Review Test 1

Question 1 should take you about 22 minutes to answer.

![Reaction mechanism for light production in fireflies]

Figure 1. Production of light in the lantern organ of fireflies

![Flash pattern characteristics in fireflies]

Figure 2. Flash pattern characteristics in fireflies

![Flash pattern characteristics of selected firefly species]

Figure 3. Flash pattern characteristics of selected firefly species

![Evolutionary relatedness among selected firefly species]

Figure 4. Evolutionary relatedness among selected firefly species
Fireflies are a group of insects that possess a lantern organ composed of numerous light-producing cells (photocytes) in their abdomens. The light is produced by a chemical reaction involving the light-emitting organic compound luciferin. In each photocyte, luciferin is activated in an ATP-dependent reaction that is catalyzed by the enzyme luciferase. In the presence of oxygen, the activated luciferin emits light as it is converted to oxyluciferin (Figure 1).

The flashes of light are controlled by neurons that innervate the lantern organ. Activated neurons stimulate the release of nitric oxide (NO), an inhibitor of the electron transport chain. The pattern of light flashes (Figure 2) emitted by males is a signal to attract females as a component of mating behavior. Different species of firefly display different patterns of flashes (Figure 3). The evolutionary relatedness of these species, as determined using multiple morphological characteristics, is shown in Figure 4.

(a) **Identify** the main source of the ATP used for activating luciferin, as shown in Figure 1, and **describe** the effect of the release of NO on oxygen levels in the photocyte during flashing.

(b) **Describe** TWO differences in the flash patterns of *P. pyralis* and *P. knulli*. **Justify** the use of differences in flash signal patterns as evidence to support the claim that *P. pyralis* and *P. knulli* are different species.

(c) **Use the template provided to construct** a cladogram based on the data in Figure 3. **Circle** the position on the cladogram that represents the outgroup.

(d) **Evaluate** the data used to construct the cladogram in Figure 4 and the cladogram you constructed in part (c) and **identify** which cladogram is most likely to represent a more accurate phylogeny of the organisms. **Propose** ONE type of additional data that could be used to refine the phylogeny of these species.
Environmental mutagens can affect DNA in cells. Benzo[a]pyrene (BaP) is a mutagen that is commonly found in urban air pollution. Researchers claim that the effect of UVA radiation (UVA), another known mutagen, is amplified by the presence of BaP. To test their claim, the researchers exposed cultured eukaryotic cells to either BaP, UVA radiation, or both mutagens. The researchers then determined the percent of chromosomal DNA that contained damage in the form of double-strand breaks. The results are shown in the table.

(a) On the template below construct a graph using the data in the table to represent the effect of UVA and BaP on DNA.

(b) Using the results from all treatments, describe the effect of BaP alone and UVA alone compared with the effect of the combined treatment of BaP and UVA on DNA.

(c) Predict the most likely effect on cell division for a cell containing DNA with double-strand breaks. Justify your prediction.

(d) Point mutations alter the DNA sequence at a single nucleotide. Describe how point mutations affect the genetic makeup of the population AND impact the evolution of the population.
3 Strigolactones and karrikins are structurally similar compounds that can affect seed germination in certain species of plants. However, plants with different life strategies (autotrophic plants or obligate parasitic weeds) germinate in response to the presence of different compounds in the soil. After germination, many species of autotrophic plant release strigolactones from their roots into the soil, which promotes uptake of nutrients.

![Graphs showing effect of karrikins and strigolactones on seed germination](image)

Figure 1. Effect of karrikins and strigolactones on seed germination in an autotrophic host plant and its obligate parasitic weed

The graphs above represent the results of a laboratory experiment to test the effect of different concentrations of strigolactones or karrikins on the seed germination of an autotrophic host plant and of an obligate parasitic weed.

(a) Based on an analysis of the data, describe the effect of karrikins on seed germination in the autotrophic host plants and the obligate parasitic weed plants.

(b) A researcher proposes that the obligate parasitic weed requires exposure to a signal from the host plant before it can germinate. Using the data as evidence, provide support for the researcher’s claim and give ONE reason the response would be an advantage for the weed plants.

Question 4 should take you about 6 minutes to complete

![Chemical structure of cyanide](image)

Figure 1. Chemical structure of cyanide

4 The secondary compound cyanide (Figure 1) is a toxic, bitter-tasting chemical that is found in apple seeds. Cyanide in seeds is only released and tasted if the seed is crushed. When animals eat apples, they typically eat the sweet fleshy part of the fruit and spit out the seeds or swallow them whole.

(a) Based on the chemical structure of cyanide, identify ONE type of biological macromolecule that could serve as a chemical precursor for the production of cyanide in a plant. Justify your choice.

