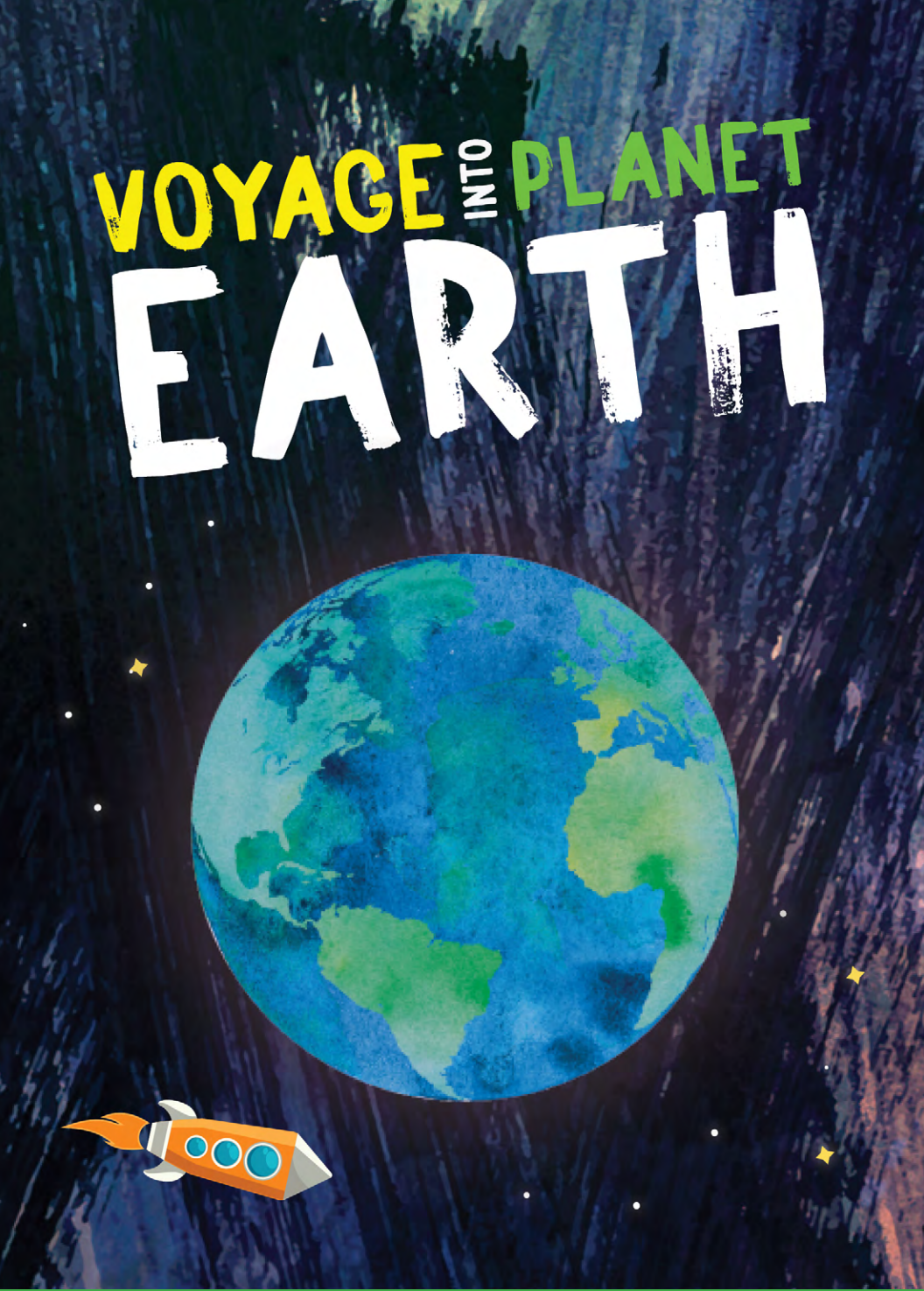
# VOYAGE INTO PLANET EARTH



National Science Foundation
WHERE DISCOVERIES BEGIN

DO YOU EVER WONDER

## WHAT'S BENEATH YOUR FEET?
## HOW DEEP DOES THE EARTH GO, AND WHAT WOULD YOU FIND?

Scientists know more about certain distant galaxies than they do about what lies miles beneath your feet.

