ANALYZE THIS! // EARTH

Analyze This: Can you outrun these geological disasters?

Yes — and well probably not

This May 2018 video of lava flowing down a road was captured during the eruption of Kilauea on the island of Hawaii.
USGS/YOUTUBE

By Lillian Steenblik Hwang
September 5, 2018 at 5:30 am

Red hot lava races down the slopes of a volcano, along with billowing clouds of ash, toxic fumes and huge rocks. People, dinosaurs and vehicles are desperately speeding away, staying just ahead of the molten rock and ominous clouds. Because, well, *life finds a way* (it has to). If this sounds familiar, that's because this is a scene from the recent summer movie blockbuster, *Jurassic Kingdom*.

Aside from the dinosaurs, though, just how realistic is this scenario? Could people actually outrun the dual dangers of lava and a *pyroclastic flow*? What about other geological disasters, such as landslides or avalanches? The movies, it turns out, aren't always totally fiction.

Lava flow

Lava is the molten rock that comes out of a volcano. How quickly lava flows depends on factors such as its chemical composition, its temperature, and its gas and fluid content. Researchers measure its speed with the same radar gun that police use to catch speeding cars. And, they find, hotter lavas can move pretty swiftly when they contain plenty of gas, such as water vapor, carbon dioxide and sulfur dioxide.

Explainer: The volcano basics

There are two main types of lava: basaltic (Bah-SAAL-tik) and andesite (AN-deh-syte). Basaltic lava is generally more fluid and free-flowing. It tends to produce low-profile shield volcanoes, such as Kilauea in Hawaii. In contrast, andesite lava contains more silica than basaltic lava. That makes it thicker, creating slower lava flows and taller volcanoes, such as those found in the Andes.

Occasionally, lava can travel briskly, such as when it's in a lava channel, lava river or lava tube. These are pathways that direct and insulate the lava flow, allowing it to move much more swiftly. These pathways form when friction slows the outer edges of a lava flow. As those edges cool they also crust over and harden. This allows them to channel the lava flow, like the edges of a creek or river channels water.

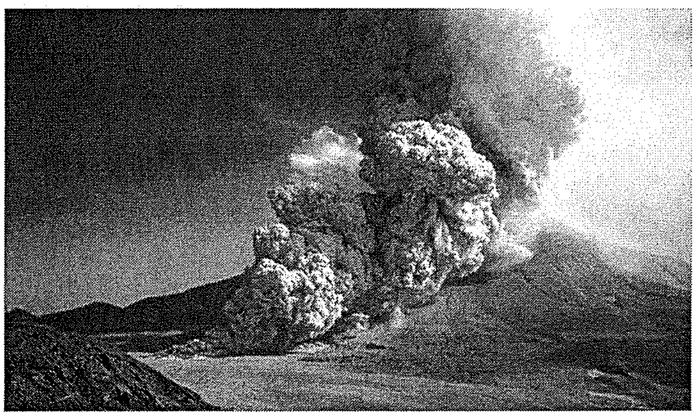
The rest of the time, though, a person should be able to escape a lava flow easily.

Fast-flowing lava gushes from one of Kilauea's most active fissures | Scie...

A glowing river of lava races from fissure 8 on Kilauea's lower east rift zone all the way to the ocean.
USGS/SCIENCE NEWS/YOUTUBE

Pyroclastic flow

This is the movie industry's classic type of volcanic eruption. Here, a giant cloud of ash, toxic fumes and large chunks of solidified lava travel downhill in the company of searing hot gases — some as hot as 1,000° Celsius (1,830° Fahrenheit). Most people unfortunate enough to be near such a fast-moving event won't escape it. The Volcán de Fuego in Guatemala, for instance, released a lethal pyroclastic flow during an eruption this summer. It killed more than 100 people.

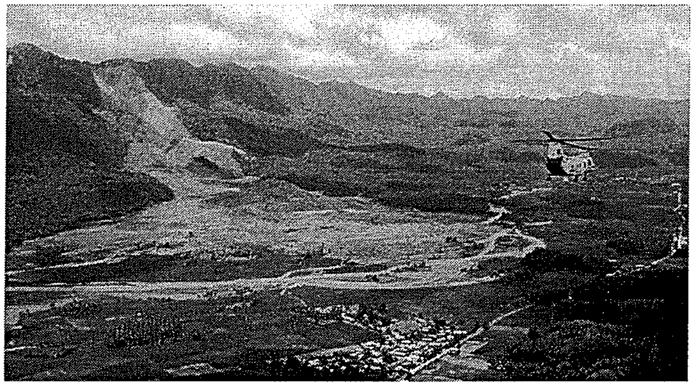


Here, a pyroclastic flow rushes down Mt. St. Helen's on August 7, 1980. This volcano is a landmark of Washington state. Under the giant cloud of ash and toxic gas moves a wave of hot and fast moving debris — and lava rocks.
P.W. LIPMAN/USGS

Landslide

Sometimes the rocks and soil on a slope give in to gravity. The resulting downhill flow is known as a landslide. Heavy rains and earthquakes are among events that can trigger a landslide. Human alterations to the environment can aggravate the risk that this will happen. Examples of such changes are stripping plants from hillsides or cutting into hillsides to build roads. Now this land may erode and give way during rains.

"Landslide is a generic term for a kind of land flow movement," explains Dave Petley. A geographer and earth scientist, he works at the University of Sheffield in England. What a landslide looks like and how fast it moves depends on many things. Most land flows move just a few centimeters (inches) a year. Others can move very fast and with little warning.

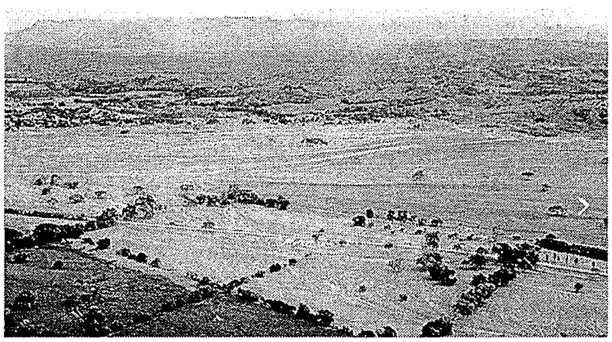


A helicopter flies over the site of a landslide on the Phillippine island of Letye in February 2006.
PETTY OFFICER 1ST CLASS MICHAEL D. KENNEDY/US DEPARTMENT OF DEFENSE/WIKIMEDIA COMMONS

Mudslides are a specific type of landslide where debris and dirt mix in with water. Mudslides tend to be slower than other land flows. They also have the potential to be very powerful and to pick up debris as they travel.

