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

Energy can neither be created nor destroyed; it can only change form

Also known as the law of conservation of energy.

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 <u>not</u> correct.

In ecosystems energy enters the system in the form of sunlight, is converted into biomass via photosynthesis, passes along the food chain as biomass, is consumed and ultimately leaves as heat. Heat is released because of the inefficient transfer of energy. The total amount of energy has not changed but the amount of available energy has reduced

2.

a) State the second law of thermodynamics

In any energy conversion there is less usable energy at the end of the process than at the beginning. Energy goes from a concentrated form into a more dispersed form.

Entropy increases.

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

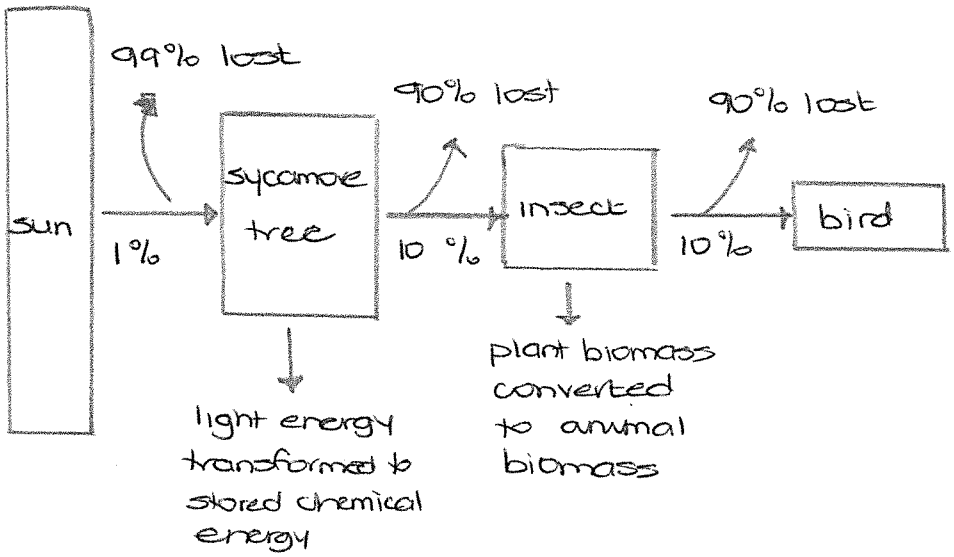
At each trophic level the energy that is passed along is dispersed to different forms such as growth, movement and heat (this reduces the amount of energy available for the next level)

3. Define "entropy"

a measure of the 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)



This explains why food chains are usually short

Equilibrium

1. Define equilibrium.

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

2.

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

In static equilibrium there is no change over time. most non-living systems are in a state of static equilibrium. A steady state equilibrium is a characteristic of an open system where there are continuous inputs and outputs of energy and matter. The system as a whole stays the same.

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
	Climax ecosystem	There are no long term changes inputs and outputs are balanced
	Human body temperature	When it rises we sweat to cool down, stays at 37°c
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 - no input or output
	Building	No change in the system.

3. Compare "stable equilibrium" and "unstable equilibrium".

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

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.

The more diverse and complex an ecosystem, the more resilient it tends to be as there are many interactions between different species and so equilibrium can be maintained. For example the Daintree rainforest in Queensland is a mature forest and so has high biodiversity. If a disease were to wipe out one species of trees (disturbance) the forest would be able to return to the original equilibrium by making new interactions.

A simple ecosystem e.g. monoculture rice field if the rice was destroyed the ecosystem would collapse.

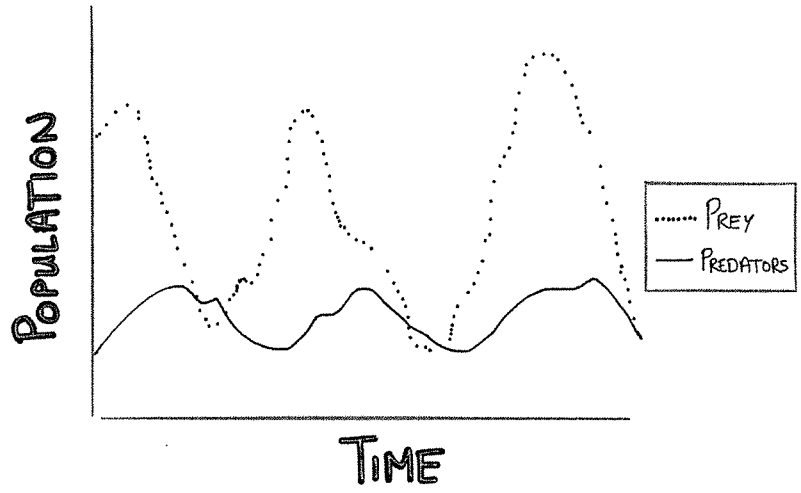
Feedback

1.

a) Define negative feedback.