Scientists have explored many areas of the Earth's crust, but that just scratches the surface in understanding the planet.

It may seem like the Earth is made up of one big, solid rock. It's really made up of a number of parts, some are constantly moving!

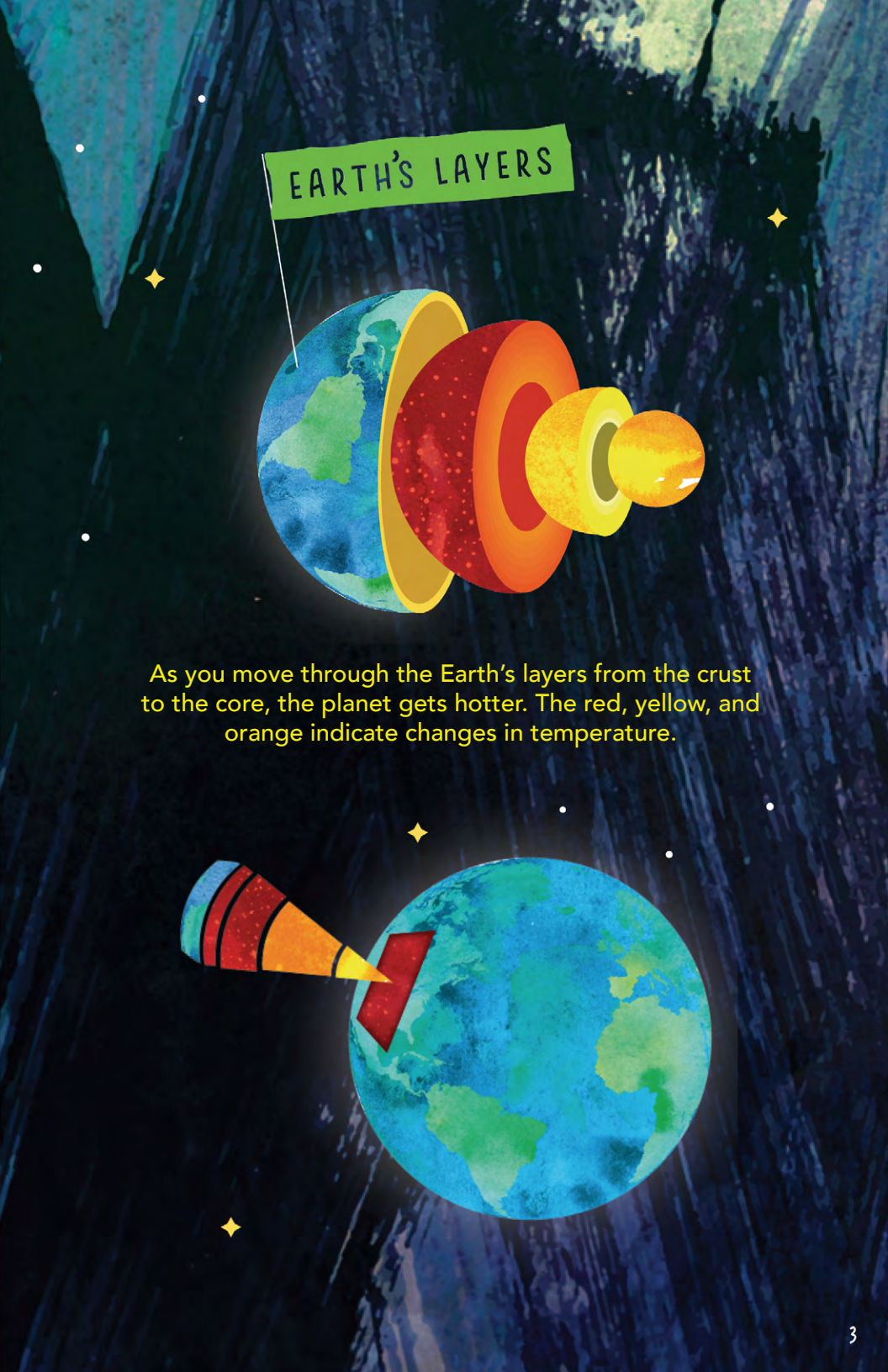
Understanding the planet is challenging because it changes all the time.

Throughout Earth's history, these changes have resulted in the formation of distinctive layers.

