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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

The first law of ~~text~~ thermodynamics is the principle of conservation of energy, which states that 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 <u>not</u> correct.

- Ecosystem is not an isolated system.
- It is an open system and it will exchange both matter and the energy with its surroundings.

2.

a) State the second law of thermodynamics

- Entropy of an isolated system not in equilibrium will tend to increase over time.
- Energy conversions are never 100% efficient.

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

Due to the 2nd law of thermodynamics energy is not equally passed through a food chain

- plants convert only 1-2% of the energy they receive into stored sugars
- only about 10% of the energy is passed from 1 trophic level to the next (rest is used in metabolism and lost as heat energy during respiration)

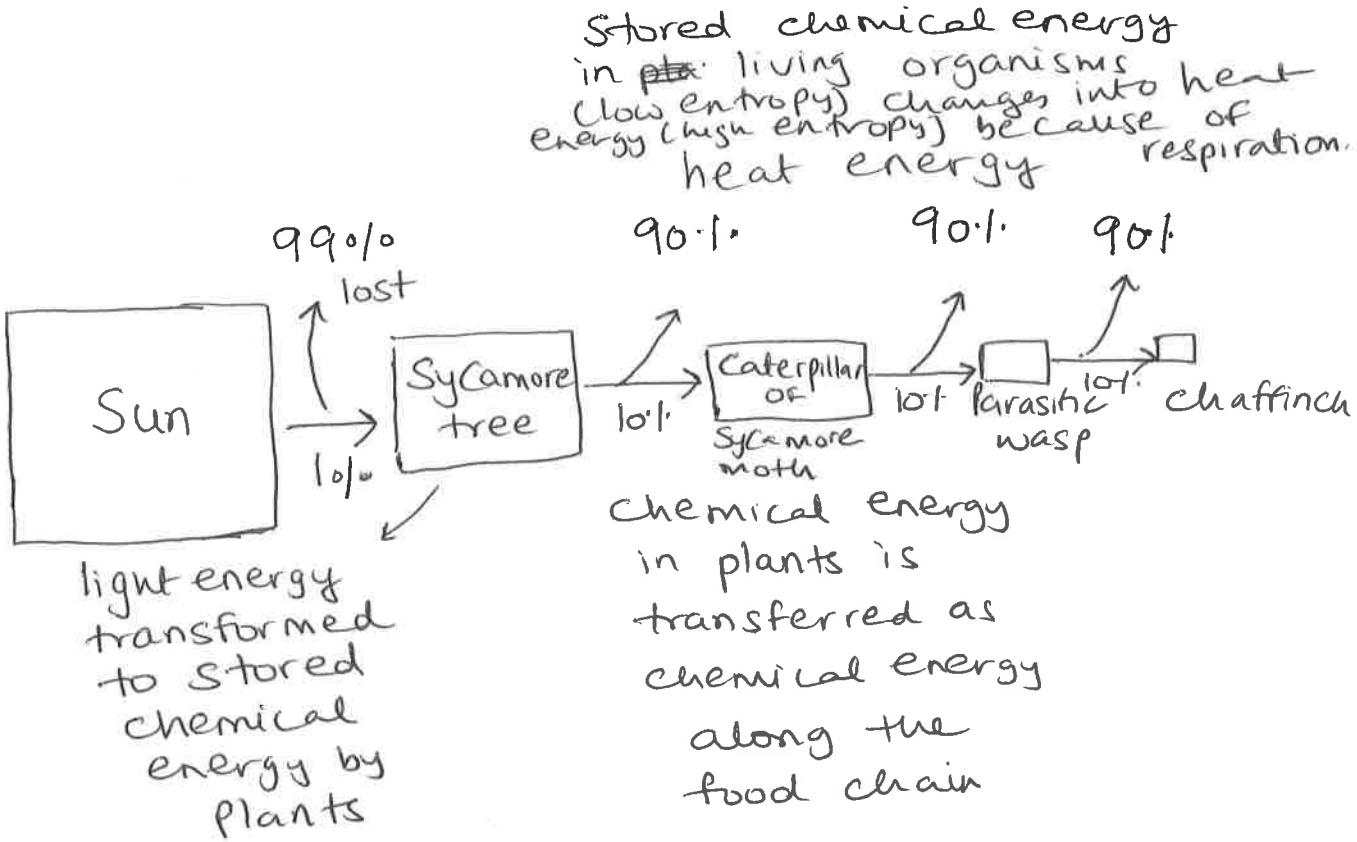
3. Define "entropy" (Pg 29 & 30)

entropy is a measure of the amount of disorder in a system.

