Refer to the graphic below and in the appropriate labeled space to the right, fill in the name of the major terrestrial biome that is characterized by the temperature and precipitation regime depicted in the diagram (6).

A. subtropical desert
B. tundra
C. temperate grassland
D. taiga or boreal forest
E. temperate deciduous forest
F. tropical wet forest

In the space below, draw and label all the possible horizontal and vertical regions of a typical lake (4).

What category of freshwater biome would the lake you drew above be classified as? (2)

Lentic system

Bonus question 1: write the name of any one of the six terrestrial biome you labelled above and then indicate what would be a dominant vegetation type that would characterize that biome (1)

A: succulents (cacti) or desiccation resistant plants, B: perennial herbs and small shrubs, C: grasses and forbs, D: evergreen conifers, E: broadleaf deciduous trees, F: broadleaf evergreen trees and vines
The table below represents a cohort of female ground squirrels that were tracked from the year they were born until the last one died. Researchers also recorded the average number of female offspring produced per female for each year they were tracked. Fill in the blank columns (three have been provided as an example) for this life table and then answer the questions below using the information you have calculated.

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>l_x</th>
<th>m_x</th>
<th>l_x m_x</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td>0.5</td>
<td>0.02</td>
<td>0.025</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>0.3</td>
<td>0.5</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>0.2</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>0.15</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>0.1</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>0.05</td>
<td>3</td>
<td>0.15</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>.02</td>
<td>3</td>
<td>.06</td>
</tr>
</tbody>
</table>

What is R_0 for this population? (1)

Σl_x m_x = 1.185 (give half credit for just Σl_x m_x)

Is the population growing, shrinking, or stable? (1)
growing

Now assume that researchers studying the population each year record 1234 individuals in year 1 and 1432 individuals in year 2. What would be the simplest expression for λ for this population during the period of time? (1)

λ = N_t / N_0 = 1432/1234

What would be the simplest expression for r? (1)

r = ln(λ) = ln(1432/1234)

In the space to the right, sketch a Hadley Cell for the Northern Hemisphere and make sure to indicate 1) where with respect to latitude it occurs, 2) the direction of airflow (you can indicate this with lines fitted with directional arrows), and where rain falls (3)

What causes the air to rise? (2)

Heat at equator warms air, it becomes less dense and rises

What causes the rain to fall? (2)

as air rises it cools and becomes less dense and can no longer hold as much water so it falls as rain
The rocky intertidal zone along the west coast of North America is home to a variety of marine organisms that are regularly covered and uncovered by tidal fluctuations. The higher up an organism is in this region, the more time it spends out of the water each month, thus organisms demonstrate varying ability to withstand desiccation depending on where they live in the tidal range which results in a distinct zonation pattern of organisms as seen in the figure to the right.

Which general marine biome would be found adjacent to the intertidal zone? (1)
Neritic or coastal zone

A long term experiment conducted by R. T. Paine on Tatoosh Island in Puget Sound found that when seastars (a predator on mussels) were removed from the rocky intertidal, mussels overgrew other organisms and became the dominant organism in the middle tidal zone and also extended their distribution to the lower tidal zone. For the following species pairs state what type of interspecific interaction is occurring in Column A and then state whether it is direct or indirect in column B (4)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seastars – Mussels</td>
<td>predation</td>
</tr>
<tr>
<td>Mussels – barnacles</td>
<td>competition</td>
</tr>
<tr>
<td>Seastars – rockweed</td>
<td>mutualism or commensalism</td>
</tr>
<tr>
<td>Gooseneck barnacles – barnacles</td>
<td>competition</td>
</tr>
</tbody>
</table>

For each of the following species indicate in which seastar treatment (present or absent) they would occupy a greater portion of their fundamental niche (2)

Gooseneck barnacle: seastar present

Mussel: seastar absent

Using your understanding of the role of diversity in community dynamics, which seastar treatment community (present vs absent) would likely demonstrate greater: (2)
Stability: present
Net primary productivity: present

Bonus Question 2: What is net primary productivity? (2) amount of biomass available to grazers and decomposers
The owl limpet, *Lottia gigantea*, is a large snail that occupies the lower middle tidal zone. When sporadic disturbances such as wave impacts clear patches of the intertidal, snails move in and actively graze the rock surface and prevent anything but algal films to grow in the newly liberated space. They maintain these farms for as long as 20+ years, grazing portions of them on a rotational basis so as to allow grazed patches to re-grow their algae. Other species of limpets will opportunistically graze these patches, but the larger *Lottia* will actively pry them off the substrate to defend this resource, resulting in the smaller limpet being swept away by the waves.

Based on this information, what of the three types of dispersion patterns would you predict *Lottia* to exhibit in the lower middle intertidal zone? (2)

**Random** – due to the random nature of where disturbance occurs to open space.

What type of succession is illustrated by the above example? (1)

**Secondary**

For each of the following pairs, indicate what type of interspecific interaction (be specific) is occurring in column A and what type of successional interaction is occurring in column B: (3)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owl limpets and mussels:</td>
<td>competition</td>
</tr>
<tr>
<td>Owl limpets and algal films:</td>
<td>herbivory</td>
</tr>
<tr>
<td>Owl limpets and other limpets:</td>
<td>competition</td>
</tr>
<tr>
<td></td>
<td>inhibition</td>
</tr>
<tr>
<td></td>
<td>facilitation</td>
</tr>
<tr>
<td></td>
<td>inhibition</td>
</tr>
</tbody>
</table>

Owl limpets reproduce each year in the springtime when females will release thousands of larvae into the water column that will drift for several weeks until settling as juveniles on rocky substrates in the intertidal region. Less than one percent of the larvae produced ever survive to the juvenile stage. What term would best characterize this type of *reproductive* (not life history) strategy (be as specific as possible)? (2)

**Seasonal iteroparous**

What type of survivorship curve would owl limpets have? (1)

**Type III**

Based on the information provided on this page and the previous one, suggest an organism that would best be characterized as a: (2)

*r selected strategist*  *rock week, barnacles, lottia, limpets mussels*

*K selected strategist* *mussels, seastars*

Many species of intertidal invertebrates that are permanently attached to the substrate such as mussels, barnacles, and gooseneck barnacles also have larvae that drift freely in the water before settling as attached juveniles. These larvae will preferentially settle near adults of their own species which they are able to locate by detecting distinct chemical cues that the adults emit. What type of behavior are these larvae demonstrating when they locate their settling site based on these cues (be as specific as possible)? (2)

**Chemotaxis**
Name/SID

Nudibranchs are sea slugs (shell-less snails) that are common in the intertidal region. They employ various strategies to defend themselves from predators ranging from blending in with their invertebrate prey such as the rosy nudibranch (right) or sequestering toxic chemicals in their tissues to make them unpalatable. Slugs that use the latter technique, such as the slug on the left, are often brightly colored as a warning. Are these examples of constitutive or inducible defenses? (2)

*Constitutive as they are always present whether needed or not*

What term would best describe the bright coloration of the chemically defended slugs? (2)

*Aposematic coloration*

One species of chemically defended slug, the clown nudibranch (top right of picture) has a crustacean mimic that has similar coloration (bottom left). What type of mimicry does this represent? (2)

*Batesian mimicry*

What are two separate ways you could characterize the behavior of the mimic? (2)

1. **communication**
2. **deception**

Would you expect these clown nudibranch mimics to be common or rare? (2)

*Rare – as deception must be rare in order to persist*

Fish predators on slugs avoid eating brightly colored slugs such as the clown nudibranch. How might you test whether this is an innate or learned behavior? (2)

*Isolation experiments*

**Bonus Question 3:** Why does the degree of seasonality increase with latitude? (1) *because the effect of the tilt or the earth’s axis increases with latitude*
Tropical savannas such as those found in East Africa are characterized by expanses of grasslands and grass like plants surrounding scattered individual trees made up primarily of several species of *Acacias*. They tend to be relatively warm year round but have moderate annual precipitation with most of the rainfall occurring in the summer months and relatively dry conditions occurring in the winter time. While they resemble temperate grasslands in some ways they also differ in several key aspects. What factor may account for the presence of trees in this system as compared to the lack of trees in temperate grasslands? (2)

*There is more rainfall than in temperate grasslands so it sustain trees.*

East African savannas are home to a variety of both grazing animals such as the Impala gazelle, and predators of grazers such as leopards. Recent studies have shown that impalas aggregate in open grassy areas rather than in more wooded areas in order to avoid predation by leopards. Aggregating increases the ability of impala to detect a predator as there are more eyes watching out, while staying in the open also makes it harder to be ambushed by a leopard. Two main species of acacia tree occur in East African savannas, *A. etbaica* (long thorn acacia) and *A. brevispica* (short thorn acacia). *A. etbaica* has long thorns used to defend against grazers while *A. brevispica* has much smaller thorns that are less effective as a defense. What term best characterizes the type of defense these thorns represent? (2)

*Constitutive as they are always present.*

As previously mentioned, impala will largely avoid wooded areas where their risk of leopard predation is much greater. In such areas, short thorn acacias are the dominant species while long thorn acacias are more common interspersed in the more open grass dominated areas. Also in areas when leopards are absent, impala will spend more of their time within wooded regions grazing on trees and in such areas long thorn acacia abundance is markedly increased. Use the information in the preceding paragraph to answer the following questions:

For each of the following indicate in which scenario – Leopards present (LP) or Leopards absent (LA) – the following would occupy a greater portion of their fundamental nice (3)

- **Long thorn acacia**
  - LA – as grazing in woods by impala reduces short thorns
- **Short thorn acacia**
  - LP – due to lack of grazing by impala
- **Impala**
  - LA – due to lower predation rates

Both leopards and impala tend to maintain stable populations over long timeframes and reproduce multiple times in their lives giving birth to a few offspring each time. What type of population growth curve would best represent this? (2)

*Logistic curve (.*

What type of survivorship curve would best characterize them? (2)

*Type I*

What term would best describe the life history (not reproductive) strategy of both these species? (2)

*K selected*
The figure on the right depicts a simple food web with the four organisms described in the preceding and current page. In the blank spaces on the left of the figure, indicate what the trophic status is for the organisms at each level (3).

Remembering that both leopards and impala are homeotherms (warm blooded), which level would you expect to have the highest production efficiency? (1)

Level 3 as both 3 and 2 have similar metabolic costs, but 3 consumes higher energy quality food

Between which two levels would you expect to find the lowest trophic transfer efficiency? (1)
Between level 1 and 2 due to the relative poorer quality of the food in level 1 (more will not be assimilated and thus pass into the decomposing food web as waste)

For each of the following indicate what type of interspecific interaction (being as specific as possible) is occurring and then indicate whether it is direct or indirect: (4)

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Direct/Indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leopard/Impala</td>
<td>predation</td>
</tr>
<tr>
<td>Impala/grass</td>
<td>herbivory/grazing</td>
</tr>
<tr>
<td>Leopard/long thorn acacia</td>
<td>mutualism or commensalism</td>
</tr>
<tr>
<td>Long thorn acacia/short thorn acacia</td>
<td>competition</td>
</tr>
</tbody>
</table>

Which two abiotic factors do you think play the most influential role in regulating NPP in this system? (2)

1 temperature
2 precipitation

Male leopards maintain hunting territories that they will aggressively defend against other males. On the axes below sketch what you think would be the relationship between Percent of males with a territory (y axis) and total number of males (x axis) for a population of leopards, (2)

What term would best describe the relationship you drew in the diagram to the left with respect to its influence on population growth for leopards? (1)

Density dependent
Many species of ants have a special relationship with certain acacia species in which trees will provide shelter and sometimes food to ant colonies while ants will defend their home trees from grazers and even assist in seed dispersal. One such ant-plant interaction exists between the whistling thorn tree (*Acacia drepanolobium*) and the biting ant (*Crematogaster* spp.). The tree provides the ants with hollowed out thorns called domatia which are specifically adapted for habitation by ants. The tree also provides nectar, which the ants collect from specialized non-flowering structures at the bases of *Acacia* leaves. In return for this investment, ants protect the tree from browsing mammals such as giraffes by aggressively swarming and biting anything that disturbs the tree. What type of interspecific interaction is occurring between: (2)

Ants and acacia *mutualism*

Ants and giraffes *competition*

After experiencing grazing, some acacias produce leaf tannin (a toxin) in quantities high enough to be lethal to grazers. They also can emit a chemical called ethylene into the air which can travel up to 50 yards. The ethylene warns other acacia trees of the impending danger, and they in turn increase their own production of leaf tannin within just five to ten minutes. What type of defense best characterizes tannin production in such trees? (2)

*Inducible defense*

What type of behavior is the plant engaged in when it releases ethylene into the air (be as specific as possible)? (2)

*Communication via olfactory cue*

*Crematogaster* ants display a unique form of eusociality due to their sex determination mechanism known as haplodiploidy. This leads to non-reproductive worker and soldier ants which are full sisters sharing ¾ of their genes. What general type of altruistic behavior are these ants displaying? (2)

*Kin selection*

Write the equation for Hamilton’s rule below (2)

\[ B > rC \]

How does the information in the paragraph above and the equation you just wrote explain why worker and soldier ants will increase their fitness more if they make more sisters rather than have their own offspring? (2)

*Since \( r \) is greater between sisters than it would be between potential offspring of female ants, they improve their fitness more by helping to make more sisters than they would if they have daughters*

**Bonus Question 4:** With respect to communities, what does the term resistance mean? (2)

*The ability of a community to withstand a disturbance*