The Earth has four layers, which are stacked like the layers on an onion. As you peel back the layers, you find the crust, mantle, outer core, and inner core. You can only see the top layer, the crust, which sustains life—plants, animals, and people!

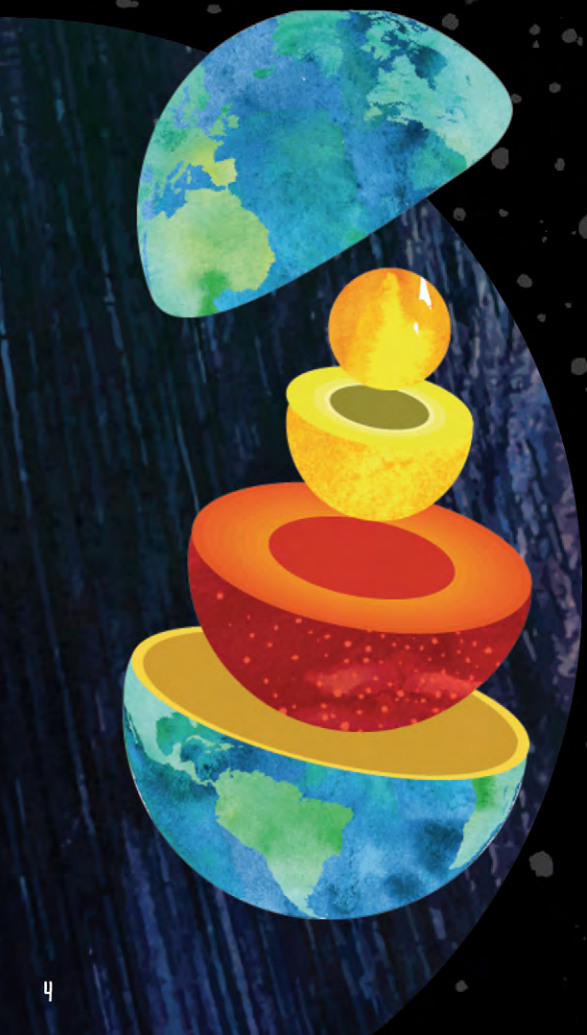
LET'S GO

ON A VOYAGE INTO PLANET EARTH—FROM THE CRUST INTO THE INNER CORE—AND EXPLORE EACH LAYER.




As you move through the Earth's layers from the crust to the core, the planet gets hotter. The red, yellow, and orange indicate changes in temperature.

# THE EARTH'S CRUST

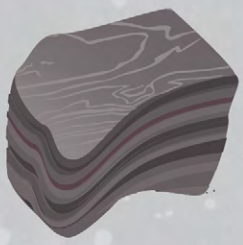


The first stop on our journey is the crust. It is the relatively thin, rocky outer skin that you stand on top of every day. Scientists have spent a lot of time studying the outer crust of the planet. The surface of the Earth is divided into 30 percent land and 70 percent ocean.

THE CRUST IS MADE OF ROCK AND VARIES BETWEEN 3 TO MORE THAN 43 MILES (4.8 TO 69 KILOMETERS) THICK.

Even though this layer seems thick, it's nothing compared to the other three layers. If the Earth was an apple, the crust would only be as thick as the skin! The crust is the only layer of the Earth that can be studied through samples collected by drilling. Scientists map the interior layers of the planet via other techniques, such as watching how seismic waves from earthquakes bend, reflect, or change velocity.

