Name: _____

Date: _____

Class: _____

IB Environmental Systems and Societies

1.3 Energy and Equilibria

Significant Ideas:

The laws of thermodynamics govern the flow of energy in a system and the ability to do work.

Systems can exist in alternative stable states or as equilibria between which there are tipping points.

Destabilizing positive feedback mechanisms will drive systems toward these tipping points, whereas stabilizing negative feedback mechanisms will resist such changes.

Energy and Entropy

1.

a) State the first law of thermodynamics

Principle of Conservation of Energy - "Energy in an isolated system can be transformed but cannot be created or destroyed

b) A student makes the following statement:

"As a consequence of the first law of thermodynamics, energy is never lost from an ecosystem."

Explain why this is not correct.

Implies the energy is always present in the same amount when losses are occuring as heat

2.

a) State the second law of thermodynamics

The entropy of an isolated system not in equilibrium will tend to increase over time

b) In a food chain, the amount of energy available to each successive trophic level decreases substantially. Explain how this demonstrates the second law of thermodynamics

Entropy has increased as energy has been lost (in the form of heat)following work due to respiration as the energy is transferred between trophic levels

3. Define "entropy"

Is a measure of disorder in a system

4. Draw a model to demonstrate energy transfers and transformations through an ecosystem.

(Help: Start with a basic food web or chain, then consider the various flows of energy, including sunlight heat, chemical energy in biomass etc. Include values for the flows, such as percentages. Note that conversion of sunlight in photosynthesis is roughly 1% efficient, and the transfer of energy to higher trophic levels is about 10% efficient)

Equilibrium

1. Define equilibrium.

The tendency of a system to return to an original state following a disturbance

2.

a) Compare "static equilibrium" and "steady state equilibrium".

Static - no change over time occurs eg. pile of books whereas in a steady-state continuous inputs and outputs of enerfy and matter occur but system remains in a more or less constant state

b) State and explain two examples of each of the above types of equilibrium. Examples are included for each.

Type of Equilibrium	Example	Explanation
Steady state	A country's population	A place will have births and deaths, but will ultimately remain unchanged (assuming they are in balance
	Water tank	It fills at the same rate that it empties with no net change so water flows in and out and it remains in a steady state
	Body temperature	Living organisms sweat to cool ourselves down and shiver to warm up but core body temperature is 37C
Static	A hat on a hook	The hat is not in motion, remaining in equilibrium. There are no inputs or outputs creating a change.
	Pile of rocks	Forces within the system are balanced and so with no inputs or outputs the system remains in a static state
	Building	Forces within the system are balanced and so with no inputs or outputs the system remains in a static state

3. Compare “stable equilibrium” and “unstable equilibrium”.

In a stable equilibrium the system tends to return to the same equilibrium following a disturbance whereas in an unstable equilibrium the system returns to a new equilibrium after a disturbance

4. Is a simple ecosystem or a more complex ecosystem more likely to maintain a stable equilibrium when faced with disturbance? Explain your answer, using examples.

Complex ecosystems are more likely to maintain a stable equilibrium following a disturbance. This is because complex ecosystems, for example the Daintree Rainforest, Queensland, is a mature forest and so has higher biodiversity in species, habitat and genes and therefore greater resilience.
There are more interactions between species
If a disease were to affect 1 species of tree (distubance), the forest would be able to return to a stable equilibrium rather than a new state

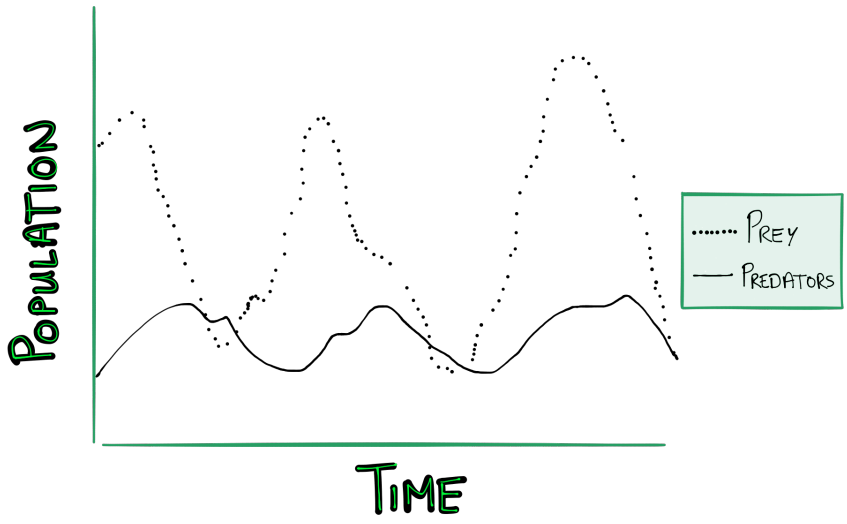
Feedback

1.

a) Define negative feedback.

Stabilising feedback loop that dampens down, neutralise or counteract deviation in a steady-state equilibria

b) Look at graph showing a predator-prey relationship:



Explain how predator-prey relationships can keep populations relatively constant through negative feedback.

As the population of prey increases so does the number of predators (as there is more available food so they can breed more). As the population of prey decreases (consumed by the increasing predators) prey numbers are reduced so reducing (stabilising)the poplulation.

c) Outline one more example of negative feedback

Global temperatures rise causing more ice cap melting. More water vapour in the atmosphere causes more clouds. More solar radiation is reflected by the clouds decreasing global temperatures

2.

a) Define positive feedback.

Destabilising feedback loop which amplify changes and drive systems toward a tipping point where a new equilibrium is adopted

b) Outline "the vicious cycle of poverty" as an example of positive feedback.

