Environmental Studies
FACT SHEET
www.curriculum-press.co.uk
Number 125

# Answering Questions on Dynamic Equilibria

The concept of dynamic equilibria seems to confuse a lot of students but actually, it is a pretty simple affair!

It involves a balance between two processes that have the opposite effect. e.g. photosynthesis removes $CO_2$ from the atmosphere and respiration adds $CO_2$ to the atmosphere.

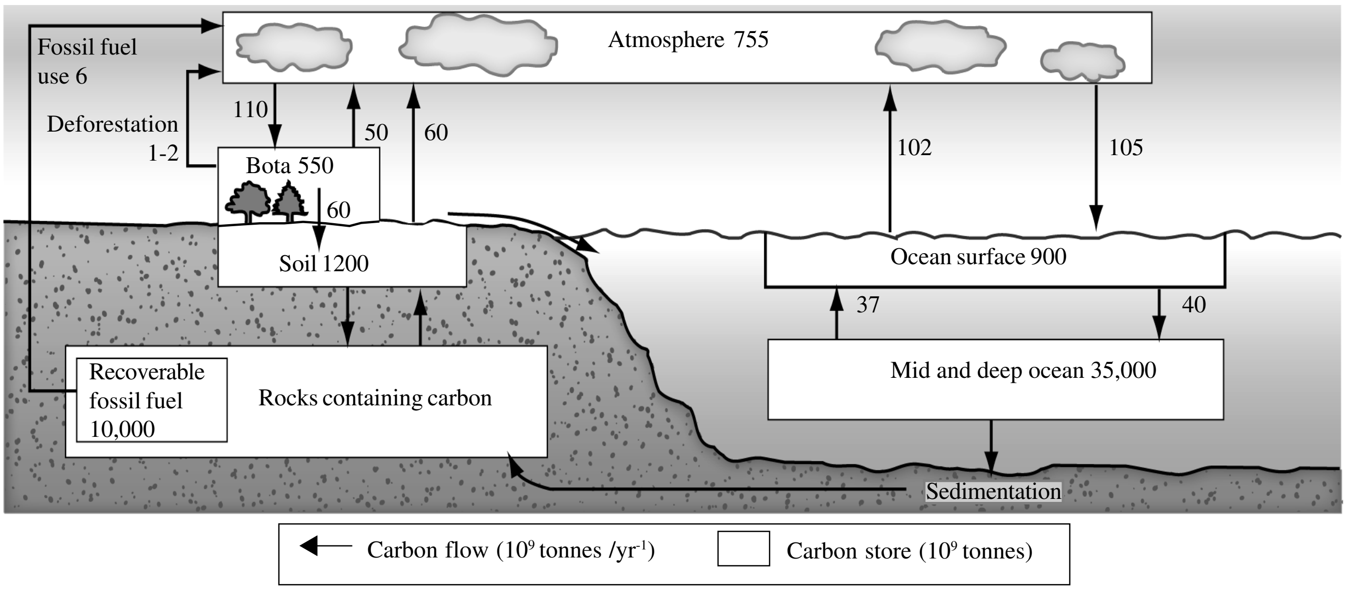
$$CO_2 + 6H_2O \underset{respiration}{\overset{photosynthesis}{\rightleftharpoons}} C_6H_{12}O_6 + 6CO_2$$

Let's start by looking at the carbon cycle in ever so slightly more detail.

## Carbon Cycle

The most common question here will ask you to explain how the amount of carbon dioxide in the atmosphere is an example of a dynamic equilibrium (Fig 1).

**Fig 1. Carbon cycle**




You simply have to describe the processes that are adding $CO_2$ to the atmosphere – respiration, combustion, anaerobic digestion etc – and state that this is balanced, in an ongoing way, with processes that are removing it from the atmosphere, namely photosynthesis and dissolution in seawater. So again, you need to identify counterbalancing processes.

As an extension to this basic question, you might be asked whether human activity is disrupting the dynamic equilibrium. If so, you should state that there is evidence that the increase in levels of atmospheric $CO_2$ are the result of a combination of:

- increasing anthropogenic emissions of carbon dioxide from the burning of fossil fuels
- reduced photosynthesis following the destruction of forests and the clearance of vegetation

Whether, via the Gaia hypothesis, which suggests that the Earth is a self-regulating system which responds to resist change, Nature will reduce these human activities, is yet to be seen!