Lahar

Sometimes water mixes with volcanic sediment and debris to create a powerful, fast-moving river that gushes down a volcanic slope. Its structure tends to resemble flowing concrete. Lahars can be triggered by severe rainfall in a volcanic area that has lots of loose sediment. They also can develop when a volcanic eruption melts glacial snow on the sides of a volcano.

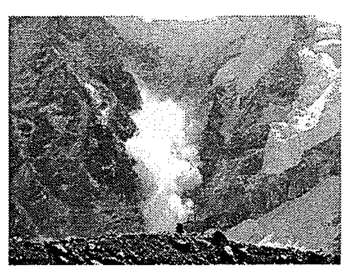


The Colombian town of Armero used to stand in the center of this image, in South America's Lagunilla River valley. But in November 1985, the eruption of the Nevado del Ruiz volcano created a lahar that obliterated the town.
JEFFREY MARSO/USGS

In 1985, the Nevado del Ruiz volcano in Colombia erupted. Pyroclastic flows burst from the volcano. These melted glaciers on the mountain's slopes. The several lahars that this created poured down the mountain at high speed. Nighttime lahars swept through the town of Amero with no warning, leaving 20,000 dead.

Avalanche

Large amounts of snow sometimes break off a mountain or hill to tumble downward — often without warning. These avalanches can be triggered when something disturbs a snowpack, such as a skier or an earthquake. The most dangerous avalanches, known as dry slab avalanches, occur when a very cold and very dry snowpack destabilizes. The unstable snow now rushes downhill, fanning out and picking up more snow along the way, which further feeds the avalanche.



A powder snow avalanche in the Himalayas, near Mount Everest, in 2006.
CHAGAI/WIKIMEDIA COMMONS

Data:

Disaster	slowest speed (kph)*	fastest speed (kph)*
lava (andesite)	0	2
lava (basalt)	<1	10
human	5	32
car	0	241
mudslide	16	56
avalanche (dry slab)	30	130
landslide	88.5	161
lahar	3.5	80.5
pyroclastic flow	80.5	724

*All speeds are presented in kilometers per hour (kph) and are estimates that can vary depending on situation and topography.

Data Dive:

1. Use the data to create a graph or chart. Be sure to use appropriate labels.
2. What is the most surprising thing about these data?
3. Convert the table from kilometers per hour to miles per hour.
4. Could you escape a lava flow on foot? What about in a car? (Hint: Take into account where these events might occur.)
5. Which three disasters would you have the most chance of escaping on foot?
6. Which disasters would you have the most chance of escaping in a car?

Analyze This! *explores science through data, graphs, visualizations and more. Have a comment or a suggestion for a future post? Send an email to* sns@sciencenews.org.

CITATIONS

Safety resources:

Ready.gov Avalanche
Popsci.com What to do if you get caught in an avalanche
Ready.gov Volcanoes
Fema.gov, Be Prepared for a Landslide, May 2018
USGS, Landslide Preparedness

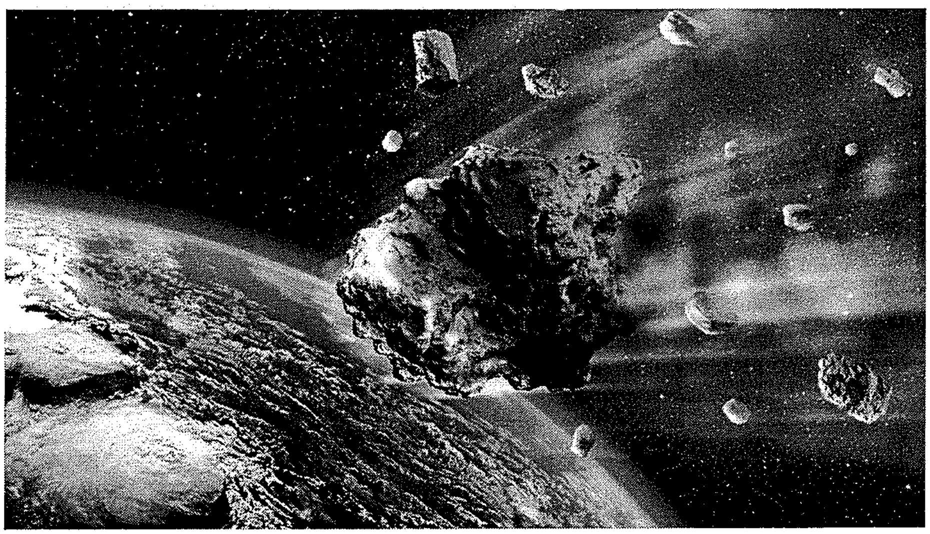
Citations:

Website: USGS Volcano Hazards Program, Lava Flows
Website: USGS Volcano Hazards Program, Pyroclastic Flows
Website: USGS, The landslide handbook—A guide to understanding landslides
Website: Michigan Tech Department of Geological and Mining Engineering and Sciences, Lahars
Website: Avalanche.org, Avalanche

EARTH

Death by asteroid may come in unexpected ways

Surprise: Winds and shock waves would claim the most lives



Here's an artist's rendering of a large asteroid breaking up as it begins to plow through Earth's atmosphere. If it lands it could do a lot of damage, but how much would depend on its size and collision site.
PATPACK223/ISTOCKPHOTO

By Thomas Sumner
May 9, 2017 at 6:10 am

Every now and then a *really* big rock from space comes careening through Earth's atmosphere. Depending on its size, angle of approach and where it lands, few people may notice — or millions could face a risk of imminent death.