Sycamore tree 100% → Caterpillar of Sycamore moth 10% → Parasitic wasps 1% → chaffinch 0.1%

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.

Equilibrium is the tendency of the system to return to an original state following disturbance.

2.

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

In static equilibrium there is no change over time. Most non-living systems like a pile of rocks or building are in a state of static equilibrium. A steady-state equilibrium is a characteristic of open systems where there are continuous inputs & outputs of matter,

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
	A mature climax ecosystem	There are no long term changes. Inputs and outputs balance each other.
	Predator & Prey Populations	There are minor fluctuations but each balances out the other.
Static	A hat on a hook	The hat is not in motion, remaining in equilibrium. There are no inputs or outputs creating a change.
	A pile of books	Same
	a building	Same

but the system as a whole remains in a more or less constant state

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

- In a stable equilibrium the system tends to return to the same equilibrium after a disturbance.
- In an unstable equilibrium the system returns to a new equilibrium after 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.

The more diverse and complex an ecosystem, the more resilient it tends to be as there are many interactions between different species. As such, it will be able to maintain a stable equilibrium.

Simple ecosystem- A monoculture of wheat or rice can be wiped out by a disease as genetic diversity is less.

Climax community of a forest will be more resilient as there is greater genetic diversity and higher resilience.

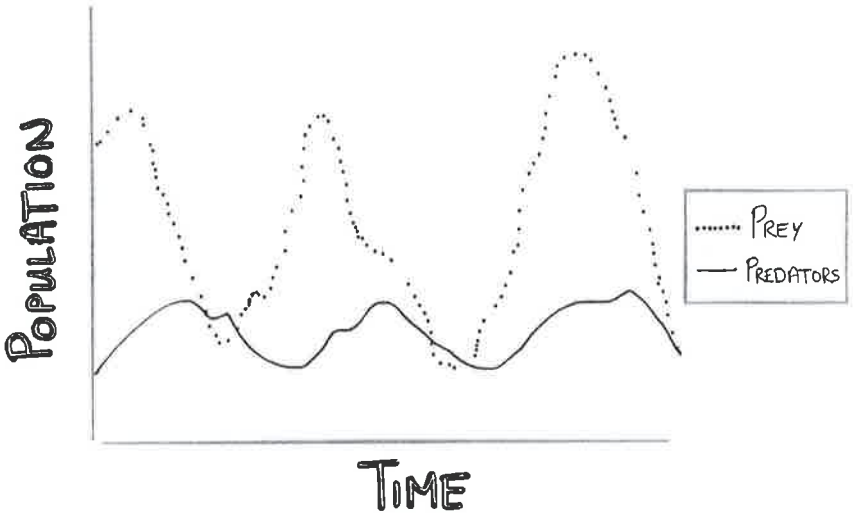
Feedback

1.

a) Define negative feedback.

Negative feedback tends to damp down, neutralize or counteract any deviation from an equilibrium and stabilizes systems.

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



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

As the prey population increases, predators have more food and their number increases. This results in lower number of prey. This cycle continues.

c) Outline one more example of negative feedback

As the Earth warms
↓
Ice cover melts, exposing soil or water
↓
Albedo decreases (albedo is the fraction of light that is reflected by a body or surface)
↓
More energy is absorbed by Earth's surface
↓
Global temperature rises
↓
More ice melts

2.

