Earth and Space Sciences

Mass Extinctions: Did bad timing kill the dinosaurs?

Scientists are fairly sure that an asteroid strike sounded the final death knell for the dinosaurs, but there might have been other factors involved as well.

In this lesson you will investigate the following:

- What are mass extinctions?
- What scientific evidence is there for an asteroid strike 65 million years ago, wiping out the dinosaurs?
- Could dinosaur biodiversity have been a factor in their demise?
- How has human activity become responsible for the sixth mass extinction recorded in geological time?

In an extinction everyone's equal, but some are more equal than others...

This is a print version of an interactive online lesson.
To sign up for the real thing or for curriculum details about the lesson go to **www.cosmosforschools.com**

Introduction: Mass Extinctions (P1)

Dinosaurs may have just been unlucky that the catastrophic asteroid collision that is thought to have wiped them out arrived when it did. If it had hit the Earth earlier or later they might have survived, some scientists now think.

A palaeontologist at Edinburgh University now believes that when the impact happened 66 million years ago many of the big plant-eating dinosaurs, including the horned triceratops and duck-billed dinosaurs, had already disappeared.

And that meant there were fewer animals for the big meat-eating dinosaurs to eat.

That made them just that bit less resilient when the asteroid hit what is now Mexico, setting off a disastrous chain of events including tsunamis and earthquakes, and forcing blankets of material into the atmosphere that blocked out the Sun and cooled the Earth by up to 10 degrees.

With ecosystems already weakened the dinosaurs didn't stand a chance...

Read or listen to the full *Cosmos* magazine article here.

Left: A Tyrannosaurus rex skeleton from the Upper Cretaceous epoch. Right: Wolfe Creek crater, Western Australia. It is 880 m across, from an impact around 300,000 years ago.

Mass extinction events have long enthralled scientists and captured the imagination of students and the general public. There have been five (maybe six, see Apply section) such events in the Earth's history. Scientists have proposed various trigger mechanisms for the die-offs including asteroid strikes, super-volcanic eruptions (sometimes lasting thousands of years), and intense climate fluctuations (both ice ages and warm periods, with enhanced greenhouse effects).

The best known and most studied mass extinction event, referred to in the Cosmos Magazine blog, occurred 65.5 million years ago. It saw the extinction of the dinosaurs and paved the way for the rise of mammals (including humans) as the dominant group on Earth. While several different causes for this extinction event have been proposed, current evidence supports a large asteroid impact. This resulted in dramatic biodiversity loss and environmental change with the extinction of approximately 75% of all species on Earth.

Question 1

Describe: You are a three-metre-tall carnivorous dinosaur living next to a large river system within a tropical rainforest just 200 kilometres from where the asteroid hit 65.5 million years ago. Describe the environment you are living in on this, your final day on Earth.

Hint: refer to the image in the Cosmos blog and the image shown at the beginning of this section.

Gather: Mass Extinctions (P1)

Left: Over 17,000 species of trilobites, like this one, flourished in Earth's oceans before all dying out in the Permian–Triassic extinction 251 million years ago. Right: Temperate rainforest similar to that through which dinosaurs roamed during the Upper Cretaceous. Western Tiers, Tasmania (Photo by Auscape/UIG via Getty Images)

What is geological time?

Most of us find it difficult to grasp the vast scale of geological time. Our experience is at the level of hours, days and years – 50 years seems an impossibly large amount of time to most high school students! But earth scientists have to work on very much longer time scales than this – typically hundreds of thousands to millions of years. To help they have created their own time scale, displayed on a stratigraphic chart, dividing up the Earth's history.

Link to an online stratigraphic chart here.

Geological time is divided into different time spans:

- eras are made up of periods,
- periods are made up of epochs, and
- epochs are made up of ages.

Each division is based on a specific set of geological or palaeontological (fossil) conditions that distinguishes it from the divisions before and after. Time is measured in millions of years (abbreviated to Ma, which in some contexts means millions of years ago).

Today we are living during the Holocene epoch of the Quaternary period, Cainozoic era ("Cenozoic" in US English). A fossil dated 160 Ma belongs to the Oxfordian age of the Upper Jurassic epoch, Jurassic period, Mesozoic era (check the chart to see).