Concern about these occasional, but potentially catastrophic, events keeps some astronomers scanning the skies. Using all types of technologies, they're scouting for a killer asteroid, one that could snuff out life in a brief but dramatic cataclysm. They're also looking for ways to potentially deter an incoming biggie from an earthboard path.

But if a big space rock were to make it to Earth's surface, what could people expect? That's a question planetary scientists have been asking themselves — and their computers. And some of their latest answers might surprise you.

For instance, it's not likely a tsunami will take you out. Nor an earthquake. Few would need to even worry about being vaporized by the friction-heated space rock. No, gusting winds and shock waves set off by falling and exploding space rocks would claim the most lives. That's one of the conclusions of a new *computer model*.

It investigated the likely outcomes of more than a million possible asteroid impacts. In one extreme case, a space rock 200 meters (660 feet) wide whizzes 20 kilometers (12 miles) per second into London, England. This smashup would kill more than 8.7 million people, computers estimate. And nearly three-quarters of those expected to die in that doomsday scenario would lose their lives to winds and shock waves.

Explainer: What are Asteroids?

Clemens Rumpf and his colleagues reported this online March 27 in *Meteoritics & Planetary Science*. Rumpf is a planetary scientist in England at the University of Southampton.

In a second report, Rumpf's group looked at 1.2 million potential smashups. Here, the asteroids could be up to 400 meters (1,300 feet) across. Again, winds and shock waves were the big killers. They'd account for about six in every 10 deaths across the spectrum of asteroid sizes, the computer simulations showed.

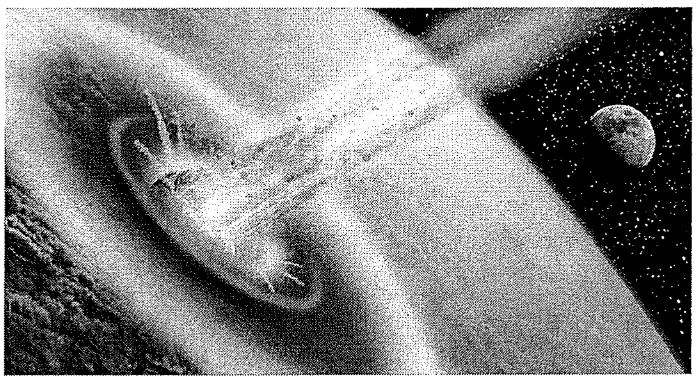
Many previous studies had suggested tsunamis would be the top killer. But in these analyses, those killer waves claimed only around one in every five of the lives lost.

Explainer: What is a tsunami?

Even asteroids that explode before reaching Earth's surface can generate high-speed wind gusts, shock waves of pressure in the atmosphere and intense heat. Space rocks big enough to survive the descent pose far greater risks. They can spawn earthquakes, tsunamis, flying debris — and, of course, gaping craters.

"These asteroids aren't an everyday concern," Rumpf observes. Yet clearly, he notes, the risks they pose "can be severe." His team describes just how severe they could be in a paper posted online April 19 in *Geophysical Research Letters*.

Previous studies typically considered individually each possible effect of an asteroid impact. Rumpf's group instead looked at them collectively. Quantifying the estimated hazard posed by each effect, says Steve Chesley, might one day help some leaders make one of the hardest calls imaginable — work to deflect an asteroid or just let it hit. Chesley is a planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. (NASA stands for National Aeronautics and Space Administration.) Chesley was not involved with either of the new studies.



Computer simulations reveal that most of the deaths caused by an earthbound asteroid (illustrated) would come from gusting winds and shock waves.
PUCHAN/ISTOCKPHOTO

Land hits would pose the biggest risks

The 1.2 million simulated asteroid impacts each fell into one of 50,000 scenarios. They varied in location, speed and angle of strike. Each scenario was run for 24 different asteroids. Their diameters ranged from 15 to 400 meters (50 to 1,300 feet). About 71 percent of the Earth is covered by water, so the simulations let asteroids descend over water in nearly 36,000 of the scenarios (about 72 percent).

The researchers began with a map of human populations. Then they added in data on the likely energy that a falling asteroid would unleash at a given site. Existing casualty data from studies of extreme weather and nuclear blasts helped the scientists calculate death rates at different distances from a space rock's point of impact. All that was then combined into the computer model to gauge how deadly each modeled impact would likely be.

Explainer: What is a computer model?

The most deadly one would have killed around 117 million people. Many asteroid hits, however, would pose no threat, the simulations found. More than half of asteroids smaller than 60 meters (200 feet) across caused zero deaths. And no asteroids smaller than 18 meters (60 feet) across led to deaths. Rocks smaller than 56 meters (180 feet) wide didn't even make it to Earth's surface before exploding in the atmosphere. Those explosions could still be deadly, though. They would generate intense heat that could burn skin, the team found. They also would set off high-speed winds that would hurl debris and trigger pressure waves that could rupture internal organs.

Where asteroids fell into the ocean, tsunamis became the dominant killer. The giant waves accounted for between seven and eight of every 10 deaths from these asteroid splashdowns. Still, the casualties from water impacts were only a fraction as high as those due to asteroids that smashed into land. (That's because asteroid-generated tsunamis are relatively small and quickly lose steam as they plow through the ocean, the computer model showed.)

Heat, wind and shock waves topped the impacts from land smashups, especially if they hit near large population centers.

Bottom line: For all asteroids big enough to hit Earth's surface, heat, wind and shock waves caused the most casualties overall. Other land-based effects, such as earthquakes and blast debris, resulted in fewer than 2 percent of total deaths, the computer projected.

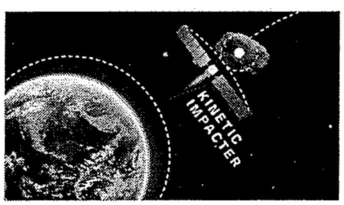
Large asteroid impacts are rare. Here, a 20-meter- (66-foot-) wide meteor left behind a smoky trail across the sky above Chelyabinsk, Russia, in 2013. Space rocks that big only strike Earth about once every 100 years.

Protecting Earth

While asteroids have the potential to kill, deadly impacts are rare, Rumpf says. Most space rocks that bombard Earth are tiny. They burn up in the atmosphere, causing little harm.