***Exam Hints:-***
- *If a question asks you to explain e.g. why the carbon cycle is a good example of a dynamic equilibrium* ***DO NOT*** *use the words dynamic equilibrium in the answer*
- *State* ***specific*** *processes that result in the opposite thing happening e.g. "****photosynthesis*** *removes $CO_2$ from the atmosphere,* ***respiration*** *adds $CO_2$ to the atmosphere"*
- *Get the word "counterbalancing" in somewhere*
- *THIS Q COMES UP JUST ABOUT EVERY OTHER YEAR!*

***Extract from Chief Examiner's Reports***
*Many candidates understood the principle of dynamic equilibrium but very few related this to actual named processes in the carbon cycle*

You have to know how the processes of the carbon cycle are affected by human activities.

### Table 1 How do humans affect the carbon cycle?

| Human activity | Dynamic effect on the C Cycle |
|---|---|
| afforestation | ↑photosynthesis → ↓ $CO_2$ |
| deforestation | ↓ photosynthesis → ↑ $CO_2$ |
| fossil fuel burning | ↑ $CO_2$ → ↑photosynthesis |
| livestock rearing | ↑ $CH_4$ → ↑ temperature → ↑photosynthesis → ↓ $CO_2$ |
| ploughing | ↑ aeration of soils → ↑ oxidation of C – containing substances → ↑ $CO_2$ |
| increased rates of photosynthesis | ↓ $CO_2$ |
| increased rates of decomposition | ↑ $CO_2$ |

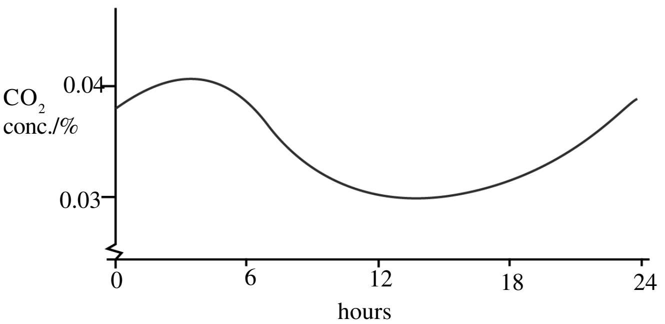
Key: ↑= increase ↓= decreased → = leads to

> ***Exam Hint:-*** *Practice extending each of these effects. For example, looking at afforestation, we could continue as follows:*
>
> *↑photosynthesis → ↓ $CO_2$ → ↓ temperature → ↓photosynthesis → ↑ $CO_2$ → ↑photosynthesis*

And even this is way too simplistic as an increase in temperature (from humans burning more fossil fuels and increasing $CO_2$ levels) would accelerate respiration **more than** it would accelerate photosynthesis. Draw a flow diagram to show where this might lead.

## Typical Exam Question

The diagram shows how carbon dioxide concentrations fluctuate over a football field over the course of a day.




Use the information in the graph to explain the term dynamic equilibrium (3)

**Markscheme**

$CO_2$ increases during evening/night because light levels too low;
for photosynthesis;
But respiration;
continues to release $CO_2$;
During day $CO_2$ absorption in photosynthesis exceeds release via respiration;
So concentration falls;
Concept of balanced processes;

## Water (hydrological) cycle

The water cycle is another good example of a dynamic equilibrium.

Water enters the atmosphere by evaporation from rivers, lakes and oceans etc and via evapotranspiration from vegetation. It leaves the atmospheric store via precipitation and condensation.

Table 2 shows that there is an approximate balance between water vapour in the atmosphere and in the other reservoirs.