Question 1

Name: The extinction event that killed the dinosaurs is of such importance that it marks the boundary between two eras – a major division. What were the era, period, epoch and age that ended with the event, and which era, period, epoch and age started after the event? Between what years did the eras before and after the event run?

The point at which the dinosaurs disappeared, at 65.5 Ma, is called the K-Pg boundary. K stands for the Cretaceous period and Pg for the Paleogene period.

You will also see the same boundary referred to as "K-T". Here, the K still stands for Cretaceous but the T stands for "Tertiary", the old name for Cainozoic (which is the name of the new era, not period, like "Cretaceous").

What is an extinction event?

An extinction event is defined as a widespread and rapid decrease in life where a large number of species around the Earth become extinct.

Scientists recognise five major extinction events since complex forms of macroscopic life evolved approximately 542 million years ago:

1. Ordovician: ~450–440 Ma
2. Devonian: ~375–360 Ma
3. Permian–Triassic boundary: ~251 Ma
4. Triassic–Jurassic boundary: ~200 Ma
5. Cretaceous–Paleogene boundary: 65.5 Ma

Question 2

Identify: Fill in the causes and consequences of each of the five extinction events in the table below.

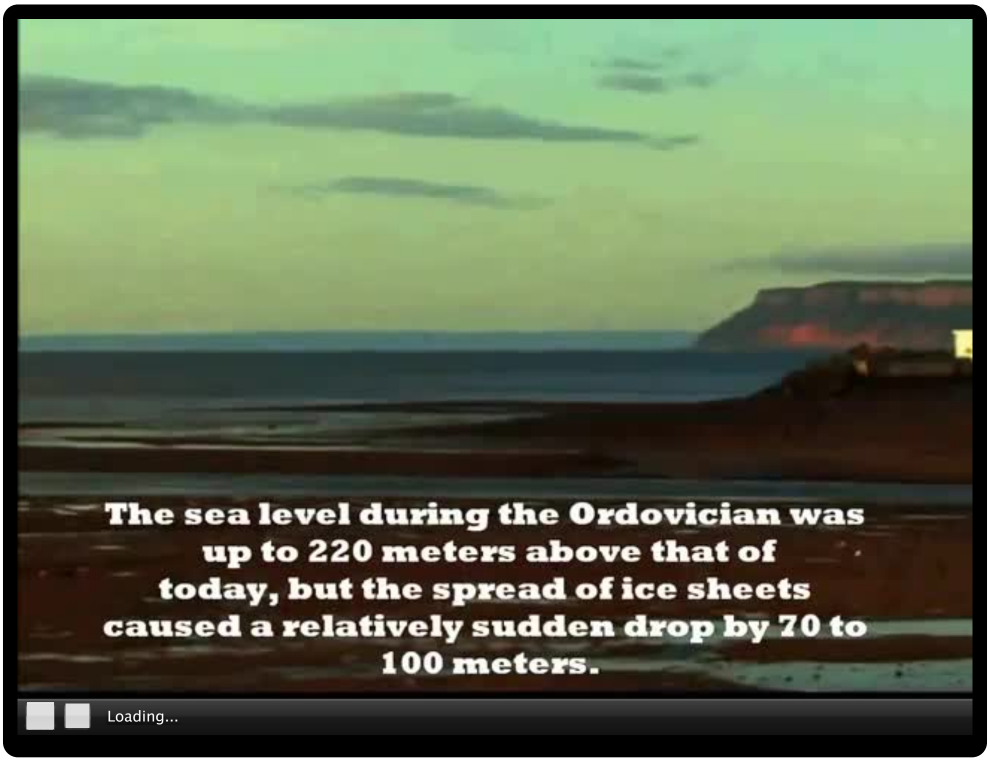
Extinction Event	Causes	Consequences
Ordovician		
Devonian		
Permian–Triassic boundary		
Triassic–Jurassic boundary		
K-Pg boundary		

Question 3

Name: Using the data collected in Question 2, which of the extinction events had the most catastrophic impact on life on Earth?

- [ ] Permian–Triassic boundary
- [ ] K-Pg boundary
- [ ] Devonian
- [ ] Triassic–Jurassic boundary
- [ ] Ordovician

The video below has more detail about the Earth's first major extinction event, the Ordovician ~450 Ma.



