatives. Additionally, convergent evolution occurs when unrelated lineages evolve similar traits independently due to similar selective pressures. Thus, statements 2 and 3 are true, making $\boxed{\text{C}}$ the answer.

6. **Difficulty:** Hard Opens
   Topic: Animals
   Clade Deuterostomia is defined by DNA similarities rather than purely by developmental patterns. Because "protostome" and "deuterostome" embryonic developments have evolved independently multiple times, not all members of the clade follow the classic deuterostome path. Therefore, $\boxed{\text{E}}$ is the false statement.

7. **Difficulty:** Hard Opens
   Topic: Animals
   Evaluating the phyla: 1 is a chordate, 2 is a sponge (basal), 3 is a mollusc, 4 is an echinoderm, and 5 is an arthropod. Chordates and echinoderms form a sister taxon (Deuterostomia), while molluscs and arthropods are more closely related as protostomes. The phylogeny that reflects these relationships is $\boxed{\text{B}}$.

8. **Difficulty:** Hard Opens
   Topic: Animals
   Ray-finned fishes (Actinopterygii) represent the first major chordate lineage to possess lungs or lung-derived structures, such as the swim bladder. In a cladogram of chordate evolution, lungs would have appeared at hatch mark $\boxed{\text{C}}$.

9. **Difficulty:** Easy Opens
   Topic: Animals
   To identify the group containing only vertebrates, we must exclude basal chordates like lancelets (C) and non-chordate echinoderms like sea urchins (A). Lampreys, fishes, and salamanders all possess a vertebral column (cartilaginous or bony). Thus, the correct option is $\boxed{\text{E}}$.

10. **Difficulty:** Hard Opens
    Topic: Protists
    Nuclear dualism, the presence of both a large macronucleus (for cell metabolism) and a small micronuclei (for genetic recombination), is a defining cytological characteristic of the ciliates. Thus, the answer is $\boxed{\text{A}}$.

11. **Difficulty:** Easy Semis
    Topic: Animals
    The image depicts a trochophore larva, which is characterized by a ring of cilia used for swimming and feeding. This larval stage is a synapomorphy for several phyla within the Lophotrochozoa, such as annelids and molluscs. The answer is $\boxed{\text{E}}$.

12. **Difficulty:** Easy Opens
    Topic: Fungi
    In Mucoromycetes and Zoopagomycetes, sexual reproduction involves the formation of a zygosporangium. This heterokaryotic structure protects the nuclei until karyogamy and meiosis occur to produce new fungal spores. Therefore, the answer is $\boxed{\text{D}}$.

13. **Difficulty:** Medium Opens
    Topic: Animals
    An exaptation is a feature that performs a function different from its original evolutionary role. The mammalian middle ear bones (incus and malleus) are exaptations, having evolved from the articular and quadrate bones that once formed the jaw joint in non-mammalian synapsids. The

answer is $\boxed{\text{B}}$.

14. **Difficulty:** Medium Opens
Topic: Protists
Diatoms are unicellular algae protected by a unique glass-like wall made of silicon dioxide. This double-layered structure (frustule) allows them to withstand the immense crushing pressures of the deep ocean. Thus, the answer is $\boxed{\text{C}}$.

15. **Difficulty:** Easy Opens
Category: Animals
Monotremes are a unique group of extant mammals that retain the ancestral trait of laying eggs. In contrast, marsupials, rodents, ungulates, and primates are all viviparous (giving birth to live young), with the latter four groups being placental mammals. Therefore, $\boxed{\text{A}}$ is the correct answer.

16. **Difficulty:** Easy Opens
Topic: Fungi
The fungus *Claroideoglomus claroideum* is an arbuscular mycorrhizal fungus (AMF) because it forms arbuscules within plant root cells. These fungi are characterized by coenocytic hyphae (lacking septa), which facilitates the rapid transport of nutrients. Thus, statement $\boxed{\text{C}}$ is incorrect and our answer.

17. **Difficulty:** Easy Opens
Topic: Animals
The image shows an ant, which possesses the characteristic "waist" (petiole) and elbowed antennae of the order Hymenoptera. This order also includes bees and wasps. Thus, the answer is $\boxed{\text{D}}$.

18. **Difficulty:** Easy Opens
Topic: Protists
Each group of protists utilizes different storage polysaccharides: dinoflagellates use starch, red algae use floridean starch, and diatoms use chrysolaminarin. Euglenoids are unique for using paramylon, a glucose polymer, as their primary storage form. Thus, $\boxed{\text{E}}$ is true.

19. **Difficulty:** Hard Opens
Topic: Plants
Tracheophytes encompass all vascular plants, including the gnetophytes *Gnetum* (A) and *Welwitschia* (C), the monocot grasses of Poaceae (D), and the seedless vascular Pteridophytes (E). *Marchantia* (B), however, is a genus of leafy bryophyte liverworts which lack a specialized vascular system. Therefore, the correct answer is $\boxed{\text{B}}$.

20. **Difficulty:** Easy Semis
Topic: Plants

Pteridophytes are seedless vascular plants characterized by independent gametophytes (B), sporangia grouped into sori (A), coiled fiddleheads (C), and true roots (E). While they possess true leaves, these are typically large, branched megaphylls. Microphylls (D) are simple, unbranched leaves restricted to the lycophytes and are not characteristic of true ferns. Thus, the correct answer is $\boxed{\text{D}}$.

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:** Our game where players can compete to climb the ranked leaderboards while practicing biology! Check it out here: bioblitz.net
- **Daily Problem**: On BioBlitz, we host a Daily Problem for you to sharpen your biology skills!
- **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

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, Editing - Class of 2027

Srikar Reddy - Writing, Review - Class of 2028

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

Expert Reviewers:

Kian Dhawan - IBO qualifier, USABO gold - Class of 2026

Eric Liu - IBO qualifier, USABO finalist - Class of 2027

Monica Zhang - IBO qualifier, CBO finalist- Class of 2024

External Sources:

Anatomy & Physiology Q1: MinnState Link

Anatomy & Physiology Q5: UMN Link

Anatomy & Physiology Q7: Ohio State Link

Anatomy & Physiology Q20: Wikipedia Link

Cell Biology Q8: Communications Biology Link

Cell Biology Q9: PLoS Genetics Link

Cell Biology Q17: Albert's Molecular Biology of the Cell

Cell Biology Q18: North American Journal of Medicine and Science Link

Plant Biology Q18: Raven Biology of Plants

Ecology Q8: Population Education Link

Ecology Q9: Population Pyramid Link