Consider the rock that lit up the sky in 2013 and shattered windows around the Russian city of Chelyabinsk. Such 20-meter- (66-foot-) wide meteors strike Earth only about once a century. Far bigger impacts are capable of wiping out species. An asteroid at least 10 kilometers (6 miles) wide that smashed into Earth 66 million years ago has been blamed for wiping out the dinosaurs. Such mega-events are especially rare, however. They may occur only once every 100 million years or so.

Today, astronomers scan the skies with automated telescopes scouting for those potential killer space rocks. So far, they've cataloged 27 percent of those 140 meters (450 feet) or larger whizzing through our solar system.



If a killer asteroid were detected, heading for Earth, NASA has plans for developing a spacecraft to slam into the space rock, deflecting it to a path that would miss us. Such a system is, however, at least some 20 years away. Once it is available, it might require a warning time of a year or two to target and redirect small asteroids.

Other scientists are analyzing how they might divert or catch an earthbound asteroid. Proposals include whacking the asteroid like a billiard ball with a high-speed spacecraft. Or perhaps part of the asteroid's surface might be fried with a nearby nuclear blast. The vaporized material should propel the asteroid away like a jet engine.

Understanding the potential threats — and options available to deal with them — could offer guidance on how people should react to a warning that an asteroid was heading Earth's way. It might help people decide whether it's better to evacuate or shelter in place — or even mobilize space troops to try and divert the asteroid.

"If the asteroid's in a size range where the damage will be from shock waves or wind, you can easily shelter in place," Chesley says. He says this should work for even a large population. But if the heat generated as it falls, impacts or explodes "becomes a bigger threat," he says "and you run the risk of fires — then that changes the response of emergency planners."

Making such tough calls will require more information about what the asteroids are made of, says Lindley Johnson. He serves as the "planetary defense" officer for NASA in Washington, D.C. Those properties in part determine an asteroid's potential for bringing devastation. Rumpf's team couldn't consider how those characteristics might vary, Johnson says. But several asteroid-bound missions are planned to provide some answers to such questions.

For now, making decisions based on the average deaths presented in the new study could be misleading, warns Gareth Collins. He's a planetary scientist at Imperial College London.

A 60-meter- (200-foot-) wide incoming space rock, for instance, would cause an average of 6,300 deaths in the simulations. But just a handful of high-fatality events inflated that average. These included one scenario that resulted in more than 12 million casualties. In fact, most space rocks of that size struck away from population centers in the simulations. And they killed no one. "You have to put it in perspective," he advises.

Death from the skies

A new project simulated 1.2 million asteroid strikes on Earth. That let scientists estimate how many deaths could result from each effect of a falling space rock. (Averages for three of the classes of asteroids that were evaluated are shown in the interactive below. People who could have died from two or more effects are included in multiple columns.)

Click the graphic to explore the asteroid simulation data.

Source: C.M. Rumpf et al/Geophysical Research Letters *2017*

Asteroid effect
Filter
Asteroid size
Cratering
Showing All Values
Ejected material
Search
Shock wave
All Values in The Database
Show Quick Filter Context Menu
50 meters
100 meters
400 meters

Undo

H. THOMPSON AND T. TIBBITTS

CITATIONS

Journal: C.M. Rumpf, H.G. Lewis and P.M. Atkinson. Asteroid impact effects and their immediate hazards for human populations. *Geophysical Research Letters*, in press, 2017. doi: 10.1002/2017GL073191.

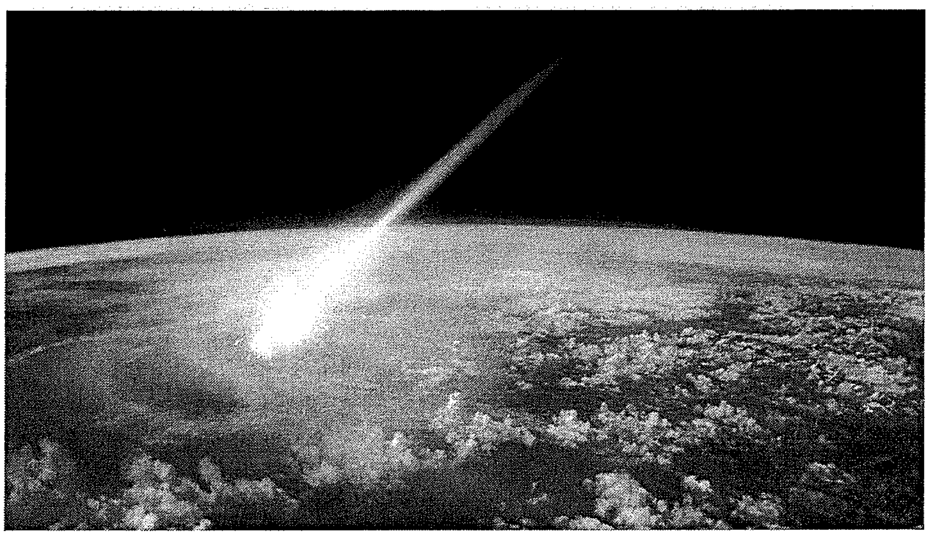
Journal: C.M. Rumpf, H.G. Lewis and P.M. Atkinson. Population vulnerability models for asteroid impact risk assessment. *Meteoritics & Planetary Science*. Published online March 27, 2017. doi: 10.1111/maps.12861.

Questions for 'Death by asteroid may come in unexpected ways'

Wordfind (click here)

CLASSROOM QUESTIONS

Questions for 'Death by asteroid may come in unexpected ways'



The actual impact of an asteroid hitting Earth would kill far fewer people than other effects, new studies show.
SOLARSEVEN/ISTOCKPHOTO

By Science News for Students
May 9, 2017 at 6:05 am

To accompany feature "Death by asteroid may come in unexpected ways"

SCIENCE

Before Reading:

1. What is the difference between an asteroid, a meteor and a meteorite? Consult a dictionary or the internet if you don't know the answer.

2. What might happen if an asteroid were to hit the Earth? What if that impact happened near your home? What do you think would happen to you?