(b) It has been proposed that apple trees are in a mutualistic relationship with the animals who eat the apples. Describe ONE benefit to each organism in the mutualistic relationship.
5. *Caenorhabditis elegans* is a species of soil-dwelling nematode (roundworm) that feeds on soil bacteria, including *Bacillus thuringiensis*. *B. thuringiensis* is a virulent bacterial pathogen that produces BT toxin, a protein that can kill different invertebrate species, including *C. elegans*.

In a laboratory experiment, *C. elegans* and *B. thuringiensis* were cultured individually (control) or together (experimental) for 150 days. Under optimal conditions, the generation time of *C. elegans* is approximately 3.5 days and the generation time of *B. thuringiensis* is approximately 25 minutes. At the end of the experiment, the change in virulence of *B. thuringiensis* and the change in resistance of *C. elegans* to BT toxin were determined.

(a) **Calculate** the maximum number of generations that is possible in individual cultures of *C. elegans* AND the maximum number of generations that is possible in individual cultures of *B. thuringiensis* in 150 days.

(b) The researchers found that after 150 days, the magnitude of the change in both *B. thuringiensis* virulence and *C. elegans* resistance was less when they were cultured individually (control) than when they were cultured together (experimental). **Provide ONE reason** for the difference in results between the two treatments.

(c) The researchers also found that after 150 days, the relative change in virulence of *B. thuringiensis* was greater than the relative change in the resistance in *C. elegans* when the organisms were cultured together. **Provide ONE reason** that the relative change in *B. thuringiensis* virulence was greater than the relative change in *C. elegans* resistance.

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6. The p53 and MDM2 proteins are involved in the DNA damage response pathway (Figure 1). In the absence of DNA damage, MDM2 mediates the degradation of p53. In the presence of DNA damage, p53 is not broken down and forms active tetramers that stimulate the expression of genes that block cell cycle progression.

Red blood cells are produced by the division and differentiation of multipotent stem cells. Researchers have observed that mice with a partial loss-of-function mutation in the *MDM2* gene have a lower concentration of red blood cells in the blood than do mice that express the wild-type *MDM2* allele.

(a) Using the model of the p53/MDM2 pathway, **connect** the reduction of MDM2 function in mutant mice to the observed concentration of red blood cells.

(b) **Predict** how a loss-of-function mutation in the *p53* gene is most likely to affect the cell cycle in response to DNA damage. **Justify** your predictions.
Figure 1. Time course of events during fertilization of a sea urchin egg

7 Figure 1 shows the events during and immediately following fertilization of a sea urchin egg. Sexual reproduction relies on the successful fusion of only one sperm with one egg (time 1) during fertilization. In sea urchins, a diploid organism, several events prevent additional sperm from fertilizing the egg. One of the first events following fertilization is the fusion of secretory vesicles called cortical granules with the egg plasma membrane (time 2). The cortical granules release their contents, a mixture of polysaccharides and proteins, into the perivitelline space. Subsequent to this, water moves into the perivitelline space, causing it to expand and physically separate the fertilization envelope from the egg plasma membrane (time 3). The fertilization envelope prevents fusion of more than one sperm with the egg.

(a) **Provide ONE reason** that preventing fusion of multiple sperm with one egg in sea urchins has provided a survival advantage over evolutionary time.

(b) **Describe** how the release of the contents of the cortical granules into the perivitelline space results in the movement of water and causes the subsequent expansion of the perivitelline space.

Question 8 should take you about 6 minutes to complete

8 Cyanobacteria are a large group of prokaryotic organisms. Cyanobacteria are found in marine microbial mats that include many species of eukaryotic and prokaryotic organisms that can participate in mutualistic symbiotic relationships. One recently discovered species of cyanobacteria, UCYN-A, lacks the genes that encode ribulose bisphosphate carboxylase/oxygenase (RuBisCo), components of photosystem II, and the Krebs cycle. UCYN-A contains genes enabling nitrogen fixation, which allows the enzymatic conversion of atmospheric nitrogen to biologically available nitrogen compounds such as nitrate. Within the microbial community there is relatively little available nitrogen. The majority of organisms in the microbial mat cannot fix nitrogen.

(a) **Identify** the metabolic process whereby UCYN-A is most likely to produce ATP.

(b) In low-nitrogen conditions, UCYN-A participates in a mutualistic symbiotic relationship with other organisms in the microbial mat. **Predict** the most likely type of symbiotic relationship between UCYN-A and the other organisms in the microbial mat if nitrogen becomes readily available from another source. **Provide reasoning** to support your prediction.