# HOW LOW CAN WE GO?

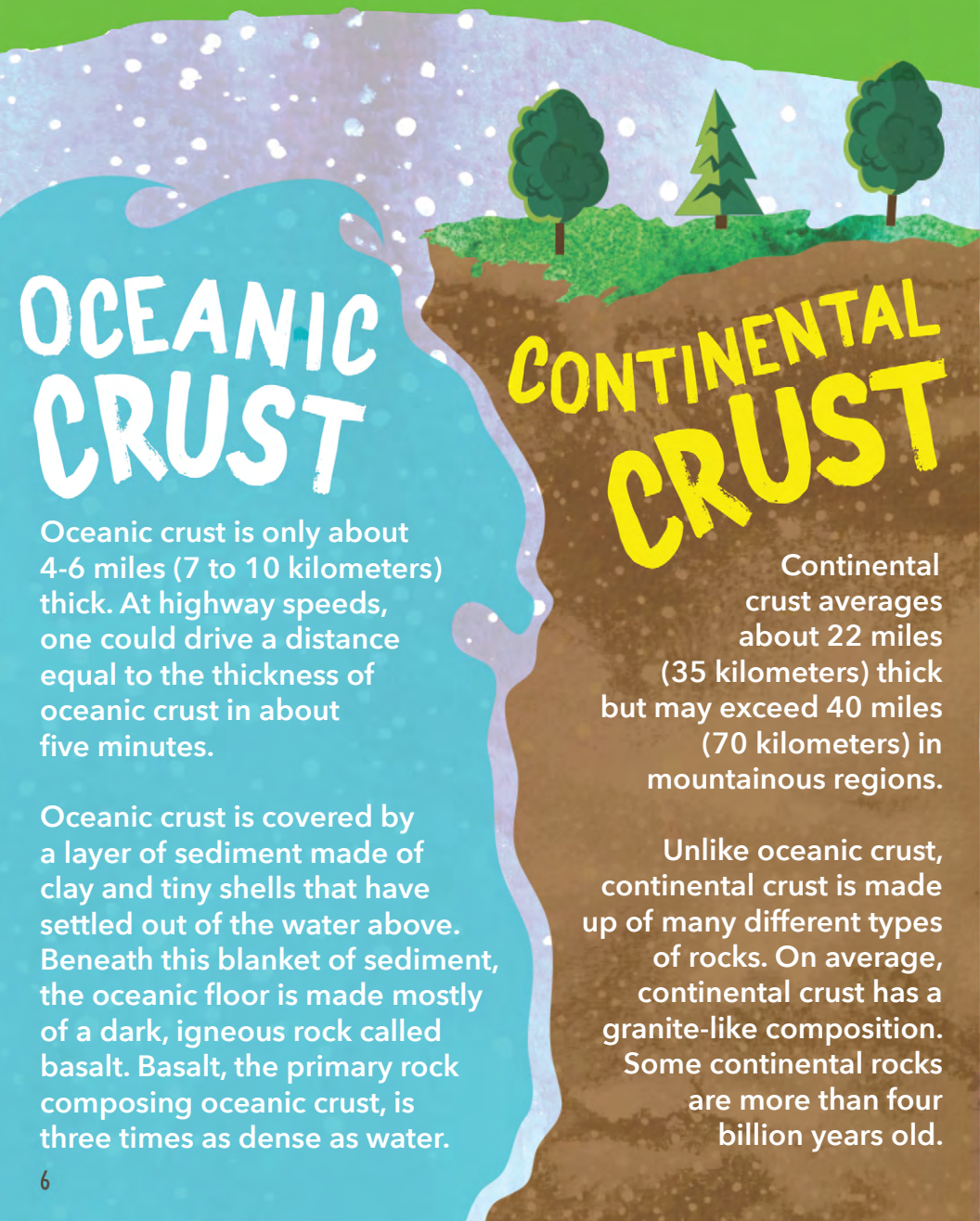


Like probes sent into outer space, scientific drilling is a technology used to obtain samples from places people cannot reach. Drill bits are cutting tools used to create holes and remove material. Scientists have designed four-headed drill bits to study the Earth. These drill bits are attached to a drill, which powers them to cut, typically by rotation.

## HOW FAR DOWN HAVE HUMANS DRILLED?

The Kola Superdeep Borehole in Russia reached 7.6 miles (12.2 kilometers) and is the deepest humans have penetrated in the Earth's crust. It took almost 20 years to reach that depth, which is only about halfway through the crust. Four miles down, scientists discovered interesting fossils of microscopic plankton. This borehole was abandoned after drillers encountered higher-than-expected temperatures. The extreme temperatures wrecked the drilling equipment.

SCIENTISTS DISTINGUISH BETWEEN TWO FUNDAMENTALLY DIFFERENT TYPES OF CRUST—OCEANIC CRUST, WHICH COMPOSES THE OCEAN FLOOR, AND CONTINENTAL CRUST, WHICH MAKES UP CONTINENTS. CONTINENTAL CRUST FORMS THE GROUND YOU WALK ON EVERY DAY. BOTH OF THESE TYPES SHARE THE WORD CRUST, BUT THE SIMILARITY ENDS THERE.