### Table 2. Water cycle reservoirs and transfers

| Reservoir | Volume / $10^3$ $km^3$ | Transfer rate in or out of the store / $10^3$ $km^3/yr^{-1}$ |
|---|---|---|
| Oceans | 140,000 | 425 |
| Ice | 43, 500 | 30 |
| Groundwater (aquifers) | 15,300 | 20 |
| Rivers and lakes | 360 | 20 |
| Atmosphere | 15 | 490 |

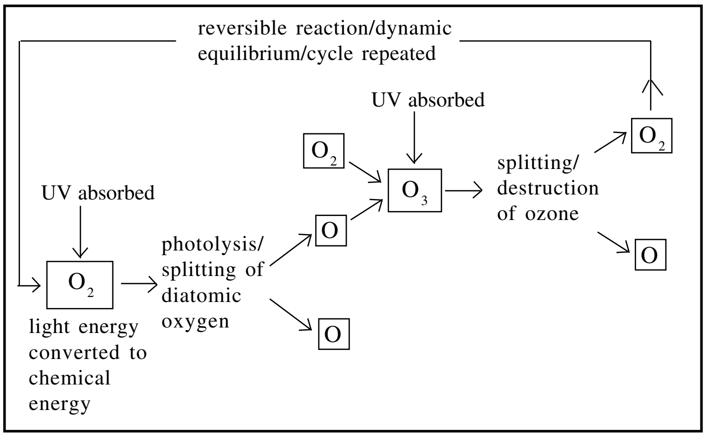
## Stratospheric ozone formation and destruction

Monatomic (O), diatomic ($O_2$) and triatomic ($O_3$) forms of oxygen form a dispersed layer in the stratosphere. They absorb ultraviolet (UV) light which results in a dynamic equilibrium of chemical reactions forming and destroying ozone. The ozone layer ($O_3$) prevents most of the UV from reaching the Earth's surface – and without this layer, life on land and surface waters would be impossible.

**So why are the natural reactions involving ozone an example of dynamic equilibrium?**

Because:
- UV light is involved in both the formation and destruction of ozone
- Overall there is a balance between formation and destruction and the chemical reactions effectively cancel each other leaving ozone concentrations about constant

**Fig. 2 Some of the reactions which occur in the ozone layer**




Thus, a dynamic equilibrium of photolysis and subsequent molecule formation produces the stratospheric ozone layer which then prevents most of the UV from reaching the Earth's surface.

In the exam, you could use the following equation as a great summary:

$$O_3 \underset{uv}{\overset{uv}{\rightleftharpoons}} O_2 + O$$

## Population sizes

Animal populations may increase in size when there is:

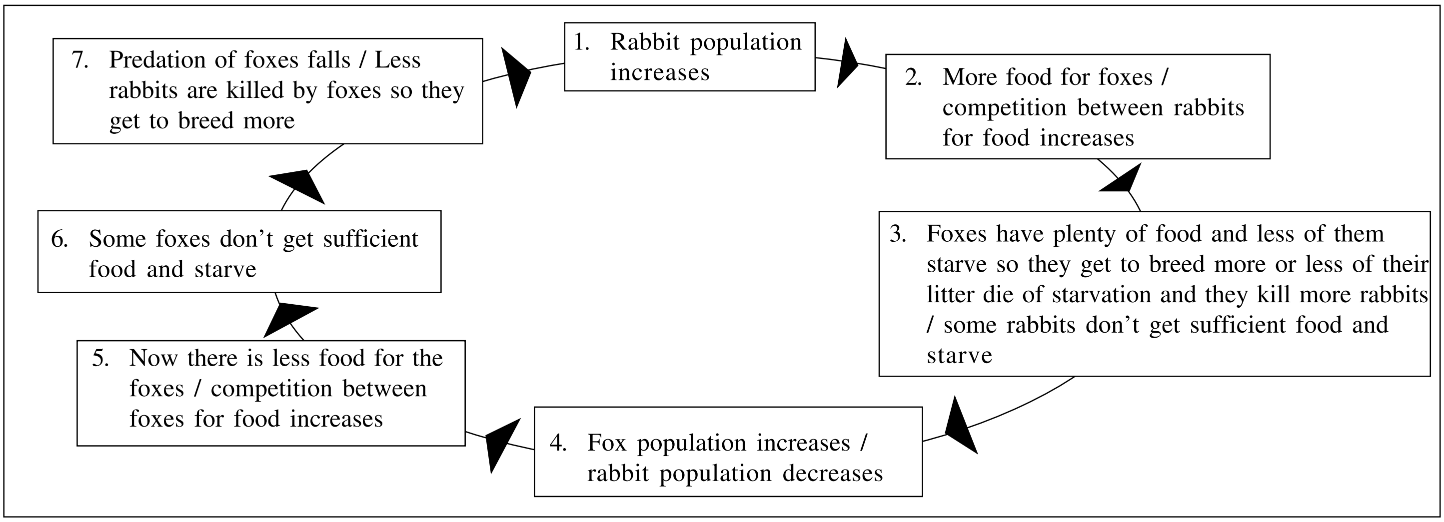
- plenty of food
- plenty of mates
- few predators, parasites or competitors