Question 4

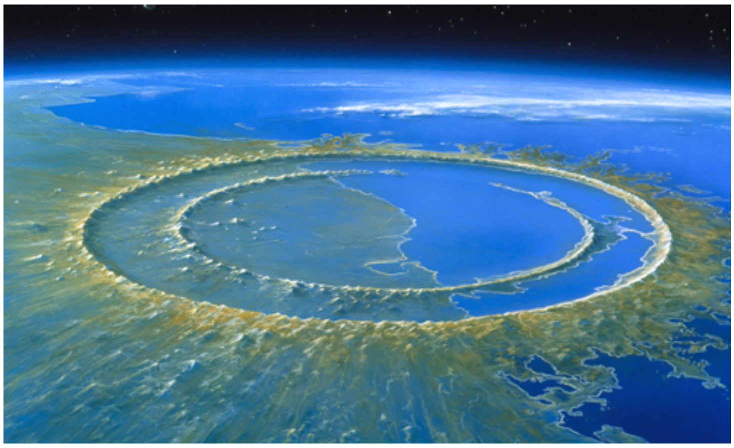
Explain: Describe the mechanisms that drove the Ordovician extinction.

Two hundred million years later the Permian–Triassic boundary extinction event, sometimes referred to as "the great dying", had quite a different cause.

Question 5

Explain: Describe the mechanisms that scientists believe led to the Permian–Triassic extinction.

Process: Mass Extinctions (P1)



What caused the K-Pg boundary extinction event?

The K-Pg boundary extinction event referred to in the Cosmos blog is probably the most well-known of all the extinction events since it represents the demise of the dinosaurs. But how do we know what caused it?

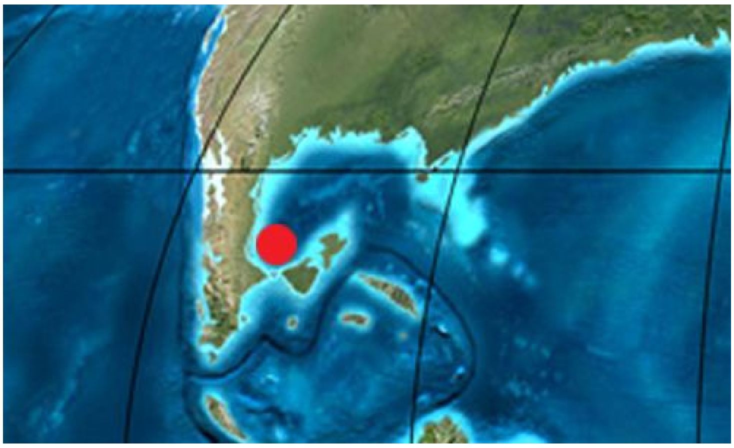
Question 1

Hypothesise: In 1980 the 65.5 million years old K-Pg boundary was known to scientists, but there was no agreement on what had caused the extinctions.

Copy each of the following statements into the table below according to its role in Walter Alvarez's thinking when he proposed a possible cause.

- The thin clay layer contained high levels of iridium.
- The K-Pg boundary extinction event was caused by a large asteroid strike.
- A thin clay layer, similar to that found near Rome and of the same age, is found at many locations around the world.
- Iridium is rare on Earth, but common in space.
- Somewhere on Earth is a large crater, 65 million years old.
- A thin layer of clay found at a site north of Rome was dated to the same time as the K-Pg boundary.

Evidence 1	
Evidence 2	
Evidence 3	
Background information	
Hypothesis	
Prediction	

Left: A rock sample from Wyoming, USA, showing the clay layer marking the K-Pg boundary. It has 1,000 times more iridium than the layers above and below. (San Diego Natural History Museum, Eurico Zimbres) Right: The Chicxulub asteroid impact point on a paleogeological map showing the coastline 65 million years ago.

Question 2

Recall: The image at the top right of the page is an artist's impression of the Chicxulub crater. At the time of the strike the area was all ocean, but is now partially covered by land (shown in the image).

Where is the Chicxulub crater and how old is it? Does the age of the crater correlate with the age of the K-Pg boundary?

What are the diameter and depth of the Chicxulub crater? Answer in imperial and metric units (1 mile = 1.61 km).

Question 3

Calculation challenge

When the Chicxulub asteroid struck, the impact caused an explosion so huge that it vaporised rock and threw thousands of tonnes of debris into the atmosphere, engulfing the whole planet.