## OCEANIC CRUST

Oceanic crust is only about 4-6 miles (7 to 10 kilometers) thick. At highway speeds, one could drive a distance equal to the thickness of oceanic crust in about five minutes.

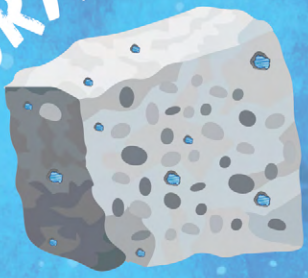
Oceanic crust is covered by a layer of sediment made of clay and tiny shells that have settled out of the water above. Beneath this blanket of sediment, the oceanic floor is made mostly of a dark, igneous rock called basalt. Basalt, the primary rock composing oceanic crust, is three times as dense as water.

## CONTINENTAL CRUST

Continental crust averages about 22 miles (35 kilometers) thick but may exceed 40 miles (70 kilometers) in mountainous regions.

Unlike oceanic crust, continental crust is made up of many different types of rocks. On average, continental crust has a granite-like composition. Some continental rocks are more than four billion years old.

## GRANITE



is abundant in continental crust. The large crystals of light-colored minerals in granite result from slow cooling of molten rock deep beneath the surface.

## BASALT

is rich in dark minerals. Rapid cooling of molten rock at the planet's surface is responsible for the rock's microscopically small crystals.

## FUN FACT

**DID YOU KNOW? OXYGEN IS THE MOST ABUNDANT ELEMENT IN THE EARTH'S CRUST.**

There are only a few special places in the world where you can see exposed oceanic crust.

Many of these places are "hot spot" island arcs–including the Galapagos and Hawaiian Islands. Iceland is another example; new oceanic crust forms there very slowly every day.

# TECTONIC PLATES


## PLATE BOUNDARIES

Large pieces of both types of crust, called tectonic plates, slide around on top of the mantle. (The mantle will be the next stop on our journey through Earth). These plates fit together like a jigsaw puzzle. They usually move along slowly—no more than a couple of inches per year. They collide to build mountains or break apart to form new seafloor. For example, when two pieces of continental crust push against each other, they don't have anywhere to go but up—making enormous mountains such as the Himalayas! Earthquakes and volcanic activity also happen because of movement along plate boundaries.

# FUN FACT

About 300 million years ago, the Earth did not have seven continents. Instead, there was one massive supercontinent called Pangaea. Because tectonic plates slowly slide and move, Pangaea eventually broke up into the continents you see today.


PERMIAN
225 MILLION YEARS AGO

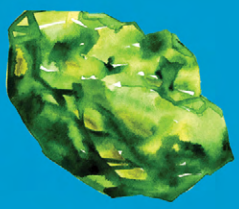

TRIASSIC
200 MILLION YEARS AGO


JURASSIC
135 MILLION YEARS AGO


CRETACEOUS
65 MILLION YEARS AGO


PRESENT DAY

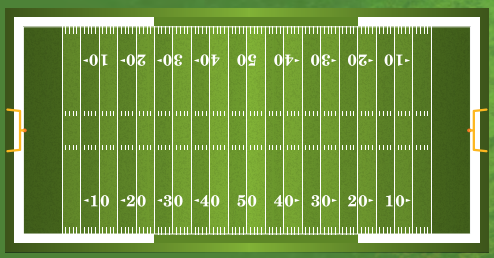
# MANTLE



OUR NEXT STOP ON OUR JOURNEY TO THE EARTH'S CORE IS THROUGH THE SECOND AND LARGEST LAYER OF THE EARTH: THE MANTLE.

The mantle makes up an estimated 70 percent of the Earth's mass and a whopping 85 percent of its volume.

THIS LAYER IS 1,800 MILES (2,900 KILOMETERS) THICK—THE EQUIVALENT OF MORE THAN 31,680 FOOTBALL FIELDS LINED UP END TO END!




The boundary and mantle represents a drastic change in chemical composition. In contrast to the crust, the mantle consists of a rock called peridotite. Peridotite, although rare at the Earth's surface, is actually the most abundant rock on our planet. It makes this layer appear green in color.

THE MANTLE IS DIVIDED INTO TWO LAYERS: THE UPPER AND LOWER MANTLE.