During Reading:

1. What effect of an asteroid impact would likely prove most deadly?

2. In a scenario in which a huge space rock hits London, England, how many people would die, according to new computer simulations?

3. Why are asteroids that explode in the air still considered potentially dangerous?

4. Why did the researchers make sure that about 72 percent of their simulations had an asteroid falling into water, and not land?

5. What are three factors that went into the researchers' simulations of asteroid hits that helped them determine how many human deaths to expect from an asteroid impact?

6. In the simulations, what happened to incoming space rocks fewer than 56 meters (180 feet) across?

7. What are the three effects most likely to kill people if an asteroid hit Earth's surface?

8. Why are deadly asteroid impacts rare?

9. An asteroid at least 10 kilometers (6 miles) wide has been blamed for wiping out the dinosaurs. How often does a rock that big hit Earth?

10. Describe three ways that nations might respond to news that an asteroid was headed toward Earth.

After Reading:

1. You hear a news report that an asteroid is headed toward your city. There is no description, though, of how big the rock is. How do you respond? Explain your answer using information from the story.

2. Astronomers have begun cataloging large space rocks that could potentially hit Earth. What size of rocks should they concentrate on? Use information from the story to explain your answer.

MATHEMATICS

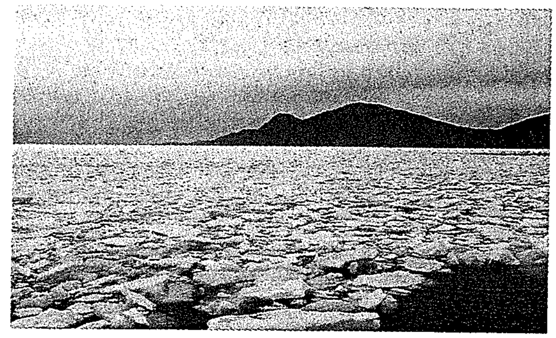
1. In one asteroid-impact scenario, a space rock 200 meters (660 feet) across hits London, England, killing 8.7 million people. Using information from the story, determine how many of those people would die from wind and shock wave. Show your work.

68 Short and Long Term Changes

Key Idea: The Earth is dynamic (constantly changing). Some of these changes occur over a short time, others take many years or even millennia.

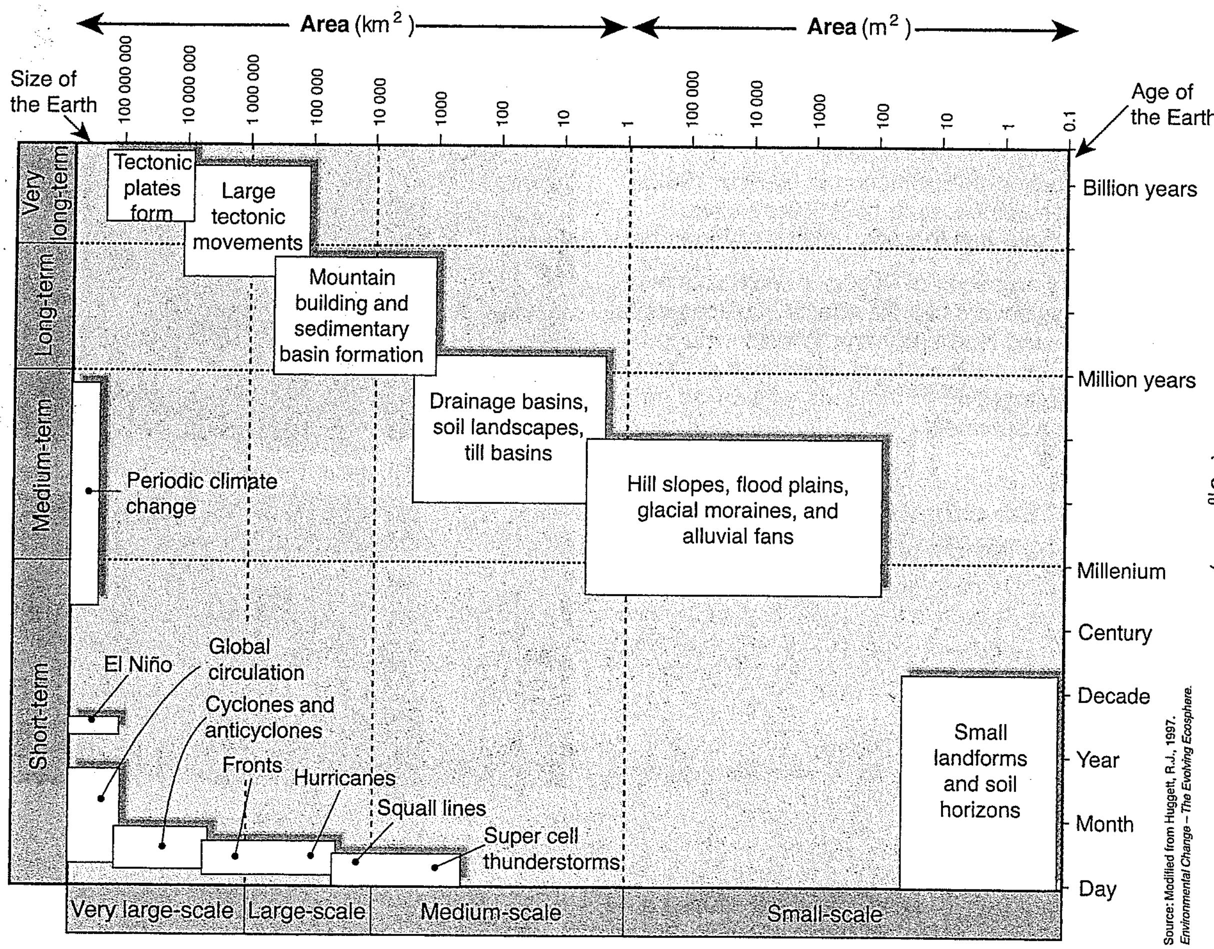
Environmental changes come from three sources: the biosphere, geological forces (crustal movements and plate tectonics), and cosmic forces (the movement of the Moon around the Earth and the Earth and planets around the Sun).