What was the energy of that explosion? With a few basic facts we can work it out and compare it to the nuclear bomb that devastated Hiroshima on 6th August 1945.

Hint: you can use the equation editor in the Text widget to answer, or write your calculations on paper then upload a photo of them.

The question is broken into steps. We've provided some of the answers so you can check that you're on track.

Basic data:

- The asteroid was 10 km diameter (assume it was spherical)
- It was travelling at 30,000 m/s (that's fast!)

Answer each question to three significant digits.

Step 1. Calculate the volume of the asteroid. The volume of a sphere is $V = \frac{4}{3}\pi r^3$, where r is the radius in metres. Don't forget to include the units in your answer.

Step 2. Assuming that the density of the asteroid was 2,700 kg/m^3 (typical for rock), calculate the mass of the asteroid. (Answer: 1.41×10^{15} kg)

Step 3. Calculate the kinetic energy of the Chicxulub impact using $E_k = \frac{1}{2}mv^2$. This will give your answer in joules.

Step 4. The Hiroshima nuclear bomb was about 67 TJ. How much bigger was the Chicxulub explosion? (Answer: 9.40×10^9 times bigger – that's almost *ten billion* times bigger!)

What killed the dinosaurs?

Question 4

Consider: Scientists can work out many of the effects of the asteroid strike, but others are less certain – especially far away from the impact zone on the other side of the Earth. And some of the effects were immediate, while others may have lasted for years.

Some of the effects that have been suggested are listed below. Think about how long these effects might have persisted and enter likely durations for them, taken from this list:

- Immediate to hours
- Weeks
- Years
- Hundreds of years

Effect	Likely duration
Acid rains caused by sulphates released into the atmosphere	
Massive tsunamis	
Freezing temperatures because ash and dust in air blocks out sunlight	
Fires	
Shockwave	
Massive volumes of CO2 released in explosion cause enhanced greenhouse effect	
Poisonous gases released in explosion suffocate animals	
Plants and plankton unable to photosynthesise due to lack of sunlight	

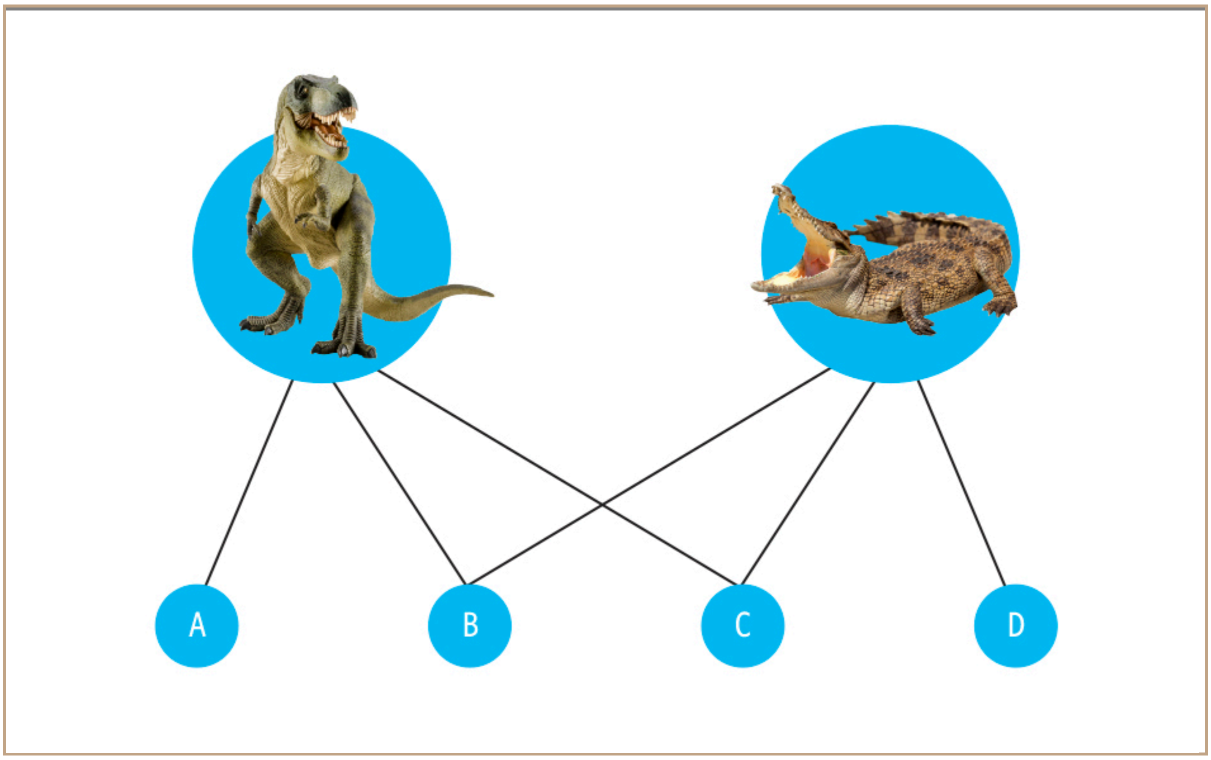
We know that not all life perished, for example mammals, birds and crocodiles survived. But creatures that survived the first few days after the explosion were still not out of danger. They may have depended on other animals or plants that had been wiped out.