Animal populations may decrease in size when there is:

- shortage of food
- shortage of mates
- many predators, parasites or competitors

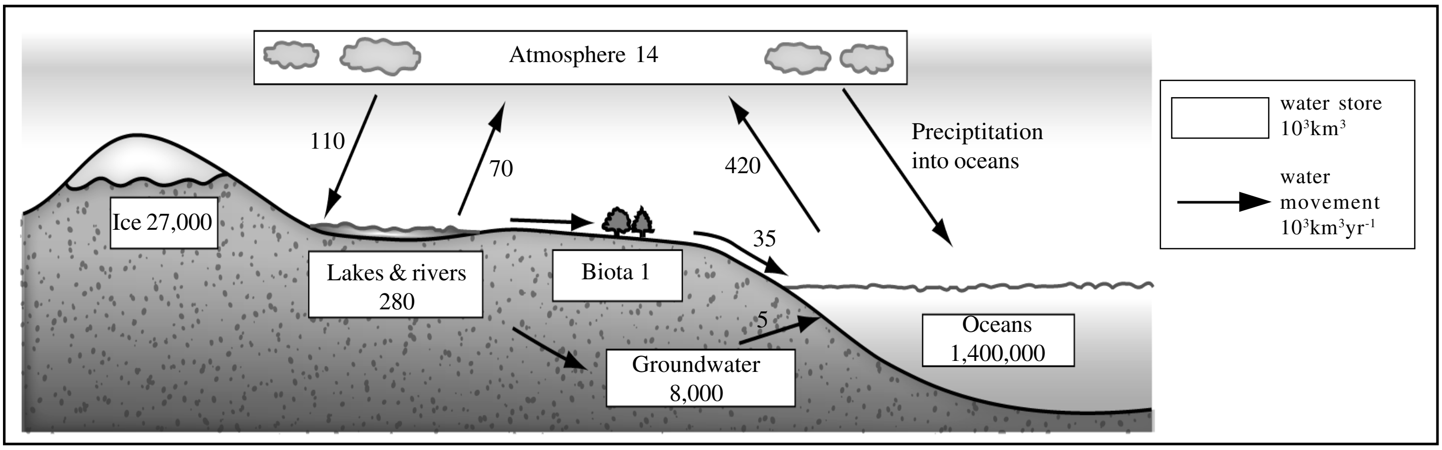
Population sizes are also example of dynamic equilibrium because if populations get too big, or fall too small, processes will kick in that help to reverse the trend (Fig. 3)

**Fig 3. Dynamic equilibrium: population size**




## Practice Questions

1. Use the carbon cycle to explain the principle of a dynamic equilibrium (2).
2. The diagram shows the process of dynamic equilibrium in the water cycle.




Suggest how the dynamic equilibrium of the water cycle may be disrupted by:
(i) large-scale irrigation (2)
(ii) deforestation (2)

3. Explain how the regulation of the population size of an animal species shows the principle of dynamic equilibrium. (3)

## Markschemes

1. Names of two opposing processes / e.g. photosynthesis and respiration;
   Processes / rates counterbalance / cancel each other out;
2. (i) Change in evaporation / transpiration / runoff / /percolation / infiltration;
   linked to change in:
   height of water table / soil moisture levels / river water levels / atmospheric water vapour / biota;
   (ii) Reduced evapotranspiration / interception / storage;
   Faster runoff / overland flow / return to sea;
   Increased flooding;
3. Population increase above optimum leads to increased predation / competition / disease;
   Results in increased mortality / decreased reproduction;
   This population decrease leads to reduced predation / competition/ disease;
   Results in increased reproduction;
   Ref to counterbalancing effects;

**Acknowledgments:** This Factsheet was researched and written by Kevin Byrne. *Curriculum Press, Bank House, 105 King Street, Wellington, Shropshire, TF1 1NU*
Environmental Studies Factsheets may be copied free of charge by teaching staff or students, provided that their school is a registered subscriber. **ISSN 1351-5136**