



THING EXPLAINER

COMPLICATED STUFF
IN SIMPLE WORDS

BIG WORDS THAT TELL
YOU WHAT THIS BOOK IS

LINES WE DRAW TO HELP
US REMEMBER STARS

THE SUN MOVES ALONG THIS PATH

GROUP OF STARS
NAMED AFTER A
PRETEND HORSE

CLOUD OF
STARS WE
LIVE IN

FIRE COMES
OUT HERE

SEA FLOOR

LAND FLOOR

SEA

COOL ROCK

HOT ROCK

LAND GOING AWAY

MY NAME

RANDALL MUNROE

author of *What If?* and creator of *xkcd*

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RANDALL MUNROE

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PAGE BEFORE THE BOOK STARTS

Hi!

This is a book of pictures and simple words. Each page explains how something important or interesting works, using only the ten hundred words in our language that people use the most. This page is here to say hello and explain why the book is like this.

I've spent a lot of my life worried that people will think I don't know enough. Sometimes, that worry has made me use big words when I don't need to.

One thing that I've sometimes used big words for is the shape of the world. The world is round, but it's not *exact/y* round. Because of how it spins, it's a little wider around the middle. If you're building a space boat that's going to fly around the world, you have to be clear about what shape the world is, and there are some big words that you can use instead of "round." But most of the time, it doesn't matter exactly what the shape is, so people just say "round."

When I was in school, I learned about space boats and learned to use lots of big words for things like the shape of the world. Sometimes I would use those big words because they were different from the small words in an important way. But a lot of the time, I was really just worried that if I used the small words, someone might think I didn't know the big ones.

I liked writing this book because it made me let go of my fear of sounding stupid. After all—when you're saying things like "space boats" and "water pushers," *everything* sounds stupid. Using simple words let me stop worrying so much. I could just have fun making up new names for things and trying to explain cool ideas in new ways.

Some people say that there's no reason to learn big words in the first place—all that matters is knowing what things *do*, not what they're *called*. I don't think that's always true. To really learn about things, you need help from other people, and if you want to understand those people, you need to know what they mean by the words they use. You also need to know what things are called so you can ask questions about them.

But there are lots of other books that explain what things are called. This book explains what they do.

Okay, I'm done talking about the book now. Turn the page to learn about space!

SHARED SPACE HOUSE

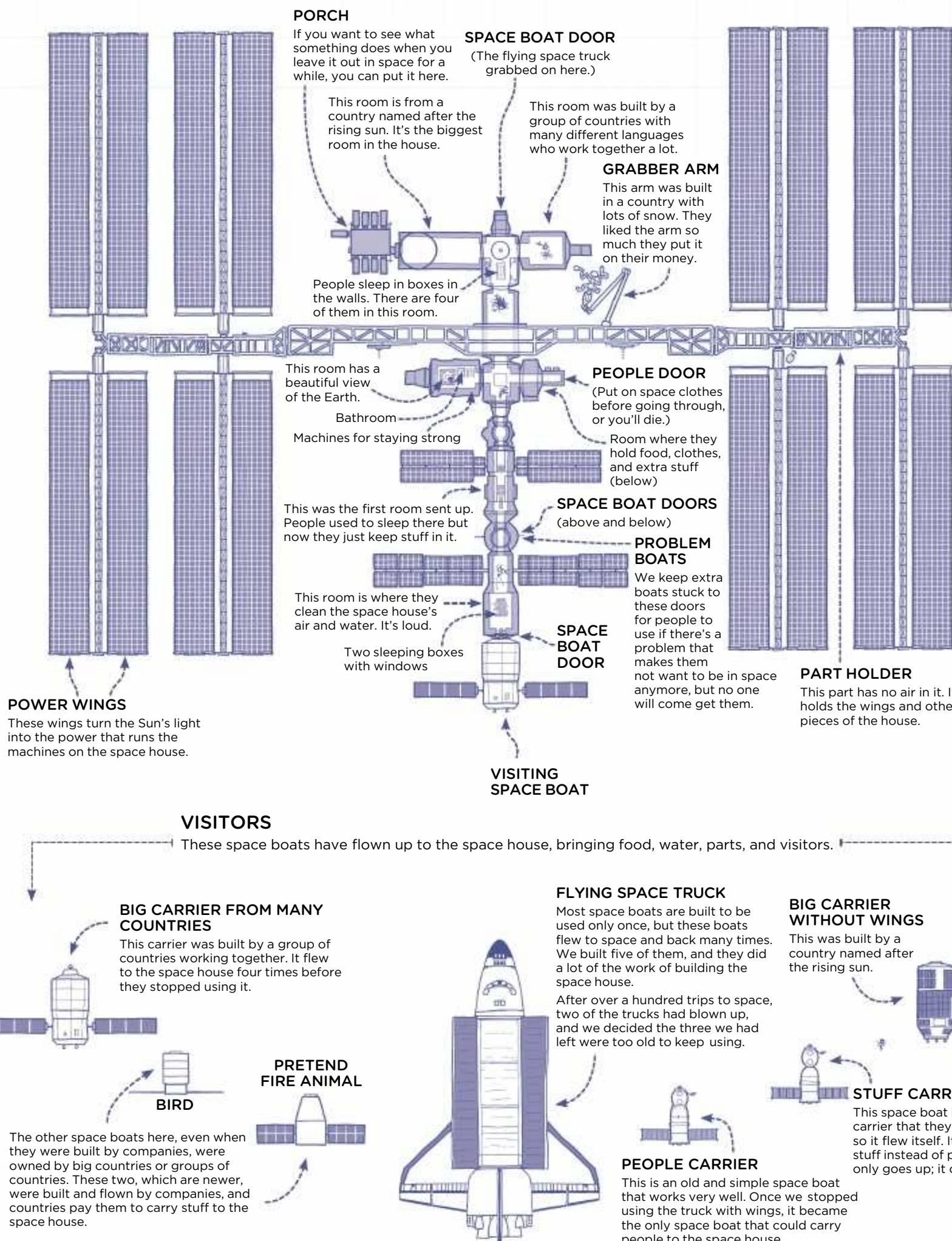
This building flies through space just above the air. People from different countries built it and fly up to visit it in space boats.

Because the house is falling around the Earth, things inside it hang in the air instead of dropping to the floor. Inside the house, normal things like water act very strange, and you can fly around by kicking off the walls. Everyone says it's a lot of fun.

The people in the house spend their time working, playing, and taking pictures of Earth. They do work for people on the ground, helping to learn how things like flowers and machines work in space. Most of the time, there are six people in the house, with each person staying for half a year.

A big reason we built the space house was so we could learn to keep people alive and strong in space for months or years without getting sick. We'll need to be good at that if we ever want to travel to other worlds.

To build the space house, we took each piece up in a boat, pushed it until it went really fast, then caught up to the house, and stuck the part to the house.



TINY BAGS OF WATER YOU'RE MADE OF

Everything that's alive is made of tiny bags of water. Some living things are made of just one bag of water. Those things are usually too small to see. Other things are made of a group of bags stuck together. Your body is a group of lots and lots of these bags that are working together to read this page.

These bags are full of smaller bags. Life uses lots of bags. All life is made from different kinds of water, and a bag keeps the stuff inside it from touching the stuff on the outside. By using bags, living things can keep different kinds of water in one place without it all coming together.

Some of the little bags you see here were once living things on their own. Long ago, some little green bags learned to get power from the Sun. Then they got stuck inside other bags, and those became flowers and trees. The green color of leaves comes from the children of those little green bags.

LITTLE ANIMALS

These are living things (not really "animals") that got stuck in our bags of water a long time ago, like the green things in tree leaves. Now we can't live without each other. They get food and air from our bodies and turn them into power for our bags.

SIZE

These bags are almost always too small to see. In fact, they're almost as small as the waves of light we see with:

BLUE
GREEN
RED

BAG FILLER

This machine fills little bags with stuff and then sends them out into the water. Some stuff gets sent out of the big bag to another part of your body.

The machine also fills bags with death water, marking them very carefully before sending them out so they don't get used in the wrong place.

OUTSIDE WALL

The water bags that make up animals have soft walls. The bags in trees and flowers, which don't need to move around as much as us, have a less soft outside layer.

GETTING IN AND OUT

Some things can go through the bag's wall on their own. Other things can only go through if the bag helps them, either by letting them through an opening, or by making part of the wall into a new bag to hold them.



THINGS THAT MAKE YOU SICK

These tiny things can get into your bags and take control of them. When they do that, they use the bag to build more of them.

When the kind shown here gets into you, your body gets hot, your legs hurt, and you have to lie down. Your whole body feels bad, and it makes you hate everything. You feel like you're going to die but usually don't. We say all life is made of bags, but these things aren't. They also can't make more of themselves; they have to get a bag to make them. So we don't know if it makes sense to say they're "alive." They're more like an idea that spreads itself.

EMPTY POCKETS

This part of the bag has pockets to hold stuff that it might need later. It also makes a few things.

One of the things it makes is that stuff that helps your arms and legs get stronger. Sometimes, people who want to run or ride fast will put bottles of that stuff into their body and then lie about it.

CONTROL AREA

This area in the middle holds information about how to make the different parts of your body. It writes this information in notes and sends them out into the bag.

Bags make more bags by breaking in half. When this happens, the control area also breaks in half, and each half gets a full set of the bag's information.

Not all bags have these control areas. The bags in human blood don't (which means blood can't grow) but the bags in bird blood do.

This control area may have once been a living thing on its own, just like the green things in leaves.

LITTLE BUILDERS

This area is covered in little building machines that build new parts for the bag. The builders sit just outside the control area, reading the notes from inside that tell them what to build.

After the builder makes a part, the part falls away into the bag. Each part has a job to do. Maybe its job is to tell another part it's time to stop working. Maybe its job is to turn one kind of part into another. Maybe it makes another part do something different. Or maybe it has a job, but waits until it sees *another* part before it starts working.

The strange thing is, no one tells the part where to go. It just falls out into the room with all the other parts, and hangs around until it runs into whatever part it's supposed to grab. (Or until another part grabs *it*!) This sounds strange, and it is! There are so many parts, and they're all grabbing each other and stopping each other and helping each other.

The insides of these bags are harder to understand than almost anything else in the world.

STRANGE BOXES

There are lots of these little boxes in our water bags. We don't know what they do.

BAGS OF DEATH WATER

These little bags are full of a kind of water that breaks things into tiny pieces. If something is put inside them, the water breaks it down into whatever it's made of.

If something goes wrong, these little bags tear open and all their bad water falls out. That makes the whole bag around it fall to pieces and die.

"Bags falling to pieces" sounds bad, since bags are what you're made of. But if a bag was having problems, it could hurt you. The death water helps clear it away so your body can make a new one.

BAG SHAPERS

The space between bag parts is full of lots of very thin hair-like lines. These are like bones for the bag; they help hold its shape, and do some other things. Some of these shapers also have holes down the middle, and can carry things from one part of the bag to another.

HEAVY METAL POWER BUILDING

These buildings use special kinds of hard-to-find heavy metal to make power.

Some of the metals they use can be found in the ground, but only in a few places. Other kinds can be made by people—but only with the help of a power building that's already running.

These metals make heat all the time, even when they're just sitting. They make two kinds of heat: normal heat—like heat from a fire—and a different, special kind of heat.

This special heat is like light that you can't see. (At least, you can't see it most of the time. If there's a whole lot of it, enough to kill you quickly, you can see it. It looks blue.)

Normal heat can burn you, but the special heat from these metals can burn you in a different way. If you spend too much time near this heat, your body can start growing wrong. Some of the first people who tried to learn about these metals died that way.

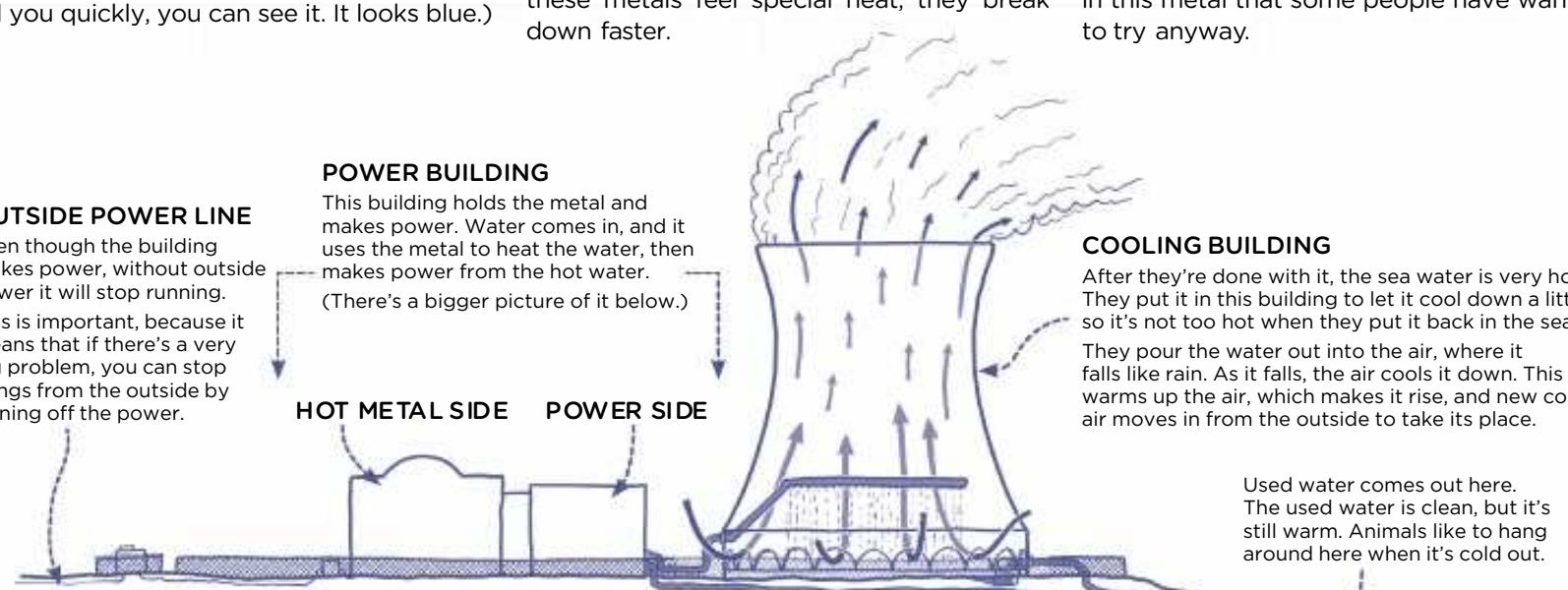
The special heat is made when tiny pieces of the metal break down. This lets out a lot of heat, far more than any normal fire could. But for many kinds of metal, it happens very slowly. A piece of metal as old as the Earth might be only half broken down by now.

Within the last hundred years, we learned something very strange: When some of these metals feel special heat, they break down faster.

If you put a piece of this metal close to another piece, it will make heat, which will make the other piece break down faster and make more heat.

If you put too much of the metal together like this, it gets hotter and hotter so fast that it can all break down at once, letting out all its heat in less than a second. This is how a small machine can burn an entire city.

To make power, people try to put pieces of this metal close enough together that they make heat fast, but not so close that they go out of control and blow up. This is very hard, but there is so much heat and power stored in this metal that some people have wanted to try anyway.



OUTSIDE POWER LINE

Even though the building makes power, without outside power it will stop running. This is important, because it means that if there's a very big problem, you can stop things from the outside by turning off the power.

POWER BUILDING

This building holds the metal and makes power. Water comes in, and it uses the metal to heat the water, then makes power from the hot water. (There's a bigger picture of it below.)

HOT METAL SIDE POWER SIDE

COOLING BUILDING

After they're done with it, the sea water is very hot. They put it in this building to let it cool down a little so it's not too hot when they put it back in the sea. They pour the water out into the air, where it falls like rain. As it falls, the air cools it down. This warms up the air, which makes it rise, and new cold air moves in from the outside to take its place.

Used water comes out here. The used water is clean, but it's still warm. Animals like to hang around here when it's cold out.

POWER LINE BOX

Sometimes animals get in here and break something, and it makes the entire building stop working.

CONTROL STICKS

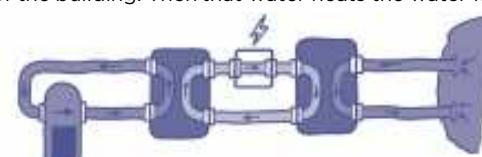
These sticks control how hot the metal gets. When they're pushed down, the ends go in between the pieces of metal and block the special heat.

Sometimes, these are held up by outside power, so if the power stops, the sticks all fall down and stop the heat.

MAKING POWER WITH WATER

The building makes power by heating water. This means they need lots of cold water, which is why they're usually built near the sea or a big river.

They don't let the water from the sea touch the water that goes near the hot metal itself. Instead, they let the metal heat up water that runs through metal lines. Then the heat from those lines heats water in another water carrier, which goes over to the other part of the building. Then *that* water heats the water from the sea.



Cold water gets pulled in here. Sometimes fish get stuck in it and they have to turn off the power building to figure out what's wrong.

WALL

For keeping problems inside

USED METAL ROOM

The water blocks the strange heat from the metal while it cools back down.

TURNING MACHINE

These machines use the hot wet air to turn a stick.

POWER MACHINE

This machine uses the turning stick to make power.

METAL LIFTER

PART LIFTER

HOLE IN WALL

New metal goes in here.

METAL

(waiting to be used)

INSIDE WALL

HOT METAL HOT WATER

EXTRA POWER BOXES

METAL SPREADING ROOM

If there are problems and everything is on fire, the special metal can get so hot that it starts moving like water. Sometimes, it can get hot enough to burn a hole through the floor. If that happens, this room is here so the watery metal can fall down and then spread out over the floor.

It's good if the metal can spread out, since when it's all close together, it keeps making itself hotter. If this room ever gets used, it means everything has gone very, very wrong.

STARTER

This engine starts the stick turning.

LIFTER

This machine lifts the stick up so the engine can turn it.

HOT WET AIR

This air is very hot and wet, so it can turn the stick.

COOLER WET AIR

This air is cooler and wet, so it can turn the stick.

SEA HALLWAYS

These go to the river or the sea.

RED WORLD SPACE CAR

This is a space car that drives around on the red world near Earth. Humans have never been to the red world, but we've sent four cars, along with lots of space ships flying around taking pictures from high above. This car is the biggest one we've sent so far—as big as a normal car on Earth.

The cars we've sent there are looking for water, because if there's water, there might be life. Right now, there's only a little water there, and it's so cold that it's all hidden away in the ground as snow. But it wasn't always that way!

By looking at the red world's rocks, our cars have learned something really cool: A long time ago, when the red world was young, it had seas.

We don't think there's life on the red world today. We haven't found any so far, and it's very cold and dry, with very thin air, so water can't last long on the ground before it turns to ice or air.

But if there used to be seas, then maybe there used to be animals, too. On Earth, when animals die, sometimes parts of their bodies turn to a kind of stone. If there were animals on the red world, maybe we can find the stones they left behind.

If we find that there was life on the red world, it will be one of the most important things we've ever learned—because if there was life on the red world, it means there's probably life in lots of places.

We now know that most of the stars in the sky have worlds around them, but we don't know if there's life on those worlds. We know there's life on our own world, but that doesn't tell us whether life is normal or not. Maybe life is a very strange thing that got started only once, and none of the other worlds have anyone on them to wonder about this question.

But if we learn that life started on the red world, too, it means that life probably gets started on new worlds all the time, and probably also got started around many of those other stars.

If our space car finds signs of life in the red world's stones, it means we are not alone.

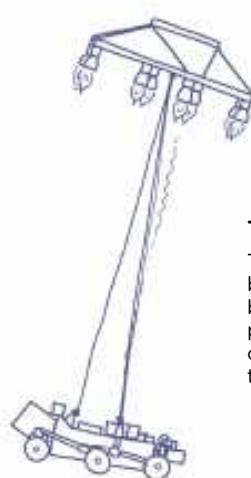
LANDING THE SPACE CAR

Because this car was so heavy, it was hard for us to make it slow down enough to land without breaking. We could hang a big sheet behind it to slow it down, but it's so heavy—and the air there so thin—that the sheet wouldn't be able to slow it down enough.



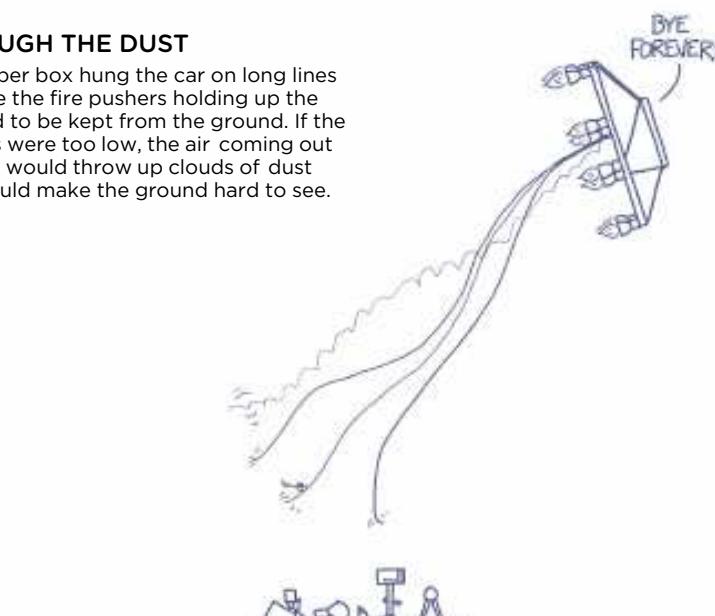
HELPER BOX

Our space doctors came up with a very strange idea. They built a flying helper box that lowered the space car to the ground carefully on a long line.



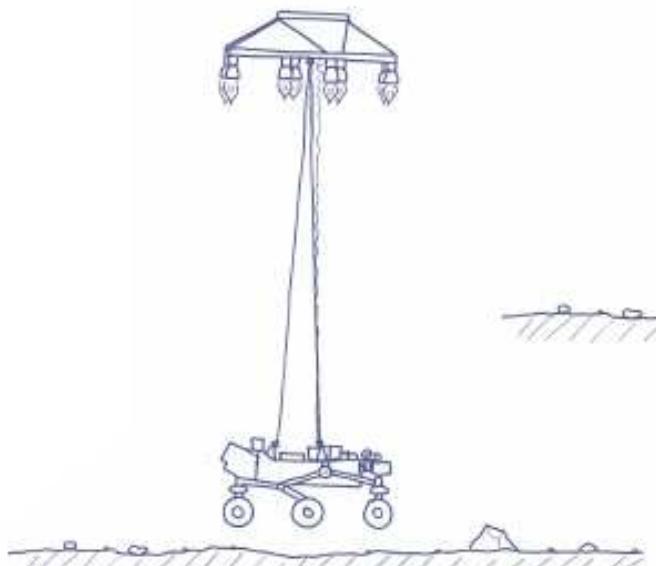
THROUGH THE DUST

The helper box hung the car on long lines because the fire pushers holding up the box had to be kept from the ground. If the pushers were too low, the air coming out of them would throw up clouds of dust that would make the ground hard to see.



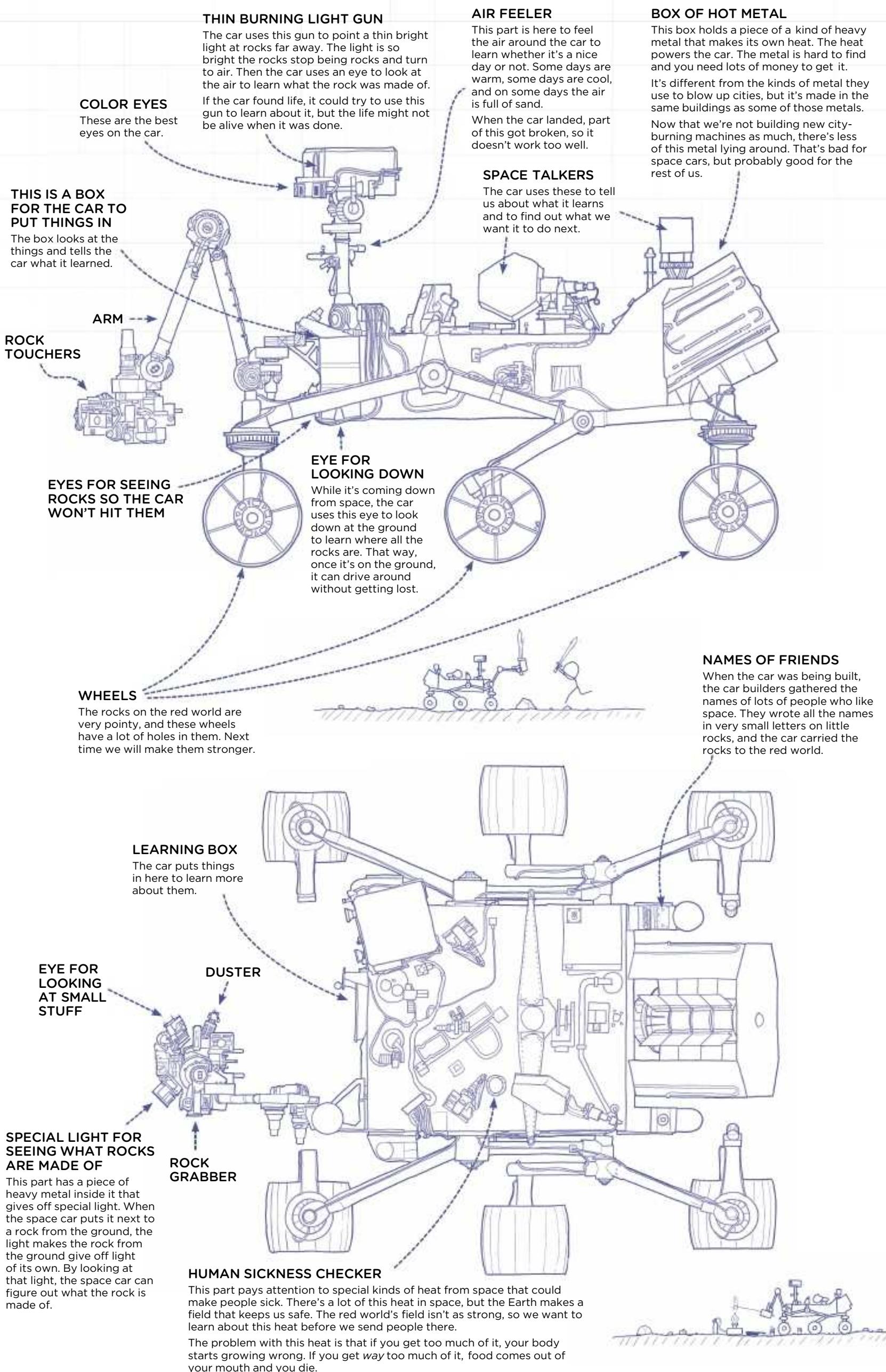
FLY AWAY

Once the car was safe on the ground, the helper box's job was done, so it flew off and hit the ground somewhere else, where it wouldn't hurt the space car.



This sounded to most people like a strange idea that probably wouldn't work. But they looked at every other idea anyone could think of, and all of them seemed even less good.

And, in the end, it worked. The space car landed, looked around, and started learning.



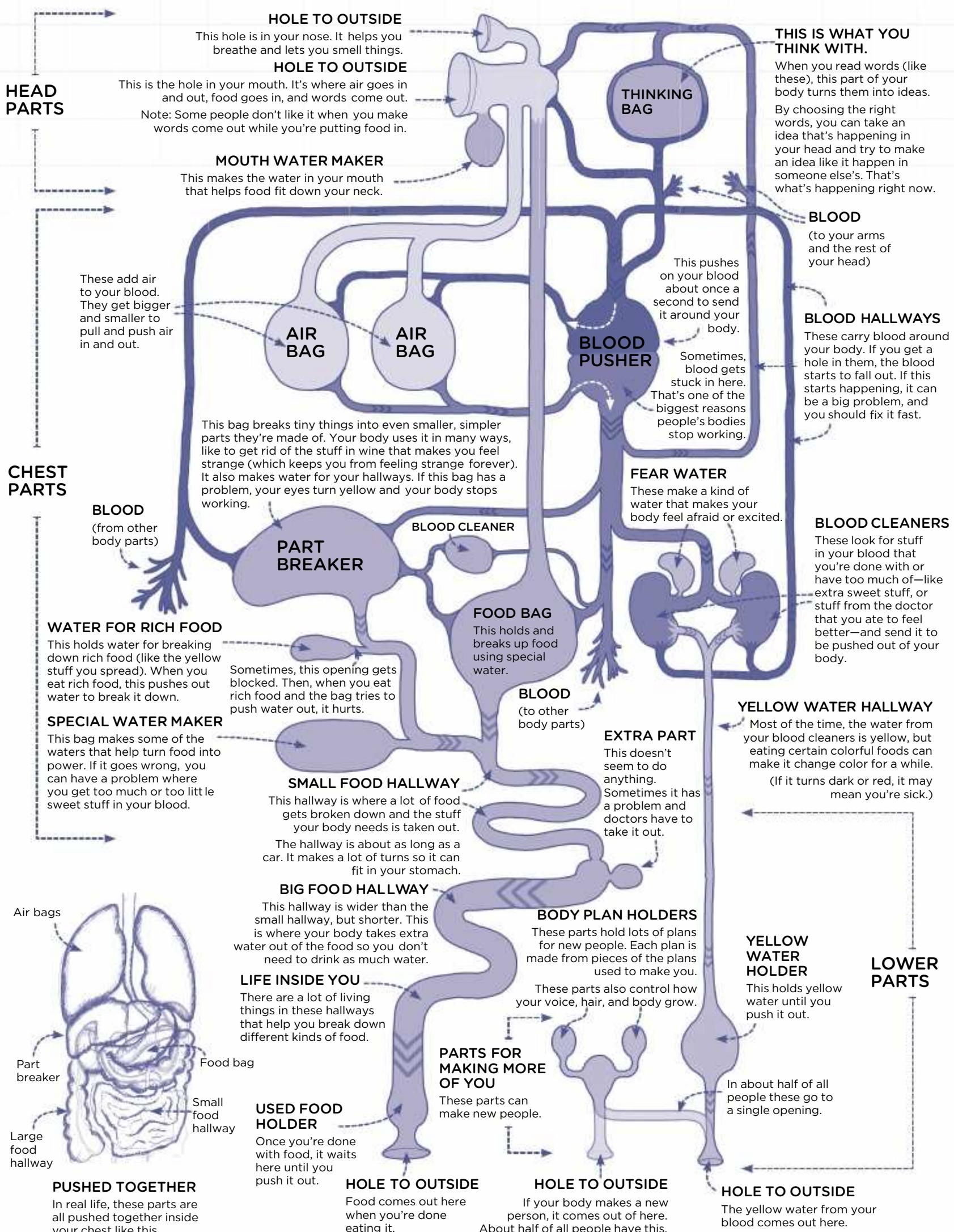
BAGS OF STUFF INSIDE YOU

This is a map of some of the different bags in your body and how they join together.

It doesn't show what they're really shaped like or how they're pushed together inside your body.

In that way, it's kind of like the colored maps in cities that tell you where trains go—it shows how the places are joined together, but not what they're shaped like or how far away from each other they are.

There are lots of important parts of your body that aren't shown on this map. But that's okay; a body has too many parts to show on *any* map.



BOXES THAT MAKE CLOTHES SMELL BETTER

Clothes don't stay clean for long. Pieces of dust and dirt stick to them, and they get coated in that clear stuff that comes off

your skin. If clothes get wet for too long, things can grow on them, which makes them smell bad.

This box holds two machines that clean clothes. The bottom one washes them with water, and the top one dries them.

DRYER

DUST CATCHER

When the air blows through the clothes, it carries away bits of dust and tiny pieces of the clothes. This thing catches the dust so it doesn't gather somewhere else in the house.

When the catcher fills up, you have to clean it out, because if it's full of dust, it blocks the air. This keeps the machine from drying—and the dust is easy to burn, so it can help a fire start.



For some reason, some people really like pulling the sheets of dust out of the catcher.

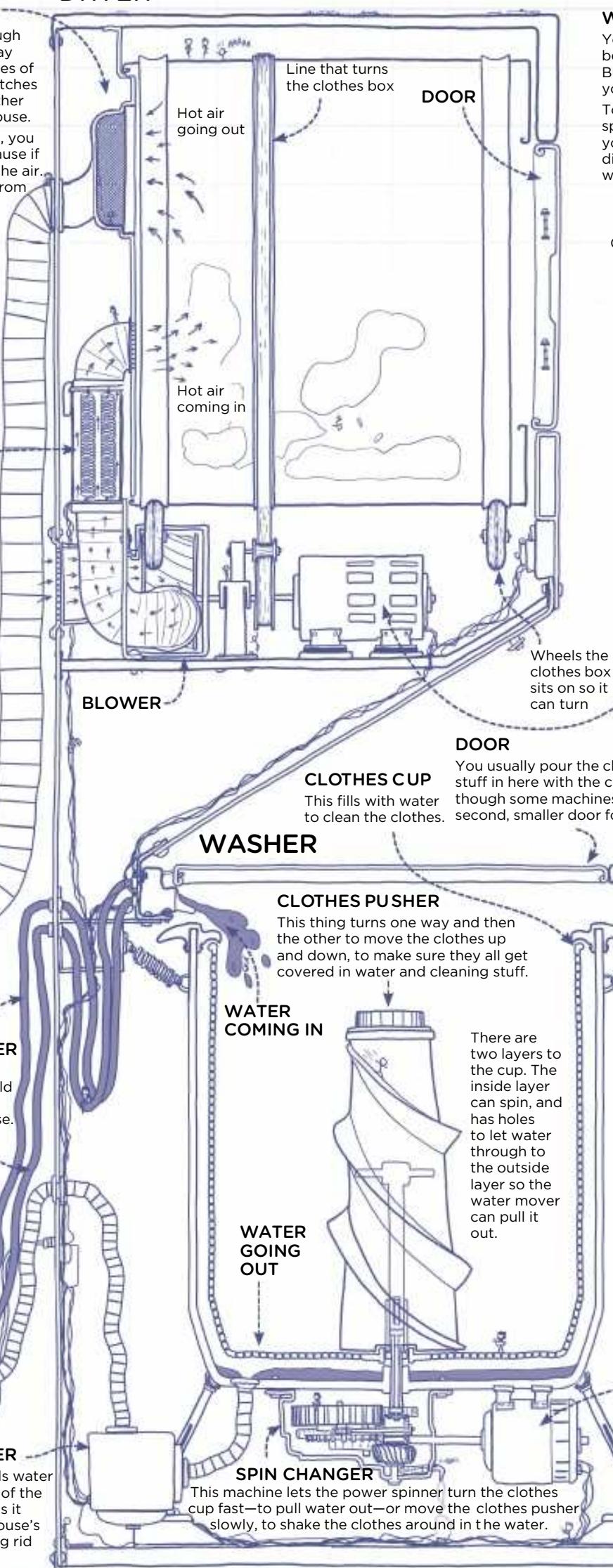
HEATER

This works the same way as a hair dryer. Power runs through metal lines. This makes the metal hot for the same reason lights get hot. Then the air blows over the metal.

OUTSIDE HOLE

This carries the hot air out of the house.

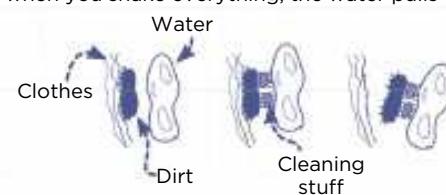
On a cold day, sometimes you walk past these holes when the machine is running, and the warm air feels nice on your face and smells like clean clothes.



WHY CLEANING IS HARD

You can wash away some kinds of dirt using water, because dirt sticks to water and gets carried away by it. But other things that make clothes dirty, like some stuff your skin makes, don't stick to water.

To get rid of stuff that doesn't stick to water, we use special cleaning stuff. When you put this stuff in with your clothes, it sticks to the stuff that makes clothes dirty, but it also sticks to the water around it. Then, when you shake everything, the water pulls the dirt free.



CONTROLS

You use these to decide how clean you want your clothes to be and how careful you want the machine to be with them.

WASHING	DRYING
Water heat	Air heat

Hot water cleans better but can also wash out colors.

Hard shaking cleans better but can tear clothes.

DRYING

Running time

Hot air dries better but hurts clothes more.

Longer time dries better but hurts clothes more.

POWER SPINNER

This spins the clothes holder so the clothes turn over. If it didn't, only the top surface of the clothes would get dry. It also turns the air blower, which pushes air into the hot air box.

SPINNING REALLY FAST

It's hard to get water out of clothes. To do it, the cup spins really fast. The edge of the cup goes about as fast as the fastest horse.

This pushes the clothes against the side of the cup, and it makes the water fall out of the clothes and into holes in the cup wall. Then the water falls to the bottom, and the water mover pulls it out to get rid of it.

SOFT HOLDERS

Because the clothes cup spins so fast, it's hard to keep it from shaking, making loud noises, or breaking.

To make the cup quieter and keep it from breaking, they hang it on holders that can stretch. This lets it move around a little, which makes it quieter. (It's just like when someone calls you and your phone shakes; it's much louder if it's sitting on a hard table than if it's on a soft bed.)

Letting the cup move around makes it quieter, but if all the clothes end up on one side of the cup, it can move around too much. Then the machine starts making a loud noise as it shakes. Most machines can tell when this is happening and turn themselves off; if they didn't, they could shake themselves to pieces.

POWER SPINNER

This turns the clothes cup and the clothes pusher in the middle. It also runs the water mover.

WAIT

Why is this in your house?

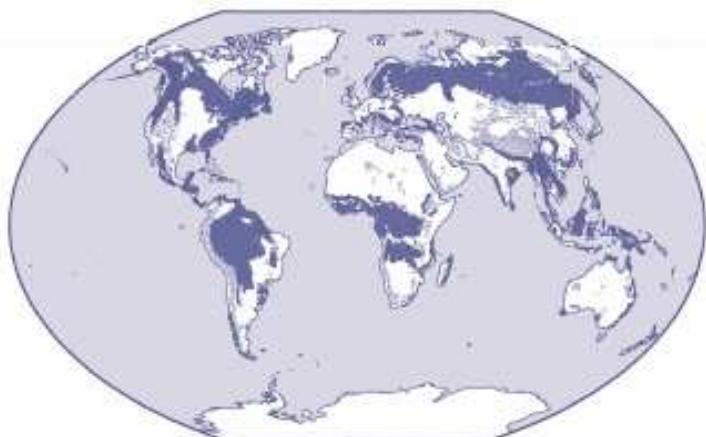


EARTH'S SURFACE

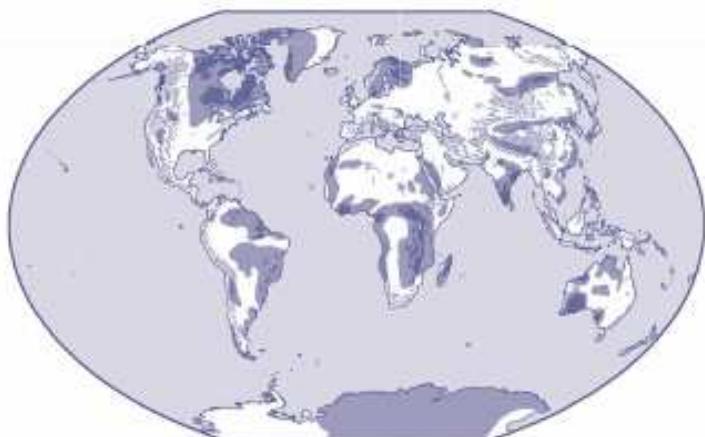
These maps show the Earth's surface. The Earth's surface is special, as far as we know. It's the only place where we've found seas of water, and the only place where the land is made of sheets of rock that move around. There are a lot of interesting things here. These maps show where some of them are.

Earth is a round ball, so to fit its surface on a page, it has to be stretched out. This changes the shapes and sizes of some areas. On this map, it makes the land at the top and the bottom look much bigger than it really is, and some of the places near the sides look stretched out.

There's no way around this problem. Every paper map of a round world is wrong about size, shape, or the direction from one place to another. The shape chosen for this map tries to keep all these things in mind, not stretching any one part too much or making any area look too wrong.

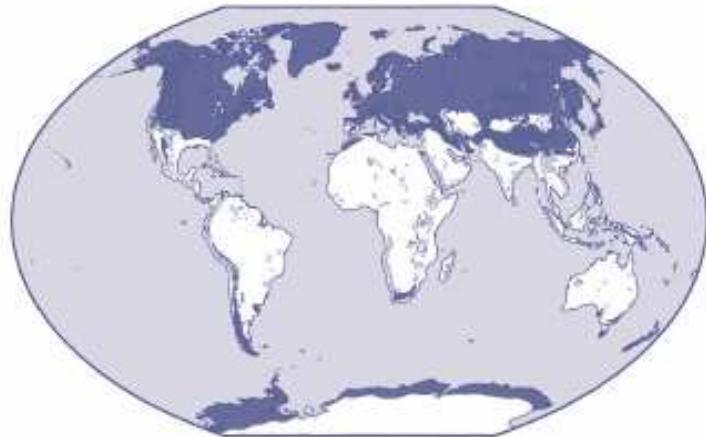


PLACES WHERE THERE ARE A LOT OF TREES

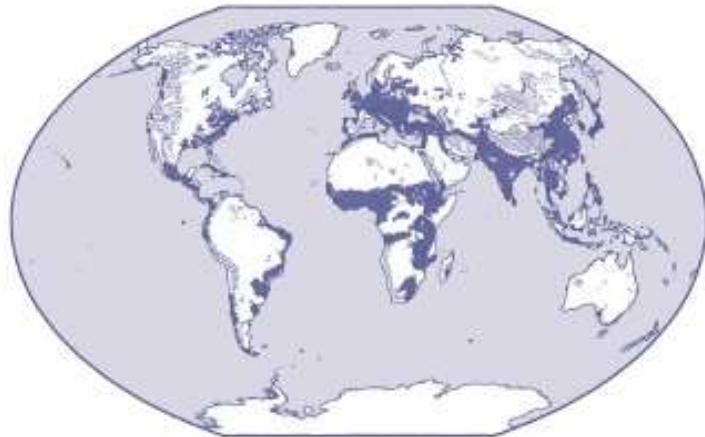


PLACES WHERE THE ROCKS ARE OLD

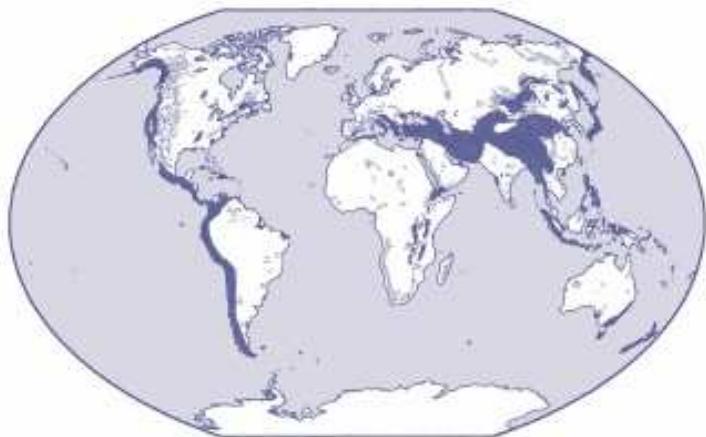
■ As old as the first big animals ■ As old as the earliest life



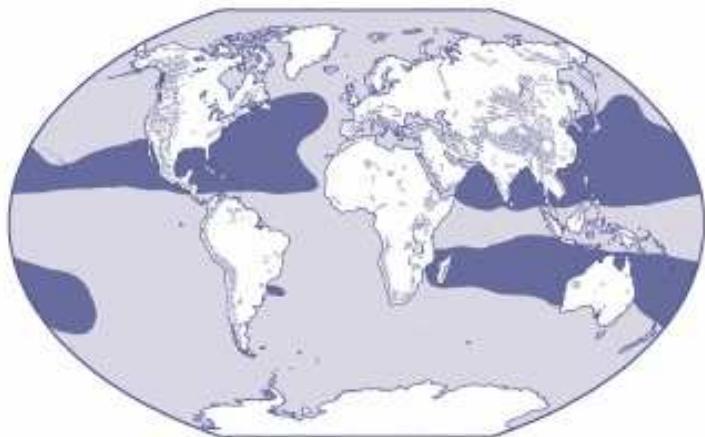
PLACES WHERE IT SNOWS



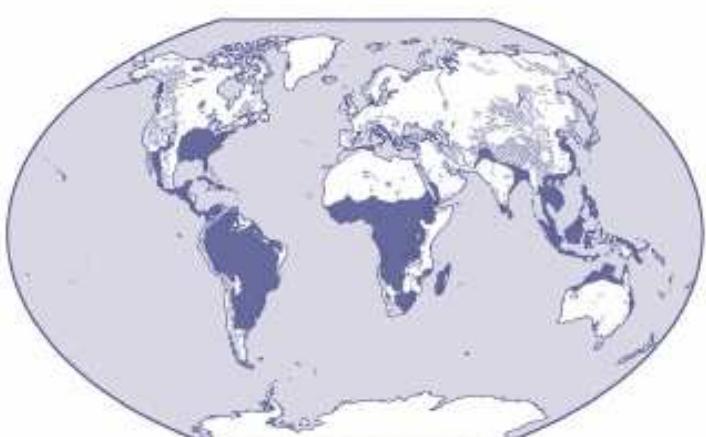
PLACES WHERE A LOT OF PEOPLE LIVE



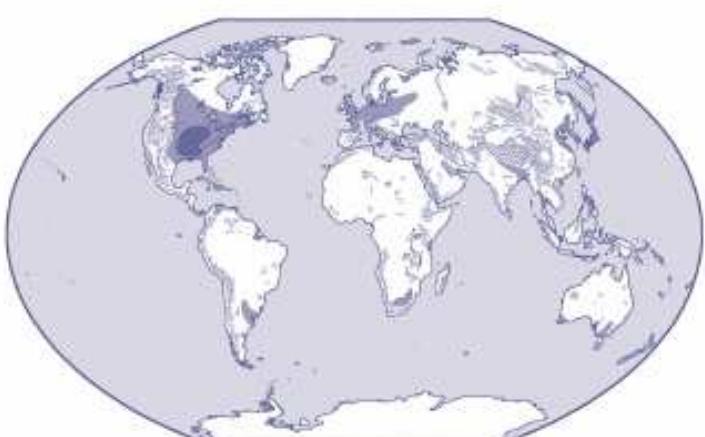
PLACES WHERE THE EARTH SHAKES A LOT



SEAS WITH BIG WARM CIRCLE STORMS

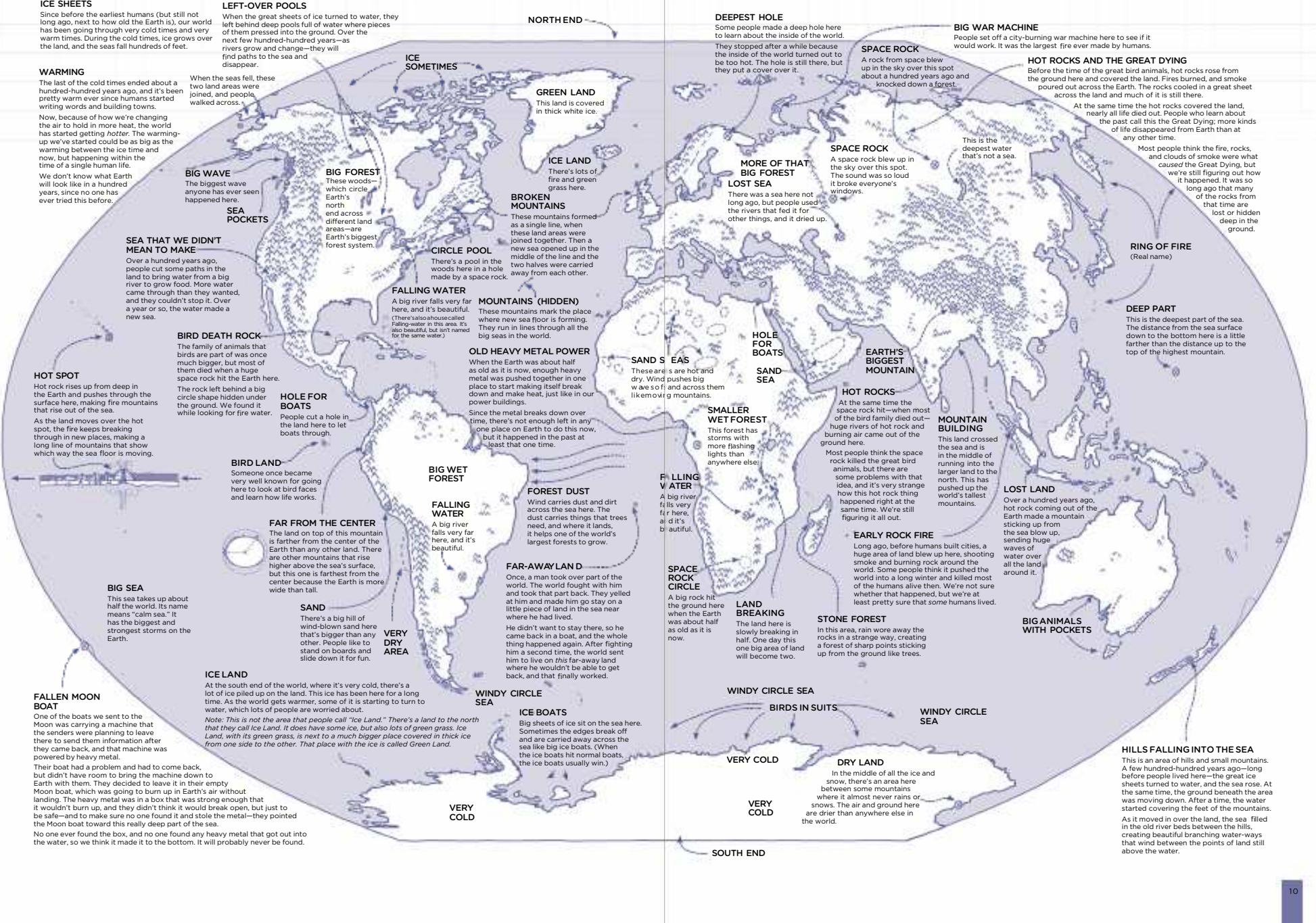


PLACES WITH LOTS OF FLASHING SKY LIGHTS



PLACES WHERE LONG SPINNING CLOUDS REACH DOWN FROM STORMS AND BLOW AWAY HOUSES

■ Sometimes ■ A lot



UNDER A CAR'S FRONT COVER

HOW COOLERS WORK

Some coolers work by just using water to carry away heat from hot things. But some machines can use power to make things colder than the air around them.

You need some cooling stuff. The best kind of cooling stuff is something that's air when it's as warm as a room, but turns to water when it gets cold. There are a few kinds of air that work for this.

The cooling air starts off as warm as the air outside.

To start the cooling, first you push the air into a smaller space. This makes it get hot ("making air smaller makes it hotter" is an important air law). For some coolers, this turns them to water.

Next, you let the stuff cool down while holding it in the smaller space. When it's done cooling, it's back to being as warm as the air again, but it's smaller.

Last, you let it get big again. (If it's water now, it will turn back to air.) Because of the air law, this means it will get colder, just like making it smaller made it hotter. You use the cold air to cool things down. You keep doing this until it warms back up, then send it back and do the whole thing again.

SLIDE FIXER

If you stop too hard, your wheels can stop turning and start to slide. Once wheels start sliding, they become less good at stopping the car.

When the car's cooler feels that one of the wheels has started sliding, this box lifts the stoppers away from the wheel enough that it grabs the ground and starts turning again. Then it presses the stoppers back down. It can do this many times each second. This box makes cars much, much better at stopping.

WINDOW CLEANING WATER HOLE

If you run out of cleaning water, you can pour more in here.

TURNING LIGHTS

These tell other cars that you're about to turn. A few moments before you turn, you should pull the stick that makes the lights flash. Some people seem to have a hard time with this idea.

FRONTLIGHTS

These let you see the road when it's dark.

CIRCLE LINE

This line goes around the fire box's turning stick, then goes around a lot of other wheels in the car. The power difference is like the fire box makes power for the power box. That way, the fire box can turn them all while it's also turning the ground wheels.

Sometimes this breaks. When that happens, your fire box can only turn the ground wheels. Your car can keep driving, but it won't be able to turn down so you'll only be able to drive for a few minutes before the car gets too hot and turns itself off.

FIRE BOX

This fire box is the car's pusher. Like sky boat pushers, it makes power by burning fire water using air from outside.

For example, when you push air from the fire water, the car burns it in little closed boxes. When the water burns, it gets hot, which makes it get bigger and push on the walls of the box. One of the walls of the box can move, and it has a stick that joins it to a wheel.

When the sides of the little boxes move, their sticks move their wheels around. Those wheels are all joined by a turning stick. That stick turns more wheels, and those wheels turn the wheels that touch the ground.

FIRE STARTERS (INSIDE)

These use power to make little flashes that light the fire water.

SMOKE CARRIER

This carries the air out of the fire box after it's done burning.

POWER CHAMBERS

These sit on top of the fire starters. They take the kind of power made by the power box and turn it into a kind of power that works better for starting tiny fires in the fire box.

SMOKE BURNER

When you burn fire water, the smoke it makes has lots of stuff in it that can make people and animals sick. This machine helps the smoke finish burning so it turns to air and water.

(The kind of air it turns into isn't good for the world, either, but at least it's better than the kinds in the smoke.)

OUT THE BACK

This line takes the cleaner smoke and sends it out through a hole in the back of the car.

There's lots of stuff under the front cover of a car. The biggest thing is usually the fire box, which turns the wheels to push the car.

But there's a lot of other stuff, too, and even someone who knows a lot about cars can have a hard time telling what every part is.

This picture shows some of the things you might see if you open a car's front cover.

NOTE:

Before opening the car to look under the cover, you should stop driving.

FOOT HELPER POWERED BY NOTHING

This machine feels when you push the stopper with your foot and helps you push harder.

It's powered by "nothing." This sounds strange, but it's the same thing that lets you drink from a cup using a drinking stick.

The fire box that powers a car pulls in lots of air to burn, which leaves nothing behind. Lines joined to it are also "full" of nothing, and the car uses that nothing to pull on stuff.

STOPPER BOX

This box is joined to the wheels by carrier lines full of stopping water. When you push the stopper with your foot, it pushes water down the lines. That water pushes the stoppers against the wheels.

STOPPING WATER

The stoppers that press against the wheels wear away over time, which means you have to push them farther to get them to touch the wheels. To push the stoppers further, the stoppers both try to push more water down the line. This cup holds water for it to use. If the water in here falls too low, it might mean your stoppers are almost worn away and you need new ones.

FIRE BOX COMPUTER

This computer watches how the fire box is working, and decides how much fire water to add to the air it sends in.

The computer also decides at exactly which point to turn on the fire starters as the fire box's stick turns. If they turn on at the wrong time, it can make the fire box stop pushing as hard, make loud noises, or break.

SHARED LINE

This power line joins one end of the power box to the meter of the car. All the other parts that use power also touch the metal of the car. That way, power runs through them, through the car, and back to the power box.

All these parts are made sure they're touching each other through the body of the car. If they don't, power could build up between them, and that can make it start running the wrong way through a part, which can break things.

HITTER

If the car runs into something, this part hits it first.

LINE FROM COOLER IN SEAT AREA

SLIDING WATER

This water helps the parts of the fire box spin without getting stuck. If you run out of it, the engine stops working, and sometimes the parts get stuck together and it can never turn again.

This water gets dirty, so you have to change it sometimes.

WINDOW CLEANING WATER

This holds the water that pours onto your windows when you pull on the cleaning control.

CLEANING WATER PUSHER

This pushes the water out.

TURNING LIGHTS

These tell other cars that you're about to turn. A few moments before you turn, you should pull the stick that makes the lights flash. Some people seem to have a hard time with this idea.

FRONTLIGHTS

These let you see the road when it's dark.

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THING THAT PUSHES AIR INTO A SMALL SPACE

This thing is like a bunch of blowers work. It cools things the same way your home ice box does (look at the top of the page to learn more about this).

STARTER

Once the stick in the fire box starts turning, it keeps itself turning with its own power, but it needs this spinner to start it turning. This is powered by the power box. If your power box is empty, this spinner can't spin, which is why your car won't start.

AIR COOLERS

These things cool down hot stuff by letting air blow over them. They're in the front of the car as it moves, but there are also blowers that pull air through the coolers even if you're not moving very fast.

WHICH COOLER IS WHICH?

There are two coolers here. The one in back cools the fire box, and the one in front cools the cooling water for the people in the car. (The people-cooler is in front because you need colder air to cool people. A fire box is so hot that warm and cold person-air are almost the same to it.)

LINES TO AIR COOLERS AND HEATERS FOR PEOPLE

When you push the go stick with your foot, this lets more air into the fire box, which makes it run faster. How fast the engine goes is controlled only by how much air you let in; the computer decides how much fire water to add.

FAST OR SLOW CONTROL LINE

When you push the go stick with your foot, this lets more air into the fire box, which makes it run faster. How fast the engine goes is controlled only by how much air you let in; the computer decides how much fire water to add.

STOPPER CONTROL STICK

This machine feels when you push the stopper with your foot and helps you push harder.

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POWER BOX

This box holds power to run different parts of the car. To start the fire box turning, you need a lot of power. This power box is built to let out its power very fast.

You have to be careful, because if you let the two lines from the power box touch, they will let out all their power. This is enough power to start a fire or turn a small piece of metal to water.

AIR CLEANER

The fire box burns lots of air very fast. If there's stuff in the air, it can hurt the fire box. This box cleans air before it gets sent to the area where fire water is burned.

WHEEL BOX

The stick from the fire box goes into a huge box full of wheels, and that box turns the ground wheels. It's there so the fire box can turn at the same number of times each second no matter how fast or slow the car is going. The wheel box is as big as the fire box and has lots of parts inside, but most of it is hidden under the other parts here.

SKY BOAT WITH TURNING WINGS

Normal sky boats have to go fast so the air hits their wings hard enough to hold them up. If they fly too slow, they fall. (Sometimes falling makes them go fast enough to fix it!)

This boat works just like those sky boats, but it uses a cool idea: Instead of the whole boat going fast, only its *wings* go fast. The rest of the boat can go as slowly as it wants—or even stop and sit in one place in the sky.

If a normal sky boat had wings that went faster than its body, the wings would fly away, but this boat's wings go in a circle. That keeps them near enough to hold on to while still going around fast enough to fly.

TURNING WINGS

These are a lot like the wings on normal sky boats, but they go around instead of forward.

POINTING WINGS

These wings keep the boat pointed straight. (The pusher next to it helps with that, too.)

POWER SPINNER

This is a fire water machine that works like a sky boat pusher, but this kind of boat uses all the spinner's power for turning the stick holding the turning wings. Hot air comes out, like in a sky boat pusher, but it doesn't push on anything.

SPIN CHANGER

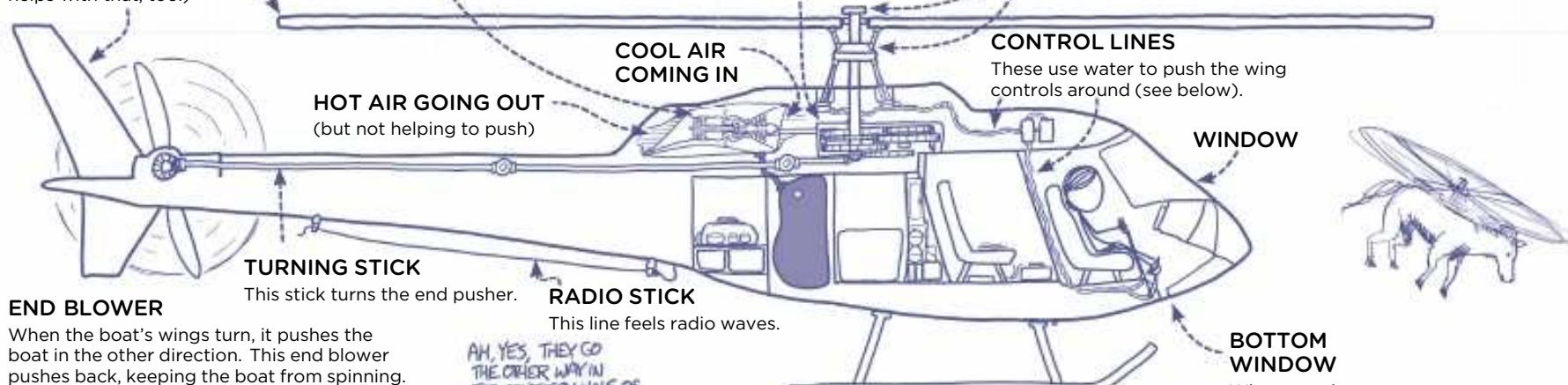
To work best, the power spinner needs to turn very fast, but the wings can't go around that fast. The spin changer uses wheels with teeth to make the wings turn more slowly than the power spinner. If the boat didn't have this box, the wings would turn the same number of times each second as the power spinner, and the ends of the wings would go a lot faster than sound. That would make them stop working, and probably break off.

BOAT HANGER

The boat hangs under the wings, and this piece of metal holds them together.

WING CONTROLLER

This is a machine for making small changes to how the wings are turned as they swing around, which changes how they push on the air. (It's a little confusing—you can read more about how it works below.)



END BLOWER

When the boat's wings turn, it pushes the boat in the other direction. This end blower pushes back, keeping the boat from spinning.



In a few countries, sky boat wings turn right. Most turn left.

HOW THESE SKY BOATS GO

A sky boat's wings can turn so that they're going straight into the wind, or so that the wind is pushing them up. If they turn straight into the wind, they don't lift the sky boat.

To go forward, a sky boat controls its wings so the one in the front goes straight into the wind, and the one in the back turns so it gets pushed up.



This makes the sky boat lean forward. Before, the wings were just pulling it up, but after it leans forward a little, they pull it a little forward, too. The more it leans, the faster it goes forward. If it leans too far, the wings will only pull it forward—not up. This causes bad problems.

WAIT, HOW DOES THAT WORK?

You might wonder how a sky boat can turn its front wing and not its back wing, since the wings keep changing places.

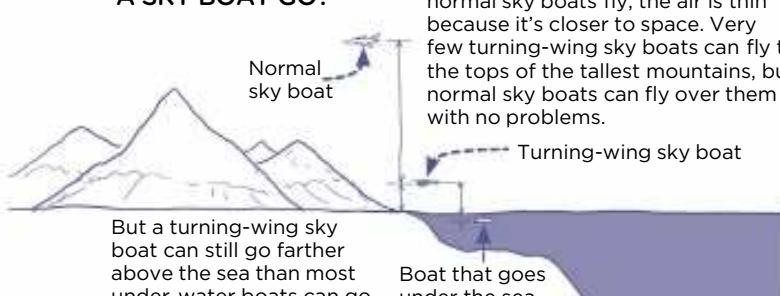


The edge of each wing has a stick on it, and these sticks run to a ring. This ring spins with the wings and turning stick, and sits on top of another ring that doesn't spin.

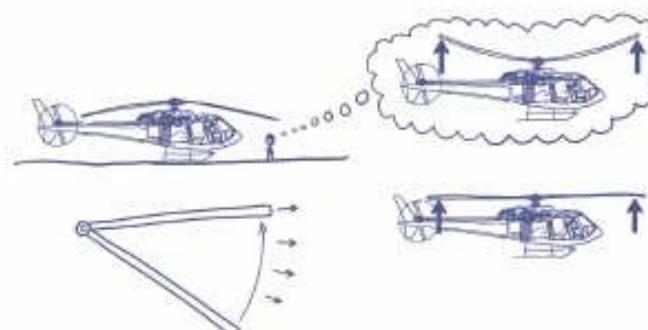
To go forward, the driver uses a control to turn the bottom ring, which turns the spinning top ring, too, so it's higher on one side. When a wing is on that side, its stick pushes its back edge up, so it goes straight into the wind and doesn't lift at all. When it goes around to the other side, its back edge gets pulled down, making it lift a lot.

A sky boat with turning wings needs more air to push against than a normal sky boat. Up high, where normal sky boats fly, the air is thin because it's closer to space. Very few turning-wing sky boats can fly to the tops of the tallest mountains, but normal sky boats can fly over them with no problems.

HOW HIGH CAN A SKY BOAT GO?



But a turning-wing sky boat can still go farther above the sea than most under-water boats can go below it.

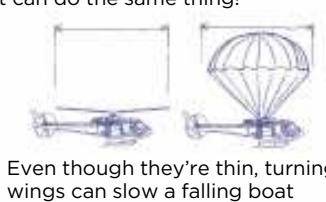
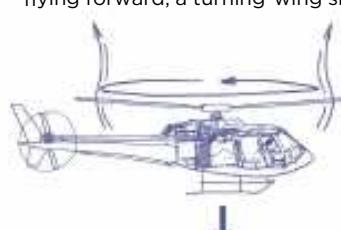


BENDING WINGS

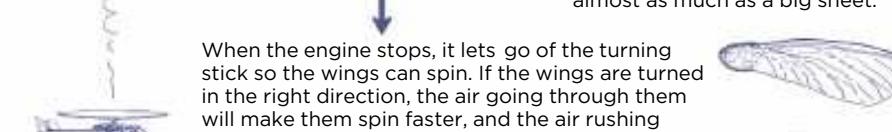
Sometimes, sky boat wings bend down while they're sitting on the ground. This might look like it would cause some problems, but it's normal! Wings that bend a little can be easier to control, and when they're swinging around, the force of the swing stretches them out straight.

WHAT IF EVERYTHING BREAKS?

If a normal sky boat stops working, it can keep going, slowly moving down from slowing down too much. It turns out that even when it's not flying forward, a turning-wing sky boat can do the same thing!

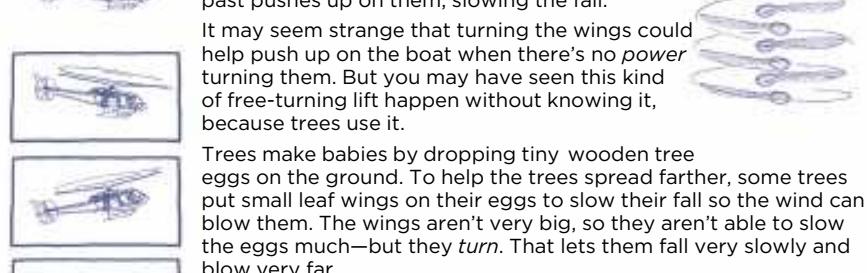


Even though they're thin, turning wings can slow a falling boat almost as much as a big sheet.



When the engine stops, it lets go of the turning stick so the wings can spin. If the wings are turned in the right direction, the air going through them will make them spin faster, and the air rushing past pushes up on them, slowing the fall.

It may seem strange that turning the wings could help push up on the boat when there's no power turning them. But you may have seen this kind of free-turning lift happen without knowing it, because trees use it.



Trees make babies by dropping tiny wooden tree eggs on the ground. To help the trees spread farther, some trees put small leaf wings on their eggs to slow their fall so the wind can blow them. The wings aren't very big, so they aren't able to slow the eggs much—but they *turn*. That lets them fall very slowly and blow very far.

So don't worry if your sky boat turns off. It can still fly, just like a tiny spinning leaf, carrying you to the ground alive and safe.

THE US'S LAWS OF THE LAND

This country was started when a group of people who were part of another country decided to break away and start their own

country. They wrote down a small set of laws to be the ground that the new country—and its many future laws—would be built on.

More than two hundred years later, those laws, with some changes, are still being followed, learned about, and understood in new ways.

People used to take other people from far-away countries, bring them across the sea, and force them to work for their whole lives without getting paid. There was a part of the law here that said that when you're counting people, you should only count a forced worker as part of a person. A while after this was written, we fought a war over whether people should be allowed to own other people like that. The side that said "yes" lost, and we crossed this part out.

This part also had some laws about buying and selling people that we changed after the war.

You may notice that this doesn't actually say whether the Second Leader becomes the First Leader or not. This made things confusing later on.

No matter how many changes people make to this system, it will probably never quite work right.

BEFORE WE START

Hi; we're the people in these little countries called "states," and we want to get together into a country. We want to make everything nice and quiet, keep anyone from hurting us, and make sure our kids will be free. That's why we're making a country. Here are its laws:

BOOK ONE: The Law Makers

Part One: Laws are made by a group called Law Makers. There are two rooms of Law Makers: the House and the Serious Room.

Part Two: The people pick Law Makers to send to the House for two years at a time. Bigger states get to have more people in the House. Oh, and the country needs to count its people sometimes so it can figure out how many chairs the room needs.

Part Three: Every state sends two Law Makers to the Serious Room for six years at a time. They can't be too young.

Part Four: States make the laws about where and how people get together to pick leaders and decide what the country should do.

Part Five: When the Law Makers get together, they should write down what they talk about.

Part Six: Law Makers get paid. They can't get in trouble for what they say at work, but they also can't do any other job for the country while they're Law Makers.

Part Seven: If the Law Makers have an idea for a new law, and more than half the people in both rooms say they like it, they send the idea to the country's leader to be made into a law. If the leader doesn't like the idea, the Law Makers can still make it a law, but it takes more of them.

Part Eight: Law Makers are allowed to take money from people, but only sometimes, and they can't just take it all from one person or anything like that. They're allowed to use the money to build certain kinds of things, like letter boxes and boats with guns on them. They can get people in trouble for a few things, like stealing boats (even if they do it far away) or making pretend money and telling people it's real.

Part After Eight: There are lots of things the Law Makers aren't allowed to do. They can't make up laws to lock someone up for something they already did, or give some people special names that mean they're more important to the country than others.

Part Ten: There are some things the country can do that the states can't, like creating money or starting wars. The states also can't take money from other states or put guns on boats.

BOOK TWO: The leaders

Part One: Every four years, the people in the country pick who should lead them. They pick a First Leader, who is the head of the country, and a Second Leader, who isn't. If the First Leader leaves or gets fired, the Second Leader takes over the work the First Leader was doing. The states get to choose the leaders by a point system where each state gets one point for each Law Maker it has.

Part Two: The leader controls the people who fight for the country. The leader can also talk to the leaders of other countries and get anyone out of trouble.

Part Three: Now and then, the First Leader should let the Law Makers know how everything is going, and suggest some ideas.

Part Four: The Law Makers can fire the First Leader, but only for doing something really bad, like becoming leader of another country at the same time and having them attack us, or stealing the country's money and going to live on a boat.

BOOK THREE: The law deciders

Part One: There's a group of people called the Top Law Deciders. They help decide whether laws have been broken. The country can set up other groups of law deciders, too, but they're not as important as the Top Law Deciders.

Part Two: The Top Law Deciders only decide certain kinds of law fights, like if the leaders of another country send someone here and they get in a fight, or when someone has a law fight with a state. The rest of the time, they can only step into certain law fights, and only when another decider has decided something and the people in the law fight don't agree.

Part Three: "Turning against the country" can only mean a few very clear things: fighting us, joining a group that's fighting us, or helping a group that's fighting us. To prove someone has turned against the country, two people need to say they saw it, or the person has to have admitted it in a deciding room. Law Makers can make turning against the country against the law, but they can't use it as a reason to do whatever they want to someone. (This had been a problem in some other countries.)

BOOK FOUR: The states

Part One: There are states, and they have to get along. When the law deciders in one state decide something, the law deciders in other states don't have to make that choice the same way, but they can't make it so the other choice doesn't count. That means that if someone gets in trouble in a state, they can't go to another state and get a law decider to tell them they're not really in trouble after all.

BEFORE WE START

country. They wrote down a small set of laws to be the ground that the new country—and its many future laws—would be built on.

Part Two: You have the same rights no matter what state you're from. Also, if you get in trouble in one state and run away to another, the other state has to send you back to the first one.

Part Three: The country can add new states. The country can also own areas of land inside states (to be used for things the country needs) just like people do.

Part Four: The country promises that every state will be run by its people, and that if someone attacks—or if they have a problem and ask for help—the whole country will come and fight for them.

BOOK FIVE: Making changes

People can change these laws, but most of the Law Makers and most of the states have to agree on the change. It can't just be a little more than half—it has to be most of them. If the states want to make a change without the Law Makers, the states can also hold a big law party where each state comes and shares their ideas for changes, and then they decide which ones they like.

BOOK SIX: Everyone, listen up

These laws are important and everyone has to follow them. Also, if the country agrees on something with another country, that's important, too. Other laws are important, but less so. Anyone working for the country has to promise that they're on our side (but they never have to say anything about God).

BOOK SEVEN: Does this all count yet?

This country only becomes real if more than eight states join.

TEN CHANGES:

Change One: The country can't make laws about God. It also can't make laws about what people talk about, who they hang out with, or what they write about, and can't stop them from telling the leaders if they're angry about something, as long as they're not starting fights.

Change Two: Since having well-trained normal people with guns is important for keeping the country safe, no stopping people from having guns.

Change Three: Just because someone's fighting for the country doesn't mean you have to let them stay in your house.

Change Four: The police can't go through your stuff without a good reason and a special pass from a law decider.

Change Five: The police can't do stuff to you just because they want to; they need to make it clear what you did wrong. They can never make you admit you broke a law.

Change Six: If you get in trouble, you can have a chance to fight about it in front of a group of normal people in a deciding room, and you can always have someone who knows about laws to help you if you want. If someone says you did something bad, you get to talk to them face-to-face.

Change Seven: You can have your law fight in front of a group of normal people even if you're not in trouble.

Change Eight: Police can't be mean for fun, even to bad people.

Change After Eight: People can do stuff not talked about here.

Change Ten: The country can only do the things these laws let it do. The states can do whatever.

MORE CHANGES:

Change: People can't have law fights with other states—only their own.

Change: We changed the laws for how we pick leaders.

Change: We just had a big war with some states over whether it's okay to buy humans and force them to work. The side that said "no" won. No more buying humans or forcing them to work.

Change: Also, now that the war is over, we're adding a number of laws about what states can and can't do to people.

Change: Oh, and people of any skin color can help pick leaders and decide what the country will do.

Change: The country can take some of your pay to get money for things we need.

Change: People, not a state's leaders, pick the Law Makers who will sit in the Serious Room.

Change: Let's get rid of beer and wine.

Change: People of any sex can help pick leaders and decide what the country will do.

Change: We moved up some of the days when new leaders take over for the old ones, because we have cars now and don't need to allow a few months for people to travel.

Change: Never mind about getting rid of beer and wine.

Change: You can't be the First Leader forever.

Change: People in the special town where the leaders and Law Makers live can help pick leaders and decide what the country will do, just like if they lived in a normal state.

Change: No making people pay to help decide things.

Change: We made it clearer what happens when a leader dies or leaves.

Change: Younger people can help pick leaders now.

Change: If Law Makers decide to change how much they're repaid, they don't get the new pay until after the people in their state have had a chance to decide whether to fire them and pick someone else.

The states have never tried making a change using the "law party" idea, and no one is really sure how it would work if they did.

We made these changes right at the start, because some people said they wouldn't agree to join unless we added this stuff.

The way this is worded has been confusing to people over the years. Making things even worse, when it was written down for the different states and Law Makers to agree to, not all of them saw it with the same marks between the words.

Later, we got a little clearer about what states can and can't do.

These are changes we made over the next two hundred years.

We made this change because it started feeling strange that the people picked new leaders, yet the old ones stayed in their job for many months.

... although it's somehow still not completely clear, even though we've tried to get it right like three or four times.

Some of the states agreed to this change, but then it got forgotten. Later, we found it and other states decided to pass it. The thing it fixes hasn't really been a problem, but it seems like an okay enough idea, so why not?

THE USS'S LAWS OF THE LAND

(A boat)

This boat is sometimes also called "Old Metal Sides" because someone once tried to make a hole in the side but couldn't.

This boat was built to fight in wars more than two hundred years before this book was written. Even though it's old, it's still part of the country's fighting forces. That means that if someone were attacking the country with boats, and the country's leader said, "Send all our boats to that boat fight," this one would have to go, too.

Of course, that's not really going to happen, since this boat is over two hundred years old and would not help very much in a fight. Instead, the country keeps it around so they can let people visit it, help people think about the past, and teach everyone how old boats worked.

Note: There are lots of special words for things on boats. If you call this thing a "boat," people who know a lot about boats might get mad at you.

When the boat was first built, they put up a message like this around the city:

Does anyone want to help their country? Our leader told us to take this boat, which has lots of guns, and get it ready to drive around on the sea as soon as we can.

We set up a place near the bird sign on Front Street and need almost two hundred people to come help their country for a year. We'll pay ten (or more, if you're good) every month, with two months of pay ahead of time if you want. No sick people.

This is a great chance for people around here to fight for our country and get even with anyone who hurts us. Come to the place we talked about. We'll be nice to you!

Signed, the leader of the boat.

Oh, also: Someone from the fighting forces will be there looking for fighters and music players. Tall people only.

WIND POWER

This boat was made before anyone had engines. It uses wind to pull it around. It has three big wooden sticks—sort of like trees—with lots of sheets hanging from them. The wind pulls on the sheets, which pulls the boat.

If you want to go faster, you can put up more sheets. But if the wind is very strong, you can't put up too many sheets or the trees will break.

MIDDLE STICK

BIRD HOUSE

This is a place where people stand to see things far away. They call it a bird house because it's like being up high in a tree. Climbing up here helps you see farther around the edge of the Earth.

BACK STICK

BOAT LAWS

When someone broke the laws of the boat, they had to stand here in front of everyone while the leaders hit them many times.

FLOOR

The floors were kept very flat and white by people who had to rub them with rocks all the time. This cleaned the floors and made them look nice, but also wore them out.

SMALL GUN

This is for shooting people from other boats who try to visit.

BIG GUNS

These are for making holes in other boats.

PULLER

This machine helps pull things that are too heavy for people.

WIND SHEETS (rolled up)

The rest room is over here. It's not a room; it's just a board with a hole in it. Under the hole is the sea.

LINES

If you're up high and you want to get down to the floor of the boat, you can slide down these lines. This is the second fastest way to get down.

WIND SHEETS

POINT

This helps to hold more wind sheets.

PRETTY PART

The wood here is cut into a nice shape on most boats, just for fun.

STOPPER

If the people want the boat to stay where it is, they drop this heavy, pointy metal thing into the water on the end of a long line. The metal drags on the bottom and keeps the boat from moving too far away. If they want to move again, they can pull in the line to bring the boat over the stopper—so they're pulling up on the line—and the stopper will come free.

LEADER'S ROOM

The leader goes here to rest, make plans, and be alone.

TURNING WING

This pushes on the water to turn the boat.

NICE DINNER ROOM

Only leaders could eat here.

ROOM FOR HANGING OUT

BLOODY ROOM

This is where they took people who got hurt during shooting.

KITCHEN

THE HOLD (FULL OF STUFF)

BIG GUNS

The boat's guns were each heavier than a car, and shot metal balls that were almost as big as a person's head.

DEAD PEOPLE

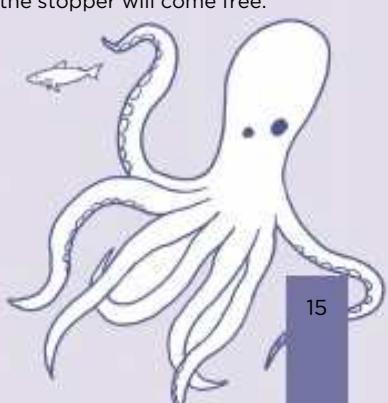
When people who lived on the boat died, the other people would put a sheet around them and a piece of metal and drop them in the water.

NOT REAL

(But people like to draw them.)

BLOW-UP ROOM

This is where they kept the stuff that burns in guns to make them shoot. They were very careful not to let fire in here.

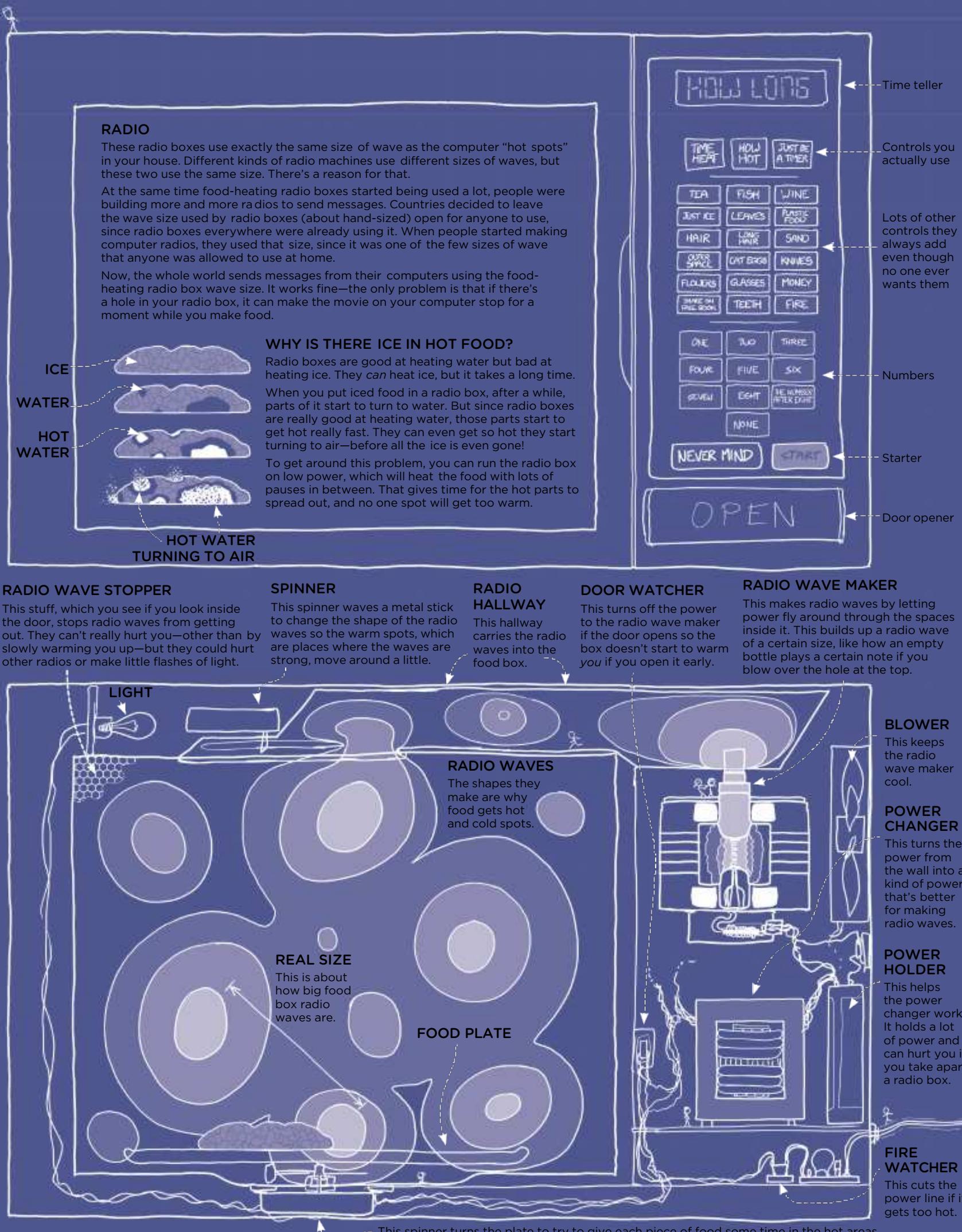


FOOD-HEATING RADIO BOX

These boxes use radio waves to heat food. Radio waves push on the tiny pieces water is made of and make them go faster. When tiny pieces in something move faster, that thing gets hotter. If you send enough radio waves through water, the water heats up.

Food-heating radio boxes can heat up cold food you saved, and let you buy food that's full of ice, keep it for a long time, and then heat it and get rid of the ice. These boxes made it much easier for people to eat without spending a long time making their food.

You can also use a radio box to take fresh food (like fish) and heat it up and turn it into different kinds of food, just like you do with the other heating boxes in your kitchen. But it can be hard to use for that, so be careful, especially with food made from animals.