The greater the number of species – the biodiversity – then the better the chances that some of them might survive.

Question 5

Model: Imagine that two top-level predators, *Tyrannosaurus rex* and crocodiles, depended on four species of animals for food, as shown in the diagram below. Two unlucky species are preyed on by both *T. rex* and crocodiles, and the other two only by one or the other.

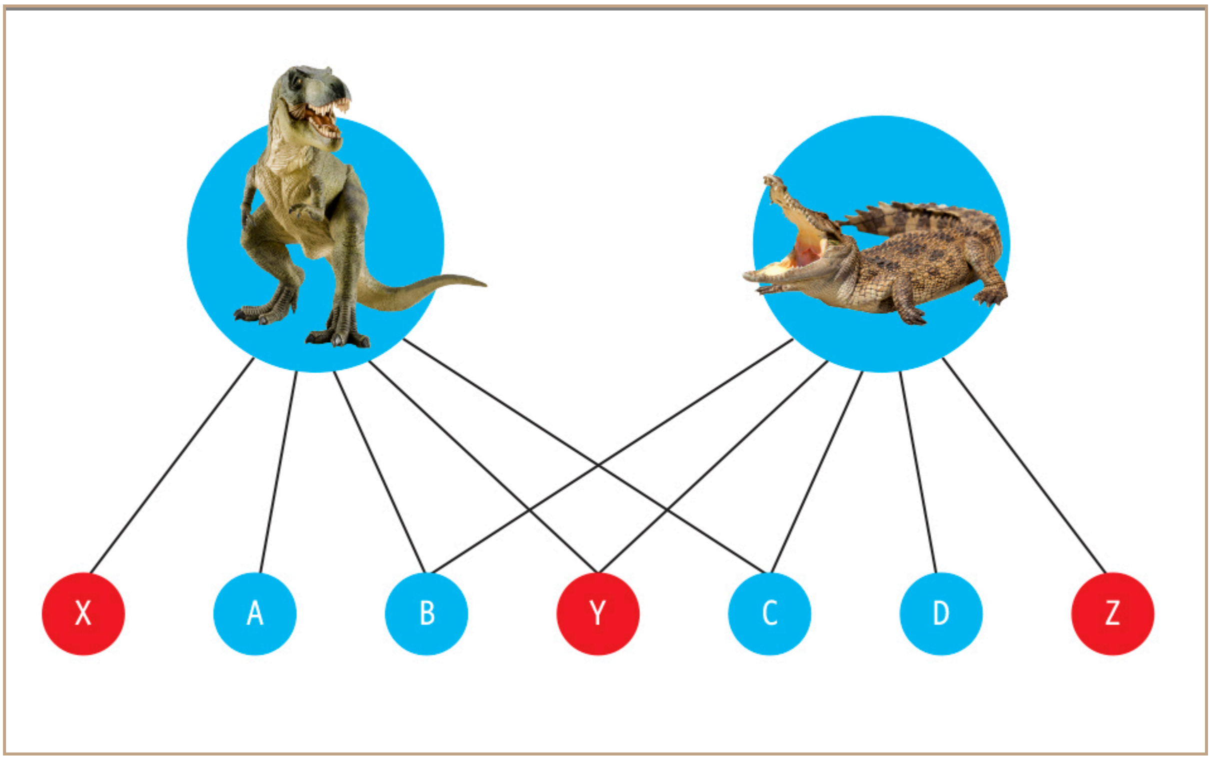
Now imagine that species A, B and C were wiped out by the effects of the asteroid impact. Cross out those species in the sketchpad, and any other species that depended on them.