- All three forces can cause cycles, steady states, and trends (directional changes) in the environment. Environmental trends (such as climate cooling) cause long term changes in communities.
- Some short term cycles, such as tides or day and night, may influence local environmental patterns. Others, e.g. seasons, can cause large scale environmental changes such as the advance and retreat of the polar sea-ice every winter and summer.



Every winter, the freezing of the sea around Antarctica almost doubles the continent's effective size.

Time scale and geographic extent of environmental change



1. Identify the geologic event that is the largest and takes the longest amount of time: ______________________

____

2. Identify two very large scale events that take a relatively short amount of time to occur: ______________________

____

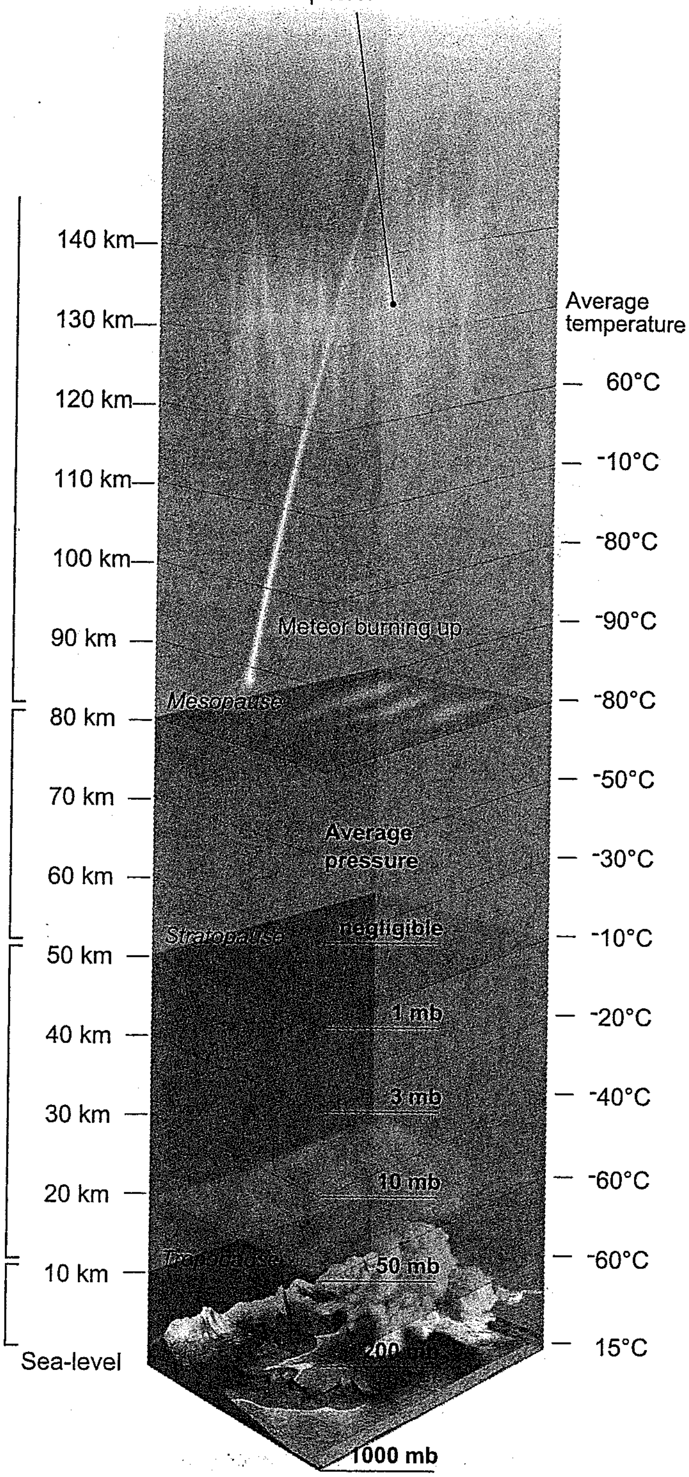
3. How long does it take for a soil landscape to form? ______________________

____

Key Idea: The atmosphere is divided into layers based on temperature. The atmosphere helps to carry energy from the Sun around the globe.

- The Earth's atmosphere is a layer of gases surrounding the globe and retained by gravity. It contains roughly 78% nitrogen, 20.95% oxygen, 0.93% argon, 0.038% carbon dioxide, trace amounts of other gases, and a variable amount (average around 1%) of water vapor.
- This mixture of gases, known as air, protects life on Earth by absorbing ultraviolet radiation and reducing temperature extremes between day and night. The atmosphere consists of layers around the Earth, each one defined by the way temperature changes within its limits.
- The outermost troposphere thins slowly, fading into space with no boundary. The air of the atmosphere moves in response to heating from the Sun and, globally, the atmospheric circulation transports warmth from equatorial areas to high latitudes and returning cooler air to the tropics.

Aurora caused by collisions between protons and electrons from the Sun and the nitrogen and oxygen atoms in the atmosphere.



Thermosphere

This layer extends as high as 1000 km. Temperature increases rapidly after about 88 km.

Mesosphere

Temperature is constant in the lower mesosphere, but decreases steadily with height above 56 km.

Stratosphere

Temperature is stable to 20 km, then increases due to absorption of UV by the thin layer of ozone.

Troposphere

Air mixes vertically and horizontally. All weather occurs in this layer.