The upper mantle extends from the crust-mantle boundary down to a depth of 410 miles (660 kilometers). The lower mantle extends down farther from 410 miles (660 kilometers) to 1,800 miles (2,900 kilometers). An increase in pressure caused by the weight of the rock pressing down from above, densifies the mantle.

The mantle is so hot that it flows under pressure, like soft road tar. But, don't worry! If drillers one day pierce the mantle, hot molten rock will not surge out of the hole like a volcanic eruption. Magma in the mantle flows as slowly as the growth rate of a fingernail—moving at a rate of less than 6 inches or 15 centimeters a year. "Flow" here does not mean liquid. Over long periods of time, mantle rock can change shape without breaking, like candle wax.

Overall, the temperature of the mantle increases the deeper you go; but, the temperature also varies a lot at locations at the same depth. The warmer regions are less dense, while the cooler regions are more dense. As hot rock rises from the depths and cooler rock descends, very slow-moving convection currents are created. Warm mantle gradually flows upward, while denser, cooler mantle sinks.

# WHAT'S THE DIFFERENCE BETWEEN MAGMA AND LAVA?

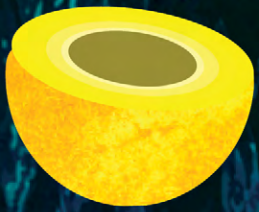
## LOCATION. LOCATION. LOCATION.

Both lava and magma result from rock superheated to the point of becoming viscous and molten. The location is key. Magma is molten rock still located within the Earth. When magma reaches the surface and erupts from a volcano, it officially becomes lava.

## FUN FACT

ALTHOUGH OTHER GEMSTONES FORM IN THE EARTH'S CRUST, DIAMONDS AND PERIDOTS FORM IN THE MANTLE.

# OUTER CORE



AS YOU CONTINUE ON YOUR JOURNEY, THE EARTH'S THIRD LAYER DOWN IS THE OUTER CORE. THIS LAYER—A SHELL OF LIQUID IRON ALLOY—IS ABOUT 1,400 MILES (2,300 KILOMETERS) THICK.

The extremely high temperatures between 4,000 to 9,000 degrees Fahrenheit (4,400 to 5,000 degrees Celsius) keep the metals in the outer core in a liquid state. It stays as a liquid because the temperature is so high, it cannot form into a solid.

## HOW DO SCIENTISTS KNOW THE OUTER CORE IS LIQUID?

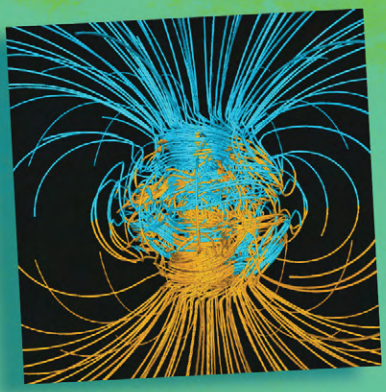
Researchers have never sampled the planet's mantle or core directly. The composition of the Earth's interior is determined by analyzing seismic waves from earthquakes. As seismic waves made up of energy penetrate the planet, they change speed, and are bent and reflected as they move through different areas or layers with different composition and properties. Earthquake monitoring stations around the world detect and record seismic wave activity.

STUDIES OF SEISMIC WAVES HAVE REVEALED THE EXISTENCE OF SUBLAYERS IN THE CORE (OUTER CORE AND INNER CORE) AND THE MANTLE (UPPER MANTLE AND LOWER MANTLE).

# DID YOU KNOW?

**THE MOVEMENT OF METALLIC IRON WITHIN THE OUTER CORE GENERATES EARTH'S MAGNETIC FIELD.**

When the liquid iron of the outer core circulates around the solid iron of the inner core, a magnetic field forms. This magnetic field protects the planet from the Sun's solar radiation.



**NSF-FUNDED RESEARCHERS HAVE VISUALIZED MANY FEATURES OF EARTH'S MAGNETIC FIELD,** including magnetic-field reversal, a recognized phenomenon that has happened many times over Earth's history.

## FUN FACT

METEORITES—METALLIC REMAINS OF METEORS—ARE MOSTLY CHUNKS OF NICKEL AND IRON. THEY HAVE A COMPOSITION SIMILAR TO THE EARTH'S CORE.

