TINYBOP HANDBOOK

STATES OF MATTER

Use this handbook to learn more in the app. Each section includes interaction tips, background information, vocabulary words, and discussion questions.

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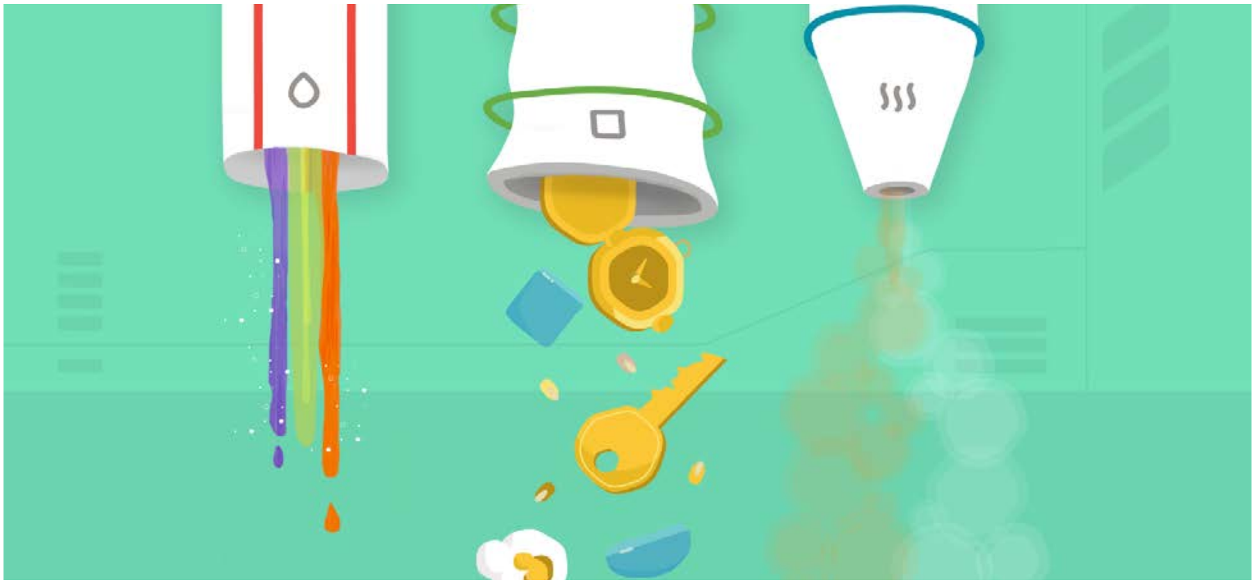
States of Matter by Tinybop

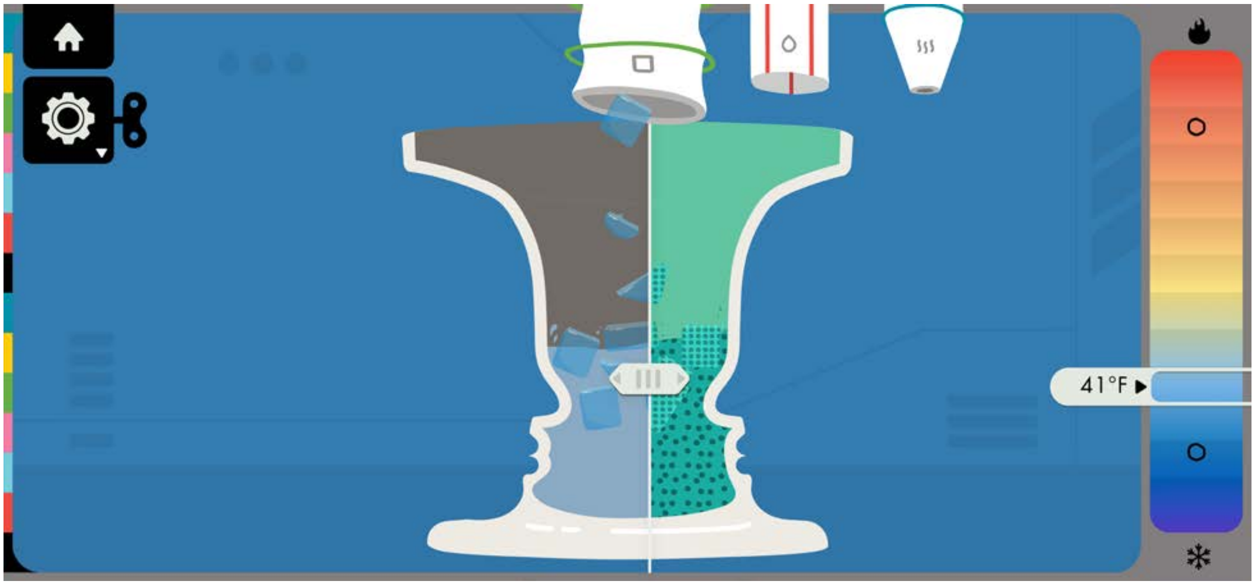


Matter is all around us. The clothes you wear, the water you drink, the air you breathe — even *you* — are made up of matter! Matter is anything that has mass and takes up space. All matter is made up of **molecules**.

Matter can exist in many different forms. The three main states of matter are **solids**, **liquids**, and **gases**. Can you think of some examples of these different states that you see every day? In the app, you will investigate the **properties** of each of these three states of matter.

Many types of matter can change from one state to another when there are changes in temperature or pressure. Have you ever seen a solid, liquid, or gas change states?

Take a snowman, for example. It's solid in cold temperatures, but what happens once the sun comes out and it begins to get warmer? The snowman melts away and becomes water! This transition from one state to another (in this case, from a solid to a liquid) is called a **phase change**. Some phase changes are **reversible** while others are **irreversible**.



IN THE APP

In *States of Matter*, you can explore how different types of matter react to changes in temperature through open play and experimentation. Which change states? Which begin to burn? Explore the different properties of matter, experiment with phase changes, and see exactly why matter, well, matters!

Investigate each object

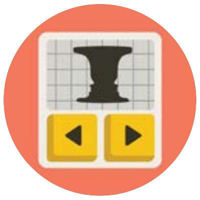
Determine whether an object is a solid, liquid, or gas by examining its observable properties. Is it hard or soft? If you are using a mobile device, turn the device and watch the matter move around. Does it appear to flow, or does it have a definite **shape** and **volume**?

Drag the slider

Notice how the molecules behave in each state. Do they move quickly or slowly? Do they have space to move around, or do they seem to stay in place?

Adjust the temperature

Observe how matter reacts when you raise and lower the temperature scale beyond certain points. Are these changes reversible?



Switch containers

Discover which objects keep their shape and which take the shape of these containers they're in. What does this tell you about the matter?

DID YOU KNOW?

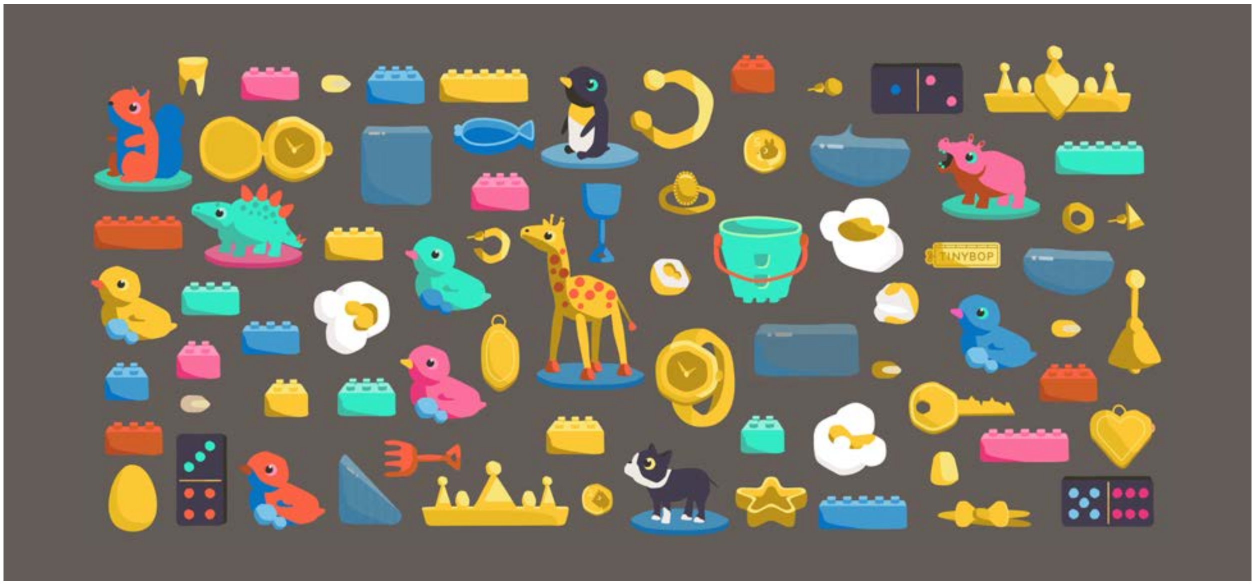
In addition to the three states of matter (solids, liquids, and gases) we've described, there is a fourth fundamental state of matter called **plasma**. Plasma refers to gases with an electric charge, such as neon signs or the sun. While these four fundamental states are the only ones we can observe in our everyday lives, scientists are *still* discovering new states of matter.

NOTE: Because the differences between gases and plasma are advanced, we do not explore plasma in this app.

DISCUSSION QUESTIONS

- What are the solids, liquids, and gases that you see every day? Do any change states? What do these transitions look like?
- What are some of the observable properties of a solid? A liquid? A gas?
- It's not always easy to identify the state of a given object. Can you think of an object like this? What are its different properties? What category do you think it would best fit into?

Solids

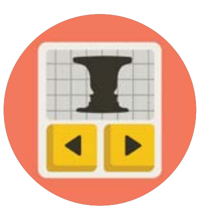


Solids have a definite shape and volume. The molecules in a solid are close together and attached by very strong **bonds**. There are two types of solids: crystalline and amorphous. **Crystalline solids** have molecules that are rigidly ordered, while the molecules in **amorphous solids** are less ordered. As a result, amorphous solids do not have as well-defined of a shape.

IN THE APP

Tap the chute on the left. What do you see?

This chute releases solids into the container. Move the solids around. Do you notice how they do not flow throughout the container? Instead, they bounce around the container in individual pieces.

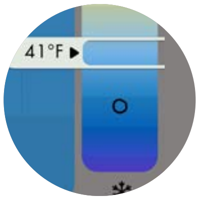


Switch containers. What do you notice?

As you try out different containers, you will notice that solids have a definite shape and volume. Regardless of the container they're in, solids will retain their shape and take up a fixed amount of space.

Drag the slider. How do the molecules move in a solid?

Solids have a definite shape and volume because of their molecular structure. As you drag the slider and uncover the molecular layer, you will see that the molecules in a solid are locked into a fixed position and that they vibrate against each other. The molecules are packed very closely because of their strong bonds.



Raise and lower the temperature. What do you see?

As you adjust the temperature, notice that some of these solids begin to undergo phase changes as they reach their **melting/freezing** and **boiling points**.

DISCUSSION QUESTIONS

- What are some solids you see every day? What are their observable properties?
- Think of two types of solids that seem or look very different from each other. How do their properties differ? How are they similar?
- What are some other examples of amorphous solids? How do they differ from crystalline solids?
- How do the molecules in an amorphous solid compare to the molecules in a liquid?

Solids: Gold

Gold is a soft and malleable metal. Everyday items made of gold include some jewelry and coins. Can you think of any other examples of gold that you've seen?

As you raise the temperature in the app, you'll notice that gold has a very high melting point. When gold melts, it forms a thick molten-like liquid. As you continue to raise the temperature, you will see that gold begins to **boil**. Once you have turned gold into a gas, try lowering the temperature. What happens? Are these phase changes reversible?

MELTING/FREEZING POINT:
1,948°F/1,064°C/1,337K

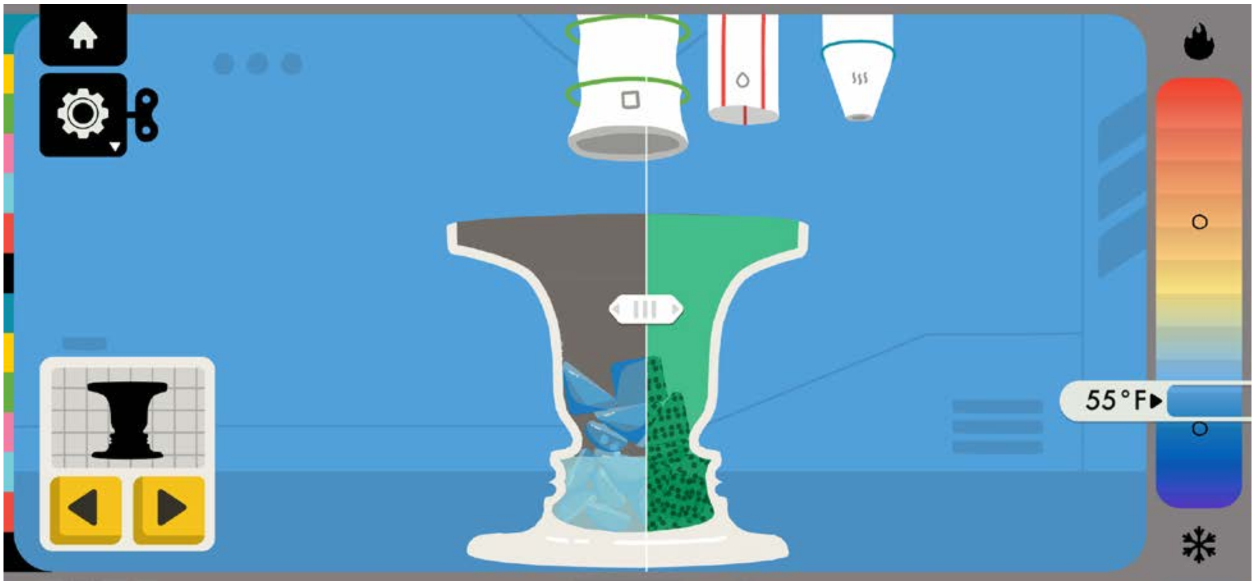
BOILING POINT:
5,137°F/2,836°C/3,109K

STATE AT ROOM TEMPERATURE:
Solid

FUN FACT

Our bodies contain about .2 milligrams of gold.

Solids: Ice



Ice is the frozen form of water. It comes in many shapes and forms: snowflakes, shaved ice, ice skating rinks — and of course, ice cubes!

MELTING/FREEZING POINT:	32°F/0°C/273K
BOILING POINT:	212°F/100°C/373K
STATE AT ROOM TEMPERATURE:	Liquid

As you raise the temperature, you will notice that the ice begins to melt at its melting point. You may recognize the melting/freezing point of ice as it is the temperature at which it snows. If the temperature is higher than 32°F/0°C/273K, it will rain, but if it drops lower, the rain will turn to snow.

Raise the temperature even more. Do you see how water begins to boil and **evaporate** into water vapor or steam? Once you've created steam, try lowering the temperature again. Are these phase changes reversible?

Solids: Popcorn

Raise the temperature so that the popcorn pops! You might notice that popcorn does not have a melting/freezing or boiling point like the other solids in the app. That's because popcorn does not undergo a phase change—a popcorn kernel is a solid, and a piece of popped popcorn is also a solid. But a popcorn kernel does undergo a cool irreversible physical change: once popcorn has popped, it cannot go back to a popcorn kernel.

POPPING POINT:
356°F/180°C/453K

STATE AT ROOM TEMPERATURE:
Solid

Do you know *why* popcorn kernels pop? Popcorn kernels contain a small amount of water. When you heat popcorn, the water inside the kernel turns to steam. The pressure from the steam then forces the kernel to turn itself inside out... and POP! You've turned the kernel into a delicious piece of popcorn.

Solids: Plastics

There are many different types of plastic: plastic bags, plastic water bottles, and plastic wrappers. In this app, you can explore the properties of plastic toys, which are typically made of a special kind of plastic called ABS plastic. Because plastic is an amorphous solid, it behaves a bit differently than many other solids.

GLASS TRANSITION TEMPERATURE:
221°F/105°C/378K

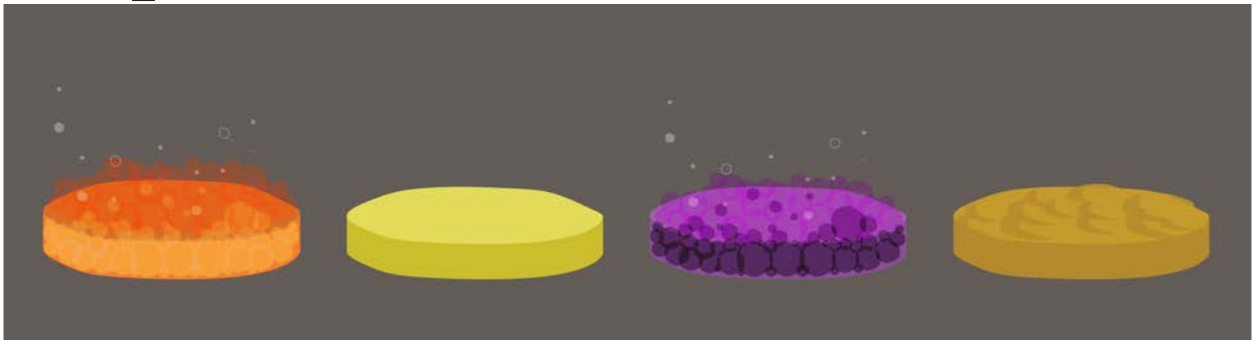
STATE AT ROOM TEMPERATURE:
Solid

FUN FACT

A single recycled plastic bottle saves enough energy to run a 100-watt bulb for 4 hours.

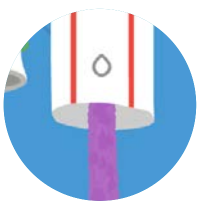
As you approach the **glass transition temperature**, plastics begin to shrink, lose their shape, and form a molten blob. Drag the slider to see how molecules move in this new substance. You will notice that even though the plastic toys have lost their shape, their molecules are still closely packed together. If you're using a mobile device, try turning the device. Do the plastics flow or mix together the way that a liquid would? Or do they remain as individual pieces the way other solids would?

Liquids



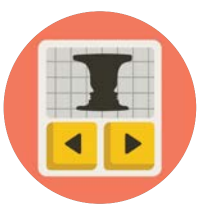
Liquids have a definite volume but no definite shape. The molecules in liquids are attached by firm bonds and are relatively close together (but not as close together as the molecules in a solid).

IN THE APP



Tap the chute in the middle. What do you see?

This chute releases liquids into the containers. Tap the liquid to see how it responds. If you're on a mobile device, try turning the device and observe how the liquid flows throughout the container.

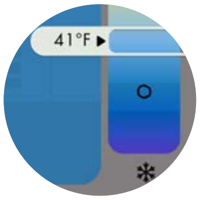


Switch containers. What do you notice?

Liquids take the shape of the container they're in, whether it's a bear, a teapot, or another shape. Why? Because liquids do not have a definite shape. They do, however, have a definite volume and take up a fixed amount of space in the container.

Drag the slider. How do the molecules move in a liquid?

The behavior of these liquids are determined by their molecular structure. When you drag the slider, you will see that the molecules in a liquid move fluidly but remain relatively close together. Even though the molecules have more room to move, they are still held together by firm bonds.

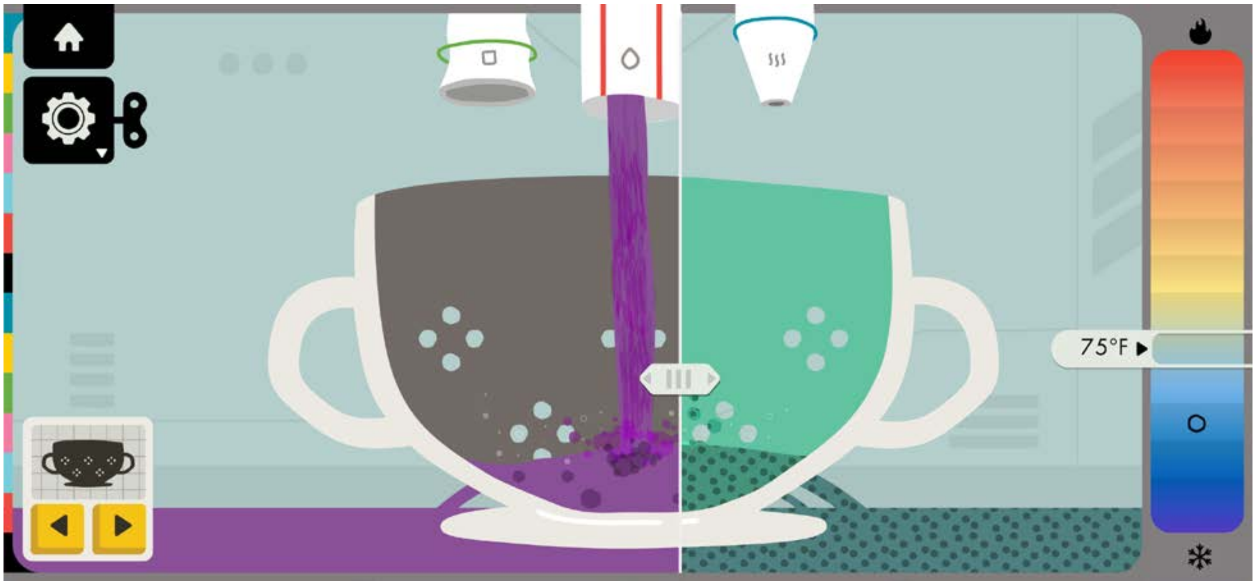


Raise and lower the temperature. What do you see?
Observe the phase changes that some of these liquids begin to undergo as the temperature reaches certain points.

DISCUSSION QUESTIONS

- What are some examples of liquids? How do you know that they are liquids? What are their observable properties?
- How do the molecules in a liquid behave?
- Some liquids, like honey, are very thick. Can you think of another example of a thick liquid? How would the molecules in that liquid compare to those in another liquid that flows more easily, like water?

Liquids: Soda

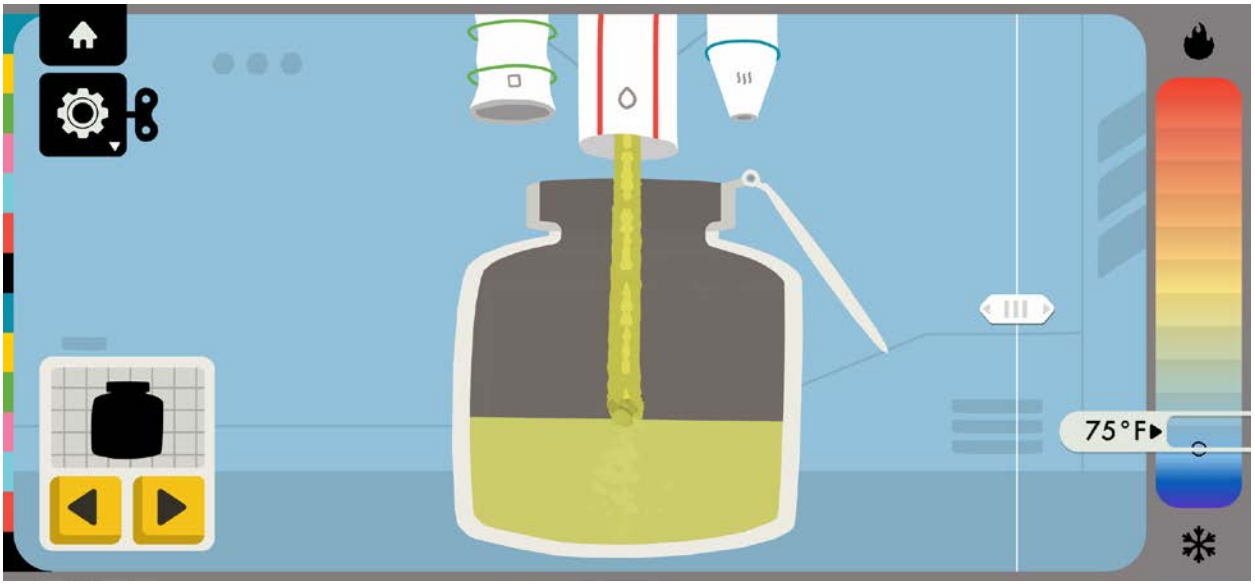


Have you ever noticed that soda has fizzy bubbles and tastes much sweeter than normal water? Soda is a unique liquid because it has certain elements from each of the three main states of matter. It is made up of water (a liquid), carbon dioxide (a gas), and some sort of sweetener (often a solid). Since these three different states of matter are present simultaneously, soda reacts differently to changes in temperature than other liquids do.

MELTING/FREEZING POINT:	28°F/-2°C/271K
BOILING POINT:	212°F/100°C/373K
STATE AT ROOM TEMPERATURE:	Liquid

As you lower the temperature, you will notice that soda **freezes** into a solid. But try boiling soda in the app. What happens? The water begins to evaporate off at water's boiling point, leaving the sugar or another sweetener behind. This is why you see sugar syrup form when all of the water in the soda has evaporated. When the temperature is lowered, the water vapor will **condense** and reabsorb the sugar. What do you notice about the color? It's a bit darker because the sugar has been exposed to heat and has started to caramelize and burn.

Liquids: Oil



Olive oil is a liquid that's typically used for cooking, salad dressing, or bread dipping. It's also used as an ingredient in many other things, like soaps, medicine, and cosmetics. Try lowering the temperature in the app. What happens? Olive oil will eventually freeze. As you raise the temperature of oil again, you will notice that this phase change is reversible: frozen olive oil melts back into a liquid!

MELTING/FREEZING POINT:
37°F/3°C/276K

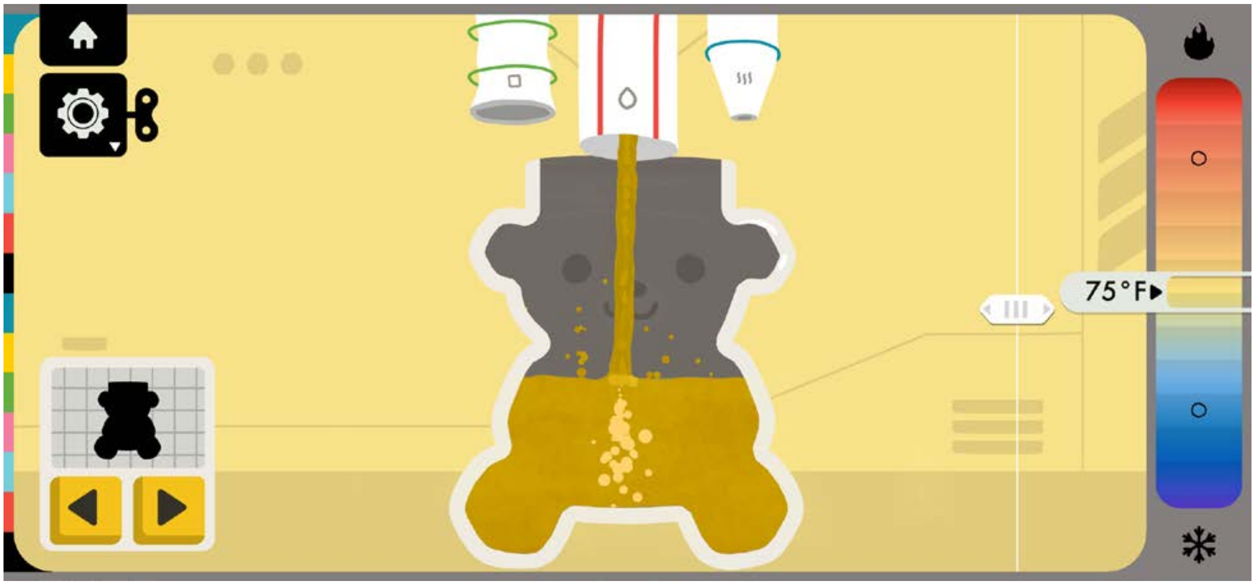
STATE AT ROOM TEMPERATURE:
Liquid

FUN FACT

On average, the world consumes ~2.25 million tons of olive oil each year.

You may have noticed that there isn't a boiling point labeled on the temperature scale. That's because we're not 100% sure what it is, since attempting to reach that point has proven very dangerous. That said, it is believed to be somewhere around 662°F/350°C/623K. Refined olive oil reaches its smoke point around 410°F/210°C/483K, which means that it starts to smoke before it boils. Once the olive oil begins to smoke, it can ignite in the air and start a fire!

Liquids: Honey



Honey is an example of both a **super-saturated liquid** (it contains more sugar than water) and a **supercooled liquid** (it exists below its freezing point but is not a solid). It is also amorphous in nature. These unique properties cause honey to behave differently than other liquids.

BOILING POINT:
212°F/100°C/373K

GLASS TRANSITION TEMPERATURE:
-44°F/-42°C/231K

STATE AT ROOM TEMPERATURE:
Supercooled liquid

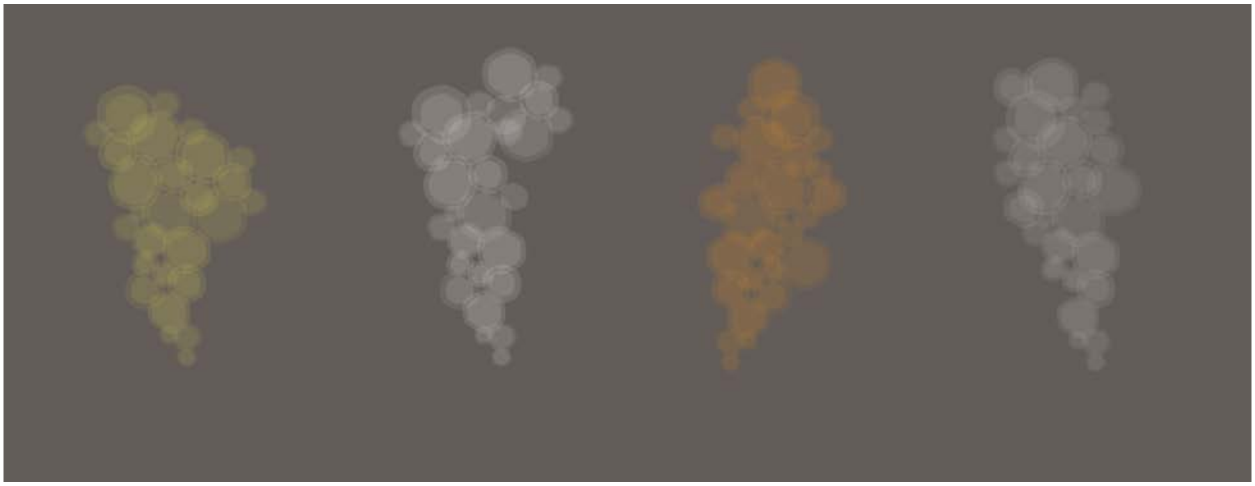
Lower the temperature. What do you notice? The honey becomes even thicker as it becomes colder! We call this an increase in **viscosity**. As you continue to lower the temperature, it will eventually reach its glass transition temperature. Below this point, honey enters a brittle, glassy state, and although it may appear to be completely solid, it will still flow — just very, very slowly.

FUN FACT

One healthy honey bee will only make 1/12 of a teaspoon of honey throughout its life.

Similar to soda, honey is made of water and sugar. When you raise the temperature, the water will begin to boil and evaporate into water vapor. However, the sugar will remain. As the water begins to evaporate, the sugar begins to caramelize and burn. As you lower the temperature again, the water vapor will condense and dissolve once again into the sugar. You may notice that the new honey is darker in color because the sugar browned when the temperature was raised.

Gases

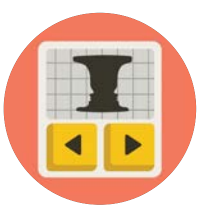


Gases have no definite shape and no definite volume. The molecules in a gas move very quickly with weak bonds (or sometimes no bonds at all) between them.

IN THE APP

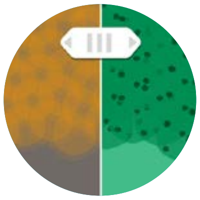
Tap the chute on the right. What do you see?

This chute releases different gases into the container. Quick — find a container with a lid and close it! Tap the gases to see how they move. If you are using a mobile device, try rotating it. You will notice that gases flow easily, sometimes even floating out of the container!



Switch containers. What do you notice?

Notice how gases expand and take the shape of the container they're in. This is how we know that gases have no definite shape and no definite volume.



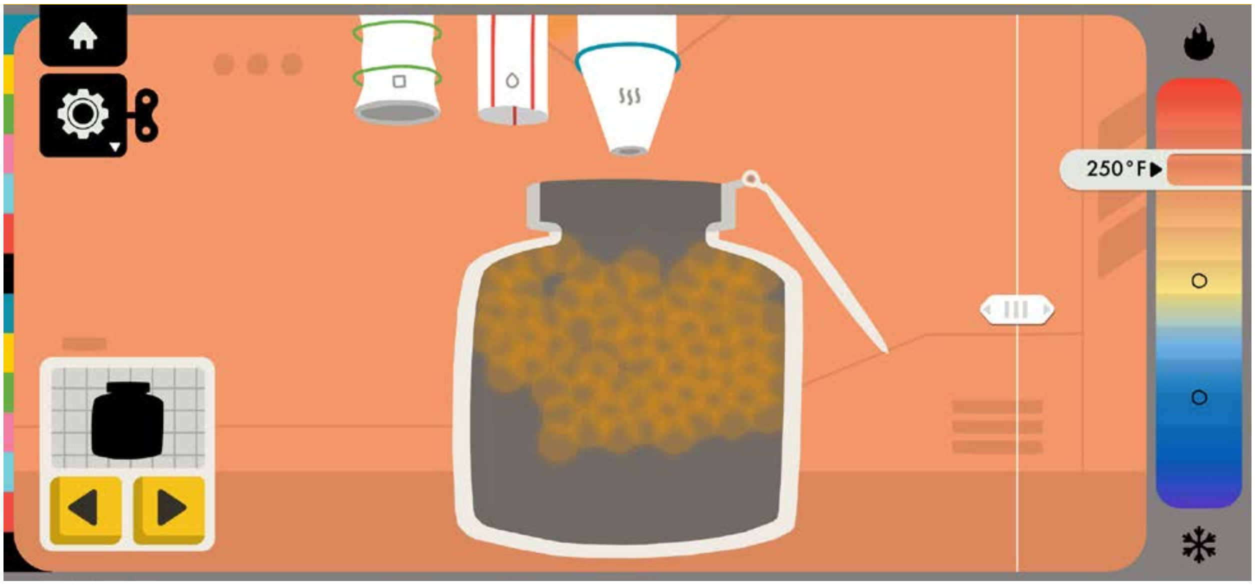
Drag the slider. How do the molecules move in a gas?
Gases have no definite shape or volume because of their molecular structure. The molecules move very quickly with weak bonds (or sometimes no bonds at all) between them!

Raise and lower the temperature. What do you see?
As you adjust the temperature, you will notice that some of these gases begin to undergo phase changes as they reach their melting/freezing and boiling points.

DISCUSSION QUESTIONS

- Even though gases are hard to see, they are around us all the time! Can you think of some examples of gases you encounter every day?
- What are the observable properties of a gas?
- How do the molecules behave in a gas?

Gases: Bromine



Bromine is a gas that is reddish-brown in color, unlike many of the invisible gases we encounter every day. Do you notice anything else unique about bromine? Most gases have very low boiling and freezing points, often in the negatives, but bromine is actually one of the only elements known to be a liquid at room temperature (the other one is mercury). When frozen, bromine remains reddish-brown in color. As you raise and lower the temperature, you'll notice that these phase changes are reversible!

MELTING/ FREEZING POINT:
19°F/-7°C/266K

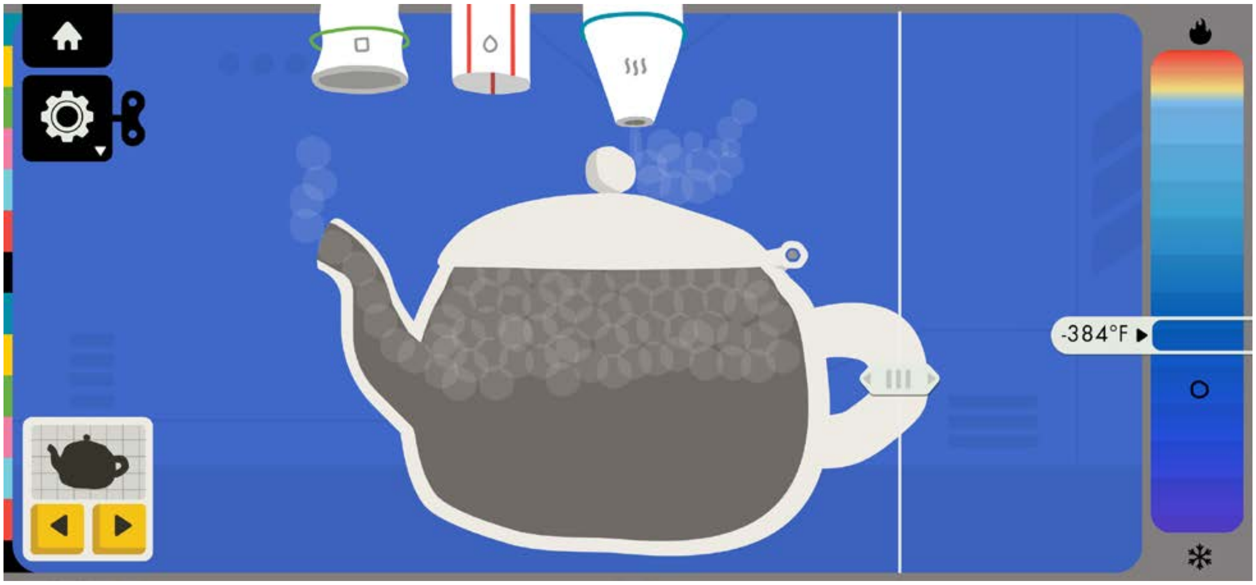
BOILING POINT:
138°F/59°C/332K

STATE AT ROOM TEMPERATURE:
Liquid

FUN FACT

At room temperature, bromine has a foul odor.

Gases: Helium



BOILING POINT:
-452°F/-269°C/4K

STATE AT ROOM TEMPERATURE:
Gas

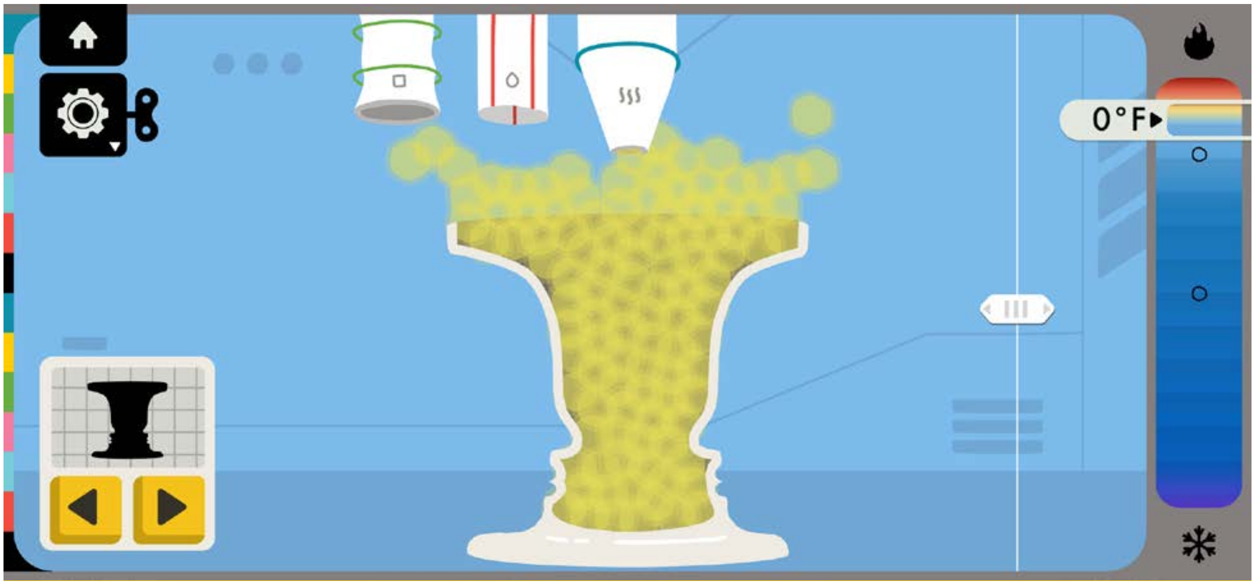
Have you ever wondered why some balloons float up into the air while others don't? Or why inhaling the gas from some balloons can make your voice sound high and squeaky? This is because of an element called helium. Helium balloons will float up into the sky because helium is lighter than air. In fact, it is the second lightest element on earth (the first is hydrogen!).

Lower the temperature. What do you notice? Helium has the lowest boiling point of all of the elements on the periodic table! You will also observe that, regardless of the temperature, helium does not turn into a solid.

As you adjust the temperature, you'll see that helium undergoes a reversible phase change from a gas to a liquid. Helium is unique and will remain a liquid up until absolute zero under normal pressure. In order to create solid helium, we must apply external pressure. The conditions in this app are set to be at **standard atmospheric pressure**, which is why you can only see helium as a gas or a liquid.

BONUS: You can hear how helium makes your voice high and squeaky by enabling the microphone in the app!

Gases: Chlorine



You might be familiar with chlorine from cleaning products — like the ones used to clean a swimming pool! Chlorine is one of the main ingredients in these products, but it is often diluted with other things. Pure elemental chlorine is a yellow-greenish colored gas.

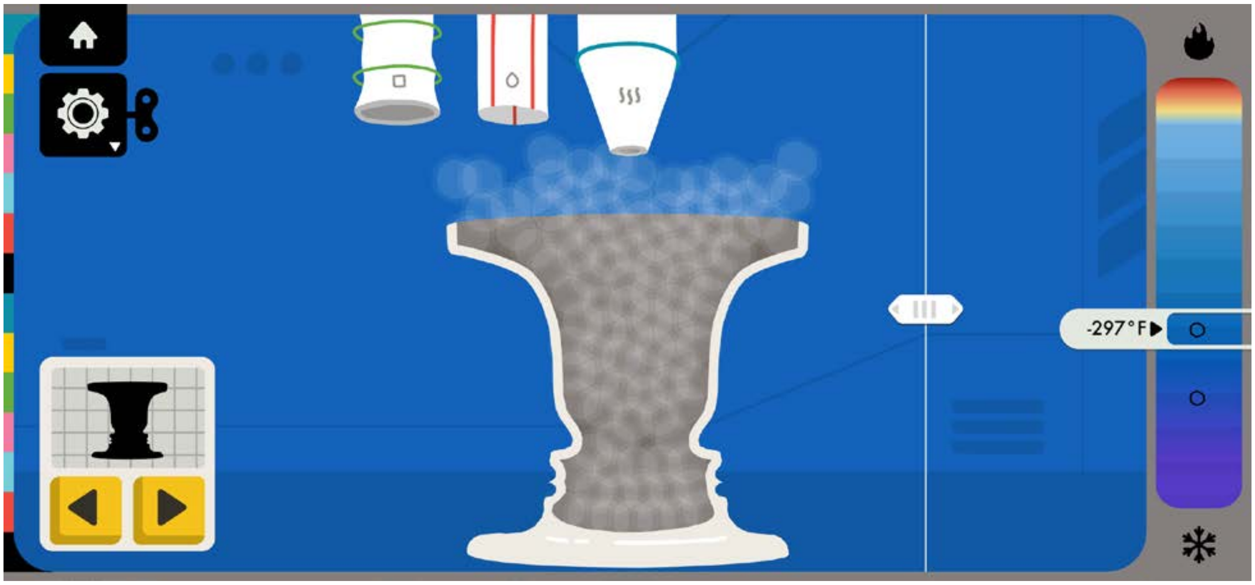
MELTING/FREEZING POINT:
-151°F/-102°C/171K

BOILING POINT:
-29°F/-34°C/239K

STATE AT ROOM TEMPERATURE:
Gas

Lower the temperature. What begins to happen? Chlorine will condense to become a similarly colored liquid and finally begin to freeze into a yellow-greenish solid. Try raising the temperature, and you'll see that these phase changes are reversible.

Gases: Oxygen



MELTING/FREEZING POINT:
-362°F/-219°C/54K

BOILING POINT:
-297°F/-183°C/90K

STATE AT ROOM TEMPERATURE:
Gas

At **standard temperature and pressure (STP)**, oxygen is an invisible gas. Lower the temperature, and you'll witness a color change: clear oxygen will condense to form a pale-blue colored liquid! As you continue to lower the temperature of oxygen, it will begin to freeze and form a pale blue solid. What happens if you try to raise the temperature once you've formed a solid? These changes are reversible: solid oxygen will turn back into a liquid, and even back into an invisible gas!

FUN FACT

Liquid oxygen is magnetic. It can be moved around and even picked up with a powerful magnet.

Glossary

Amorphous solid

A solid with molecules that are semi-ordered but not as rigidly ordered as in crystalline solids.

Bonds

The attraction between molecules.

Boiling

The action of rapidly turning a liquid into a gas.

Boiling point

The temperature at which a liquid begins to evaporate or a gas begins to condense. Unlike the melting or freezing point, the name of this point doesn't change. We always call it the boiling point even though condensation also begins to occur at this point.

Condensation

The transition from gas to a liquid.

Crystalline solid

A solid with molecules that are rigidly ordered and a well-defined shape.

Evaporation

The transition from a liquid to gas.

Freezing

The transition from a liquid to a solid.

Freezing point

The temperature at which a liquid begins to freeze into a solid. The freezing point and melting point of an object are often the same because melting and freezing are reverse reactions.

Gas

One of the four fundamental states of matter. Gases have no definite volume and no definite shape. Their molecules move so fast that there are weak bonds (and sometimes no bonds at all) between them.

Glass transition temperature

The temperature, or range of temperatures, at which an amorphous material transitions from a hard and glassy state to a viscous liquid state or vice versa.

Irreversible change

A change that cannot be undone. In an irreversible change, a new material is always formed.

Liquid

One of the four fundamental states of matter. Liquids have a definite volume but no definite shape. Their molecules are more spread out and held together by weaker bonds than the molecules in solids.

Matter

Anything that has mass and takes up space.

Melting

The transition from a solid to a liquid.

Melting point

The temperature at which solids begin to melt into liquids. The melting point is often the same as the freezing point because melting and freezing are reverse reactions.

Molecules

A group of two or more atoms, which are the smallest unit of matter.

Phase changes

The transition from one state of matter to another. Phase changes that you can explore in this app are melting, freezing, evaporation, and condensation.

Plasma

One of the four fundamental states of matter. Plasma is a gaseous substance with an electric charge. Like gases, plasma has no definite volume, no definite shape, and has weak bonds (and sometimes no bonds at all) between its molecules.

Property

A characteristic of an object, such as shape, height, color, texture, hardness, or volume. An observable property is a characteristic that we can see.

Reversible change

A change that can be undone. A reversible change may alter the way an object looks, but no new materials are formed.

Shape

The form of an object. When talking about states of matter, we use this term to describe which objects have a definite form and which objects take the form of the container they're in.

Solid

One of the four fundamental states of matter. Solids have a definite shape and volume. Their molecules are close together and attached by very strong bonds.

Smoke point

The temperature at which an object begins to smoke and release vapors into the air. After the smoke point is reached, it is possible for these vapors to ignite.

States of matter

The different forms in which matter can exist. There are four fundamental states of matter: solids, liquids, gases, and plasma.

Standard temperature and pressure (STP)

The conditions used for comparing certain properties of matter, such as density and weight. Standard temperature is 32°F/0°C/273K. Standard atmospheric pressure is 1 atm.

Supercooled liquid

A liquid that exists below its freezing point but has not turned into a solid.

Supersaturated liquid

A liquid solution which contains more of the dissolved material than could typically be dissolved (for example, if the solution contains significantly more sugar than water).

Viscosity

The thickness of a liquid. If the liquid is very thick, we say that it has a high viscosity. If the liquid is thin, it has a low viscosity.

Volume

The amount of space something takes up.

RESOURCES

Buthelezi, T., Dingrando, L., Hainen, N., Wistrom, C., & Zike, D. (2017). Glencoe chemistry: Matter and change. McGraw-Hill Education.

SPECIAL THANKS TO

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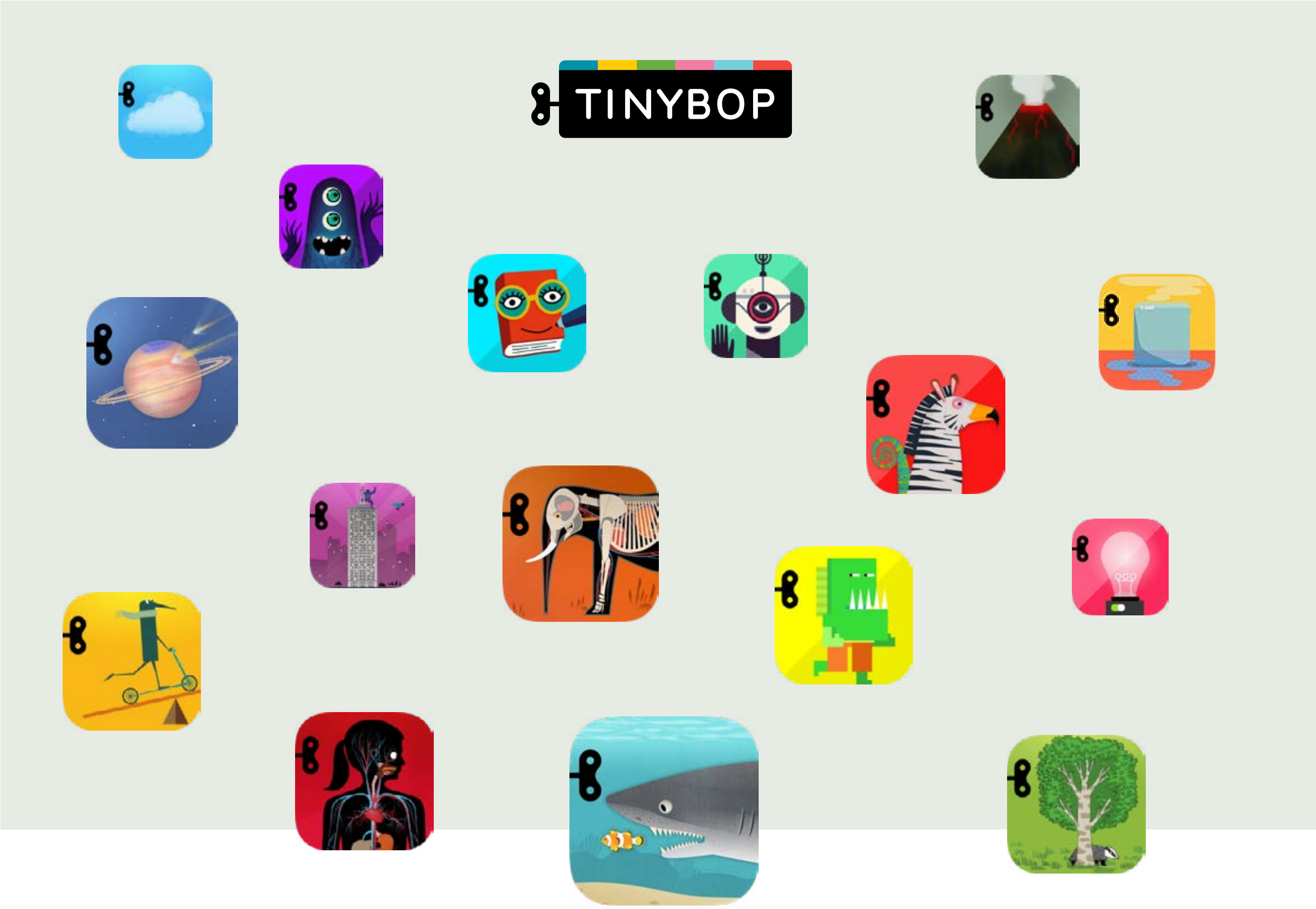

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