1. Describe two important roles of the atmosphere: ______________________

____

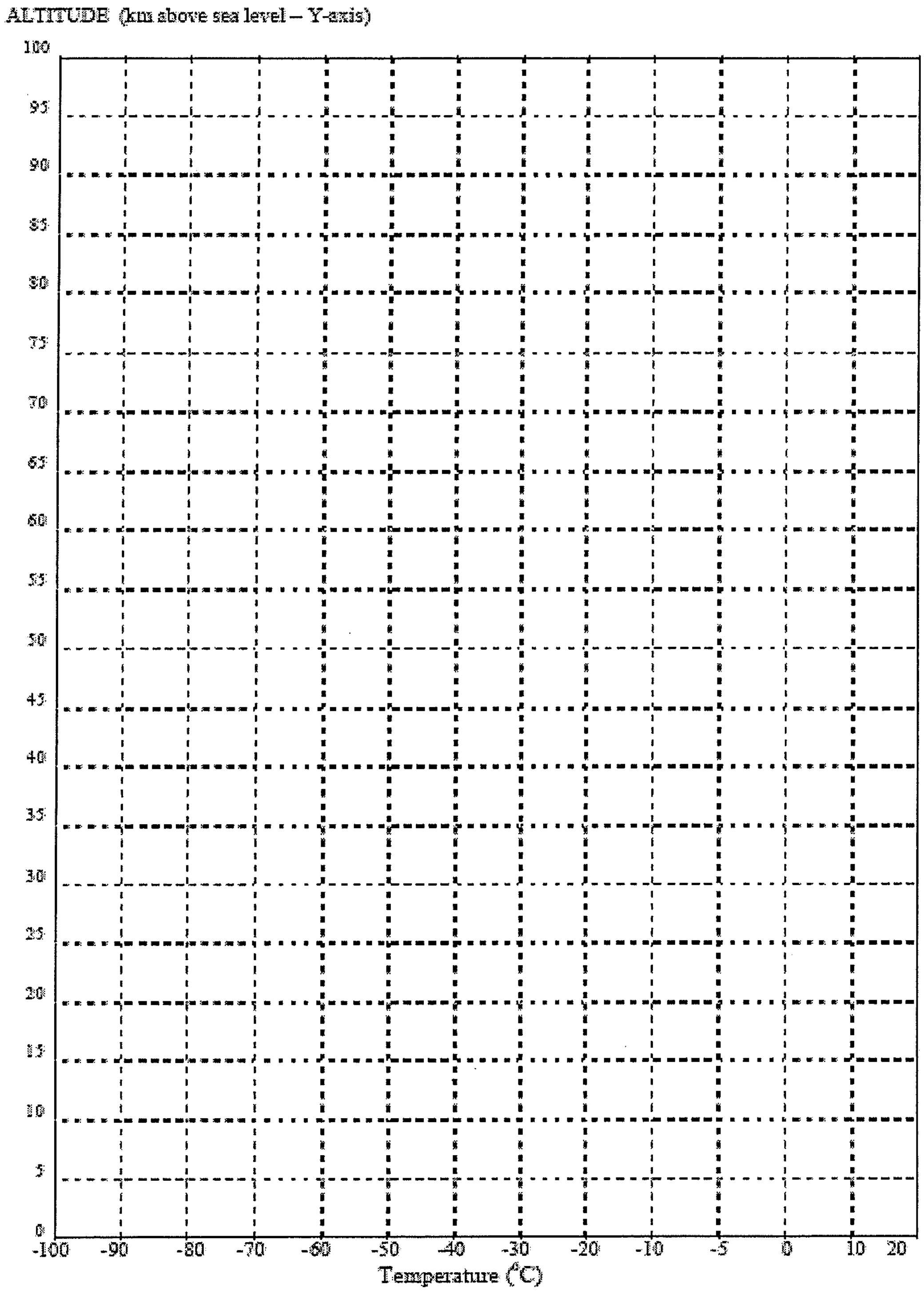
2. What causes aurora? ______________________

____

ISBN: 978-1-927309-37-7

Graph the temperature of the atmosphere as it increases in altitude using the picture and data from the previous page

Graph of Temperature at Various Altitudes



3. At which layer of the atmosphere do meteors burn up? ____________________ Look at the temperature at this layer, why would meteors burn at this temperature?____

4. Which layer of the atmosphere contains clouds and weather? ______________________

5. If any airplane flies just above the clouds, about how high and which layer of the atmosphere is an airplane flying?

Altitude ____________________ Layer _____________

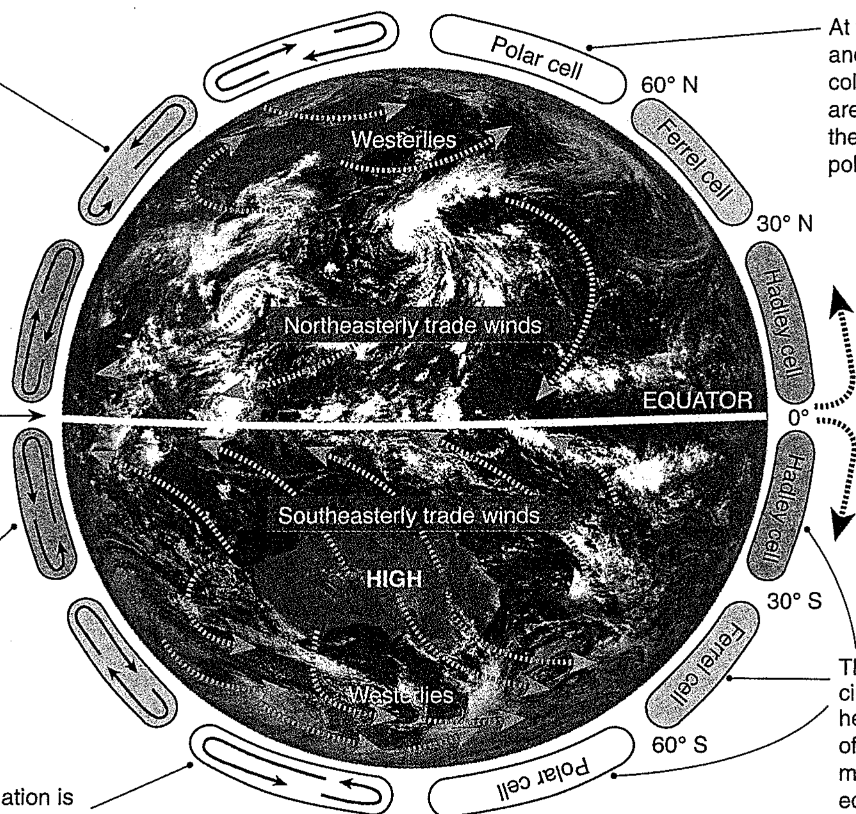
6. Look up the ozone layer, which layer is the ozone layer a part of? ____

94 Atmospheric Circulation and Climate

Key Idea: The rotation and differential heating of the Earth has a major effect on the circulation of the planet's atmosphere and therefore climate.