# INNER CORE

FINALLY, YOU HAVE REACHED THE CENTER OF THE EARTH—THE INNER CORE. THE INNER CORE HAS A RADIUS OF ABOUT 746 MILES (1,200 KILOMETERS). IT IS ALMOST AS LARGE AS THE EARTH'S MOON.

Even though the inner core is hotter than the outer core, the metals are squeezed into a solid ball by extreme temperature and pressure. The inner core has immense heat energy. It's the engine room of the Earth!

Temperatures reach almost 9,000 degrees Fahrenheit (5,000 degrees Celsius), which is almost as hot as the sun! Pressures are more than 3 million times the air pressure you feel at sea level.

Scientists think the inner core spins slightly faster than the Earth itself.

## FUN FACT

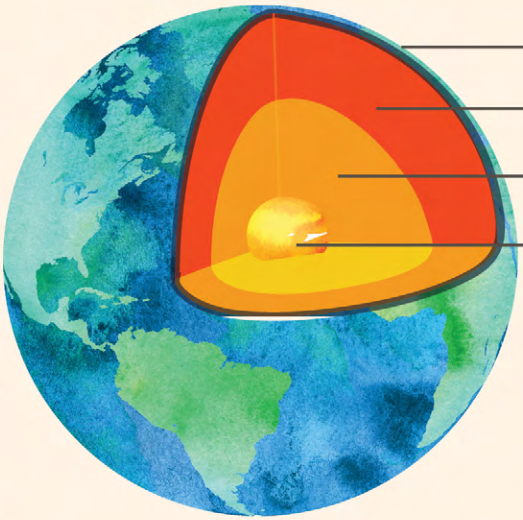
YOU WOULD IMMEDIATELY VAPORIZE IN THE EARTH'S INNER CORE.

# LAYERS OF THE EARTH

Your voyage to the center of the planet has come to an end. The different layers tell a story about the history of the Earth, which is about 4.5 billion years old.

Now you know more about what lies beneath your feet.

CHALLENGE YOURSELF WITH THIS QUIZ TO SEE WHAT YOU LEARNED. CAN YOU NAME EACH ONE OF THE EARTH'S LAYERS?




## BY FILLING IN THE APPROPRIATE LAYER OF THE EARTH.

THE _____ IS MADE OF MOLTEN MAGMA.

THE _____ IS WHERE WE LIVE, AND WHERE THE CONTINENTS AND OCEANS ARE.

THE INTERACTION BETWEEN THE _____ AND _____ CREATES THE EARTH'S MAGNETIC FIELD.

THE _____ IS THE ENGINE ROOM OF THE EARTH.

THE _____ IS A SOLID METAL BALL.

MOST GEMSTONES FORM IN THE EARTH'S _____.

THE PLANET'S THIN, ROCKY OUTER SKIN, IS CALLED THE _____.

THE MAJORITY OF THE EARTH'S VOLUME IS CONTAINED IN THE _____.

THE _____ IS A SPHERE MADE OF SOLID IRON.

# EARTH'S LAYERS WORD SEARCH

N M T Y Z W O X M E D F X Z X
H T R A E N V A T X I I R O N
U K A J S A G Q N S A O W X J
L L I R D M E E L E M D Q I Z
M Q L M A K N A W L O J J H J
J M B B M V D L G O N E E N M
E R O C R E T U O N D G R Z R
C R U S T N K B A K A U O M W
X C D S W C W C Q E C P C A B
W H M X O L P Z R R G A R N R
J K J R R T M Q K C Y Q E T J
T E C T O N I C M C N X N L O
G M I V B K O E H G U M N E O
B Q P R R F O T R W B C I F T
D Z O Y B V O T Q N M B O E E

CRUST
EARTH
MAGMA
PANGAEA
DIAMOND
INNER CORE
MANTLE
ROCK
DRILL
IRON
OUTER CORE
TECTONIC

# NOTES

# NOTES

QUIZ #1:
CRUST, MANTLE, OUTER CORE, INNER CORE

QUIZ #2:
MANTLE, CRUST, INNER CORE/OUTER CORE, INNER CORE, INNER CORE, CRUST, CRUST, MANTLE, INNER CORE

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WHERE DISCOVERIES BEGIN

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