Feedback that counteracts any change away from equilibrium, contributing to stability.

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 population of predators (more food). As the population of prey decreases (consumed more by predators) prey population will then reduce the predator population stabilising both.

c) Outline one more example of negative feedback

Global temperatures rise causing more ice caps to melt. This increases the water vapour in the air + more clouds. More solar radiation is reflected by the clouds decreasing global temperatures.

2.

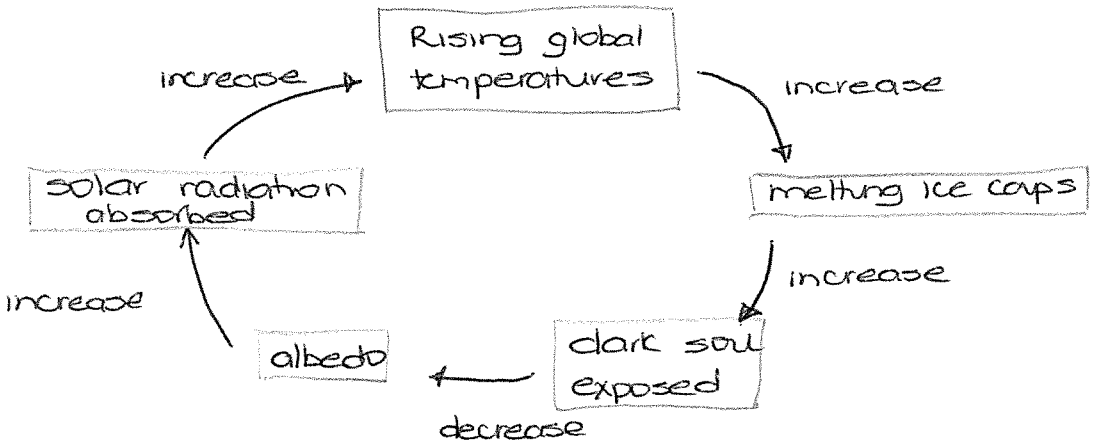
a) Define positive feedback.

Results in a further increase or decrease change in response to change in the system. Moves the system away from its original equilibrium towards instability.

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

Low income → decreased access to education → lower job prospects → less income.

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



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 - end result is a new equilibrium with the student less able to do work

Resilience

1.

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

refers to the tendency of a system (ecological or social) to avoid tupping points, and maintain stability thrugh steady-state equilibrium. Returns to initial state following a disturbance

b) Describe the connection between resilience and stability.

The more resilient a system the more disturbances it can deal with. This helps maintain the stability of the system

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

When small changes in a system add up and together tip the equilibrium over a threshold (tupping point) to a new unstable equilibrium

3.

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

The more diverse and complex an ecosystem the more resilient it tends to be as there are more interactions between species The bigger the storage the less significant a small change would be.

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	A monoculture of corn can be wiped out by a disease - small gene pool reduced resistance to disease. Also vulnerable to pests
An isolated village community in the Gobi desert, with a population of around 1000 people.	Low/ Moderate	small, isolated population has low genetic diversity. This makes population vulnerable to disease. Food quality is poor. With migration the resilience is increased to moderate
The community of Shanghai, China. Population roughly 24,000,000.	Moderate/ High	Large population implies large genetic diversity. Access to varied resources (high) Disease does spread quickly due to high population density (moderate)

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*

Low resilience. More CO_2 and SO_2 due to fossil fuel combustion leads to acid rain and ocean acidification. Reduces the ability of crustaceans to form shells and leads to coral bleaching. Both result in the decrease of species diversity.

Activity: *Introduction of invasive bird species*

System: *A forest ecosystem*

Low resilience if introduced species outcompetes native species and depletes their food supply.
Moderate resilience if native species can adapt to a new food source.

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

System: *A large society*

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

Low resilience. Reduction of workforce as population ages. Not enough care for aging population

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?)

With increase in greenhouse gases there will be an increase in ocean acidification 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 due to thinning of their shells (less absorption of $CaCO_3$ + acidity) Ocean food web would need to find an alternate food source (disadvantage). A diverse ecosystem means that most species would be able to adapt to the change (advantage)

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 (many factors) and so difficult to know how resilient the global climate system is. This means it is difficult to know how much of an increase in temperature the earth can tolerate before the tipping point is reached.

As significant timelags can occur between the pressures driving the change (increase in GHG) and the appearance of the impact of change it is very difficult to predict how resilient the global climate system is and when the tipping point is reached.

As the global climate system is complex both positive and negative feedback loops are operating at the same time - some regions are getting wetter/warmer others drier/colder. Each ecosystem could respond differently making predictions on a large scale challenging