Atmospheric circulation and the tricellular model

▶ High temperatures over the equator and low temperatures over the poles, combined with the rotation of the Earth, produce a series of separated atmospheric cells that circulate at specific areas in the atmosphere. This model of atmospheric circulation, with three cells in each hemisphere, is known as the **tricellular model**.



Rising mid-latitude air divides, flowing to the poles and the equator forming the **Ferrel cells.** These mid-latitudinal cells produce westerly winds.

In the tropics, wind blowing towards the equator as part of the Hadley cells is deflected (by the Coriolis effect) and forms the northeasterly and southeasterly trade winds.

Air within the **Hadley cells** rises moist at the equator and subsides dry at the tropics.

Polar air circulation is caused by subsiding air at the poles flowing towards the equator.

At the poles, air cools and descends as a cold, dry high pressure area, moving away from the pole to produce the polar easterlies.

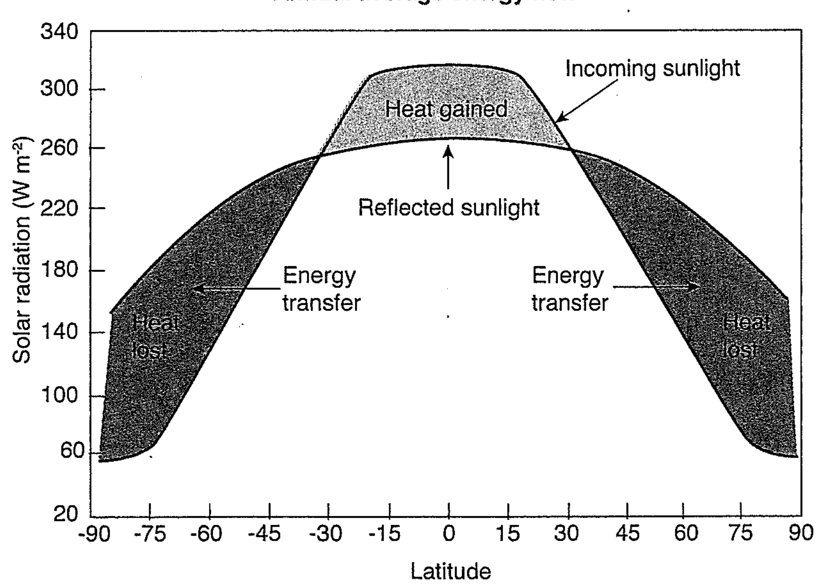
Warm air rises at lower latitudes and moves poleward through the upper troposphere at both the north and south poles.

The atmospheric circulation in each hemisphere consists of three cells (at polar, mid-latitude, and equatorial regions). These cells, produce belts of prevailing winds around the world.

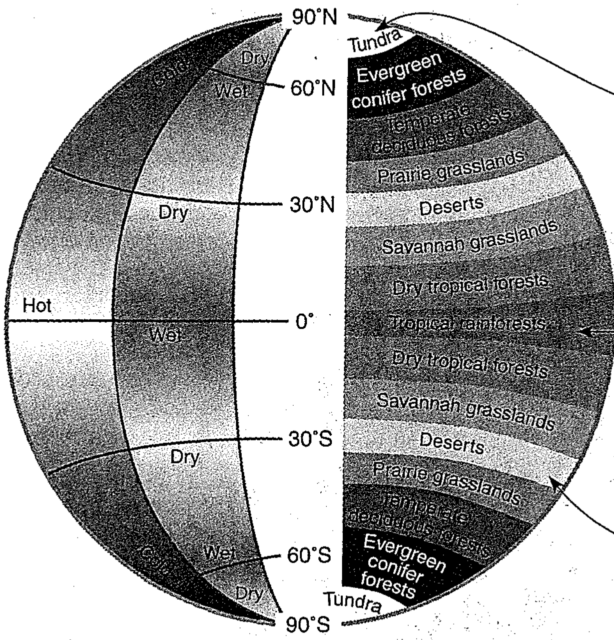
▶ The energy gained from solar radiation becomes progressively less from the equator to the poles. Heat gained at the tropics is transferred to cooler regions by atmospheric circulation, producing a more even spread of temperatures over the globe than would otherwise occur if there was no atmosphere. Similarly heat gained by the oceans also transfers heat about the globe. The ice caps of the poles reflect so much of the sunlight they receive that they produce a permanently cold climate.

▶ If there was no heat flow, the poles would be about 25°C cooler and the equator about 14° C warmer.

Annual average energy flow



As the air travels away from the equator its cools and descends as dry air. The division of atmospheric circulation into three separate cells in each hemisphere produces climatic conditions that are mirrored on each side of the equator. These conditions produce **biomes**, large areas with the same climatic conditions and vegetation characteristics. Tropical rainforests are one such biome and are found circling the equator, bordered by deserts, then temperate forests and finally polar deserts.



Cool dry air descending at the poles produces polar deserts. Because water remains locked up as ice, these are some of the driest places on Earth.

Warm air rising at the equator carries moisture with it, which falls as rain in often violent rainstorms. The warm wet climate produces the most biodiverse regions on Earth.

Dry air descending beyond the tropics strips moisture from the land as it travels back to the equator. Deserts have the most extreme temperature changes because there is no moisture or clouds to regulate the heat.

1. Identify the latitudes that each of the atmospheric cells lie between:

   (a) Polar cell: ______________________________

   (b) Ferrel cell: ______________________________

   (c) Hadley cell: ______________________________

2. Identify the cell that produces mid latitude westerlies: ______________________________

3. Which cell is responsible for producing the trade winds: ______________________________

4. How does the tricellular model explain why the tropics are hot and wet and the deserts to either side of the tropics are hot and dry:

   ____

   ____

   ____

   ____

   ____

5. State the latitude at which the incoming energy from sunlight equals the energy lost? ______________________________

6. Using the diagram above, identify the approximate latitude of each of the following biomes and describe their climate:

   (a) Evergreen conifer forest: ______________________________

   (b) Temperate deciduous forest: ______________________________

   (c) Tropical rainforest: ______________________________

   (d) Deserts: ______________________________

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