Question 6

Now imagine that the asteroid had hit 10 million years earlier, when the scientists referred to in the Cosmos Magazine blog believe that there was more biodiversity. That might have meant more species for *T. rex* and crocodiles to prey on, as shown in the diagram below.

This time imagine that, as before, species A, B, and C were wiped out by the asteroid strike, as well as species X and Z. Again, cross out these species in the sketchpad and any species dependent on them.



Question 7

Explain: What difference did the increased biodiversity have on the top-level predators? Explain why greater biodiversity improves the chances of there being some species that survive a cataclysmic event such as the Chicxulub asteroid strike.

Apply: Mass Extinctions (P2)

The Holocene extinction: the sixth major extinction event?

Effects of deforestation in the Amazon, Brazil.

"Biodiversity" refers to the range of variation amongst particular groups of living things.

- *Genetic* biodiversity refers to the number of gene variations within a species
- *Species* biodiversity refers to the number of species living within an ecosystem
- *Ecosystem* biodiversity refers to the number of ecosystems within a geographic area, or the whole Earth

The Cosmos Magazine blog article suggests that the greater the biodiversity the more resilient life is (including human life).

Yet, even if biodiversity is a good thing, many have argued that the impact we humans are having on the Earth constitutes a sixth major extinction event, sometimes referred to as the Holocene extinction. This began in the 19th century as industrialisation coupled with an exponentially growing human population resulted in increasing demands on the Earth's natural resources.

Question 1

Research: Working in groups of two or three, use Google Earth to choose an area in the vicinity of your school. It could be a city area, suburbs, agricultural land, a bay or nearby ocean area – anything at all. It might even be a conservation area or national park.

1. What do you think the original land or seascape would have been like in terms of faunal and floral biodiversity before human impact? What evidence or reasoning can you offer for this?
2. Assess the situation in the area now with respect to biodiversity. Think in terms of ecosystem, species and genetic biodiversity.
3. Using the HIPPO acronym, identify the particular challenges to biodiversity the area has faced in the past, and faces now.
4. List some practical measures you could take to increase biodiversity in the area, returning some of the species or ecosystems that might have been lost. Annotate a Google Earth image with these. Can these measures coexist with the uses that humans currently have for the area?
5. What would be some short and long term benefits to humans from undertaking these actions? Could the increased biodiversity help life on Earth withstand a catastrophic event?

Career: Mass Extinctions (P2)

Brought to you by RiAUS

What makes one species of fly thrive in the warm tropics while another dies out? And what does this mean in the context of climate change? Rahul Rane is trying to figure that out.

As a geneticist at the University of Melbourne, Rahul studies how different fly species adapt to climate change. Fruit flies, for example, live in many different environments, yet even slight changes to the range of temperatures they experience within those environments can threaten their survival. With the help of experiments and supercomputers that show him the variations in the flies' DNA, Rahul hopes to understand why this is so. With global temperatures rising it's important work that will help predict which species will – or won't – be able to survive in the near future.

Rahul, an avid science fiction fan, describes nature as being like a complex machine that needs biodiversity to function. No single species can perform every role needed to sustain an ecosystem so nature requires many participants acting together in order to keep the ecosystem alive. And if we keep losing biodiversity we will lose a lot of the relationships that make nature work. "In the end," he warns, "we may find that Earth cannot support life as abundantly as it currently does."

Rahul loves that his job lets him play with a range of amazing gadgets, including some of the largest supercomputers in Australia. The advanced machines and robots in his lab also make experiments a joy. He especially enjoys trekking through farms and vineyards across the country in search of interesting fly species to study – it allows him to indulge his loves for travel and photography at the same time! But the ability to make a difference in the world is what is truly exciting about being a scientist, he says.

When he isn't working, Rahul relishes any opportunity to travel and experience new cultures and cuisines.

Question 1

Choose: Rahul is interested in how all of nature works together like a complex machine, where every part – even flies – has a role to play. What part of nature, micro or macro, are you most interested to discover more about? What role do you think your chosen type of organism plays in maintaining the ecosystem it inhabits? What would be the consequences if it failed to play that role?

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