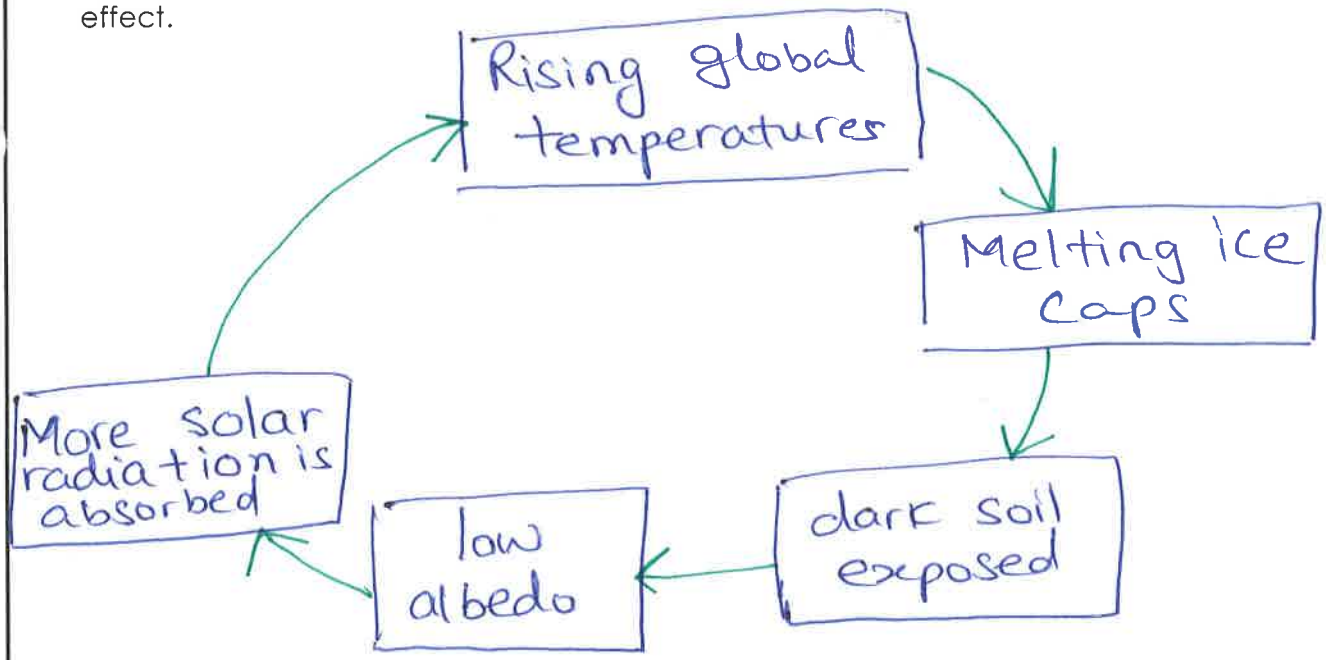
a) Define positive feedback.

Positive feedback results in a further increase or decrease in the output that enhances the change in the system

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

poverty in a community → lack of access to education → fewer job opportunities → poverty in the community

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

Resilience

1.

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

Resilience is the ability of a system to return to its initial state after a disturbance.

b) Describe the connection between resilience and stability.

The more resilient a system, the more disturbance it can deal with and more stable it is.

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

When a system is pushed past the point of returning to it's original state, it will destabilise it, causing it to adopt to a new 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. Bigger the storage more difficult it would be for a change to happen more resilient

4. Outline factors affecting ecosystem resilience? pg 38

a degree of change within a system that will destabilise it, causing it to adopt a new equilibrium.

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 wheat or rice or corn can be wiped out by a disease if none of the plants have resistance which is more likely in a diverse gene pool.
An isolated village community in the Gobi desert, with a population of around 1000 people.	low	Population is low, low genetic diversity, humans are more susceptible to disease. Climate adverse, food source is limited
The community of Shanghai, China. Population roughly 24,000,000.	moderate	In high density population disease can spread ~~happen~~ very fast, however, gene pool is bigger (diverse) some individuals will show high resistance.

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 because of fossil fuel combustion, leads to acid rain. lead to Coral bleaching, loss of habitat for fish, food webs will be destroyed.

Activity: *Introduction of invasive bird species*

System: *A forest ecosystem*

low resilience, invasive species might be better adapted to feeding in a particular environment. They will deplete the food supply and native species might go extinct.

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

System: *A large society*

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

low resilience
Not enough care for aging population as children might leave for better opportunity in an Urban area.

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 (GHG) there will be increase in ocean acidification.
This will lead to destruction of coral reefs, phytoplanktons, marine food chains, etc) → positive feedback.
This will lead to a tipping point and pH of ocean will decrease to a new constant. At this pH very few organisms would be able to survive.

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*

- Models are used to predict tipping points, however, models have strengths and limitations
- The delays involved in feedback loops make it difficult to predict tipping point i.e. how different do two system states need to be to say a tipping point has been reached.
- Not all properties of a system will change abruptly at one time, and so it may be difficult to say when a tipping point has reached.
- Not all the factors that could lead to tipping points have been identified.
- It may be difficult to determine the causes of a tipping point - whether it has been reached because of the inherent nature of the system or external factors such as human activity for example.