In some LEDC's poverty causes illness and contributes to poor education standards. Lack of education can limit family planning knowledge and hygiene. This contributes to more population growth and illness adding to the causes of poverty

c) Draw a diagram to represent a positive feedback mechanism involving the albedo effect.

Textbook p35,
figure 1.3.14

3. An IB student has a lot of work to do and gets stressed. As a result, they might struggle to focus on their work, and delay in completing it. The workload piles up more and more because they aren't getting through it, making them more stressed.

What type of feedback mechanism is being described here? Explain your answer.

Positive feedback loop - increase in stress reduced the ability to focus on work so the student puts off doing the work. The work does not get done in time. This causes more stress and further reduces the ability of the student to start the work

Resilience

1.

a) Describe what is meant by the term "resilience".

Resilience is the ability of a system to return to it's initial state following a disturbance

b) Describe the connection between resilience and stability.

Resilience helps maintain the stability of a system. The more resilient a system, the more disturbance it can deal with. If it has low resilience a system will enter a new state

2. Describe what is meant by the term "tipping point".

When small changes in systems add up and together the changes tip the equilibrium over a threshold called the tipping point

3.

a) Explain how the size of storages and the diversity of a system can affect its resilience.

If storages are large then the system is more resilient. For example in a large population small changes (ie deaths) can be recovered from faster so mainatinaing stability. If diversity in a system is large, then the system can also withstand changes and so less likely to reach its tipping point

b) Using the table, state and explain the resilience of the stated systems

(Help: consider the disturbances that might occur, such as diseases, invasive species, weather changes etc...)

System	Resilience (high / moderate / low)	Explanation
A very large forest ecosystem with high biodiversity	High	There are many interactions between organisms if the biodiversity is high. If there is a change, e.g. a decrease the population of a particular species through disease, those organisms that feed on it will have alternative food sources to turn to. The system will remain mostly unchanged.
A large field with only corn growing in it, with a small number of insects feeding on the corn.	Low	Monocultures are simple systems and so vulnerable to spread of disease if none of the plants have resistance. Also vulnerable to pest sepcies. The system would move to a new state following a disturbance and so is an example of an unstable equilibrium
An isolated village community in the Gobi desert, with a population of around 1000 people.	Moderate	As the village is isolated it is likely the genetic diversity will be low. This decreases the resillience of the population and increases the risk of a tipping point being reached in the event of a disease or illness such as flu. However, people are able to migrate and relocate an so risk is reduced
The community of Shanghai, China. Population roughly 24,000,000.	High	As the popluation is large, genetic diversity is likely to be high which increases the resilience of the system. Humans can migrate and mitigate threats to the system resulting in a faster recovery

4. Explain how the following human activities might affect the resilience of the system stated. Note: there is a range of possible correct answers for each system (but you only need to state one)

Activity: *Extensive use of fossil fuels, resulting in increased atmospheric levels of greenhouse gases.*

System: *The ocean food web*

In a positive feedback loop, an increase in greenhouse gases can lead to an increase in the acidity of the oceans as more CO2 is absorbed. This reduces the ability of some crustaceans to form shells which in turn reduces crustaceans as a food source for marine species. This decreases the species diversity and so decreases the resillience of the ocean food web

Activity: *Introduction of invasive bird species*

System: *A forest ecosystem*

An introduced invasive bird species can out-compete native species searching for food which then reduces the population of native species. This decreases the resillience of native species to disturbances such as disease or a change in climatic conditions.

Activity: *Population control using a "one child policy"*

System: *A large society*

(Help: think about possible problems associated with an "aging population")

A major reduction in population can reduce the ability of the system to cope with change and reduces the number of population of working age and the ability to care for and provide for an aging population. The resillience of the system is reduced

5. Choose one of the examples in question 4. Imagine that the activity described pushes the system to a tipping point.

Describe the tipping point and evaluate the consequences.

(Help: Think about the new equilibrium the system might reach and what it would be like. What are the advantages and disadvantages to the system?)

Increase in greenhouse gases resulting in an increase in the acidity of the oceans leading to a decrease in crustaceans as a food source - the tipping point would be reached when the crustaceans are no longer able to survive with the thinning of the shells resulting from the increased acidity of the ocean.
The ocean food web would be forced to find a new equilibrium if species of crustacean were lost.
A disadvantage would be the loss of crustaceans from the food web forcing consumers to find an alternative source.
An advantage is the marine food web is diversen and complex so most species would be able to adapt to the changes

6. Global climate change is an example of a disturbance on the environment that humans are causing. Most scientists agree that the planet is warming, and that humans are the cause of it. However, the future consequences are still debated. Some people may argue that the Earth environment as a whole is very resilient because of it is such a complex system, though others may argue it is not resilient enough to withstand the pressure we are putting on the system.

Using climate change as an example, explain why is so difficult to predict the tipping point of a system.

Include the following ideas in your response:

tipping points *resilience* *delayed feedback* *equilibrium*

Tipping points are well-known in local or regional ecosystems but there is debate about whether we are reaching a global tipping point.
It is difficult to predict the threshold point precisely and so difficult to know how resilient the global climate system is. This means it is difficult to predict how much of a warmer state the earth can tolerate before the tipping point is reached and a new unstable equilibrium is established following this disturbance.
As signifcant timelags can occur between the pressures driving the change (a continous increase in greenhouses gases) and the appearance of the impacts of the change, such as mass extinctions or migrations, it is very difficult to predict how resilient the global climate system is and when the tipping point will be reached.
As the global climate system is complex both positive and negative feedback loops are operating at the same time making predictions even more difficult to predict the tipping point. For example, some regions are getting warmer, some cooler, some wetter and some drier. It could be that individual ecosystems are responding differently to change making it even more difficult to predict when the threshold for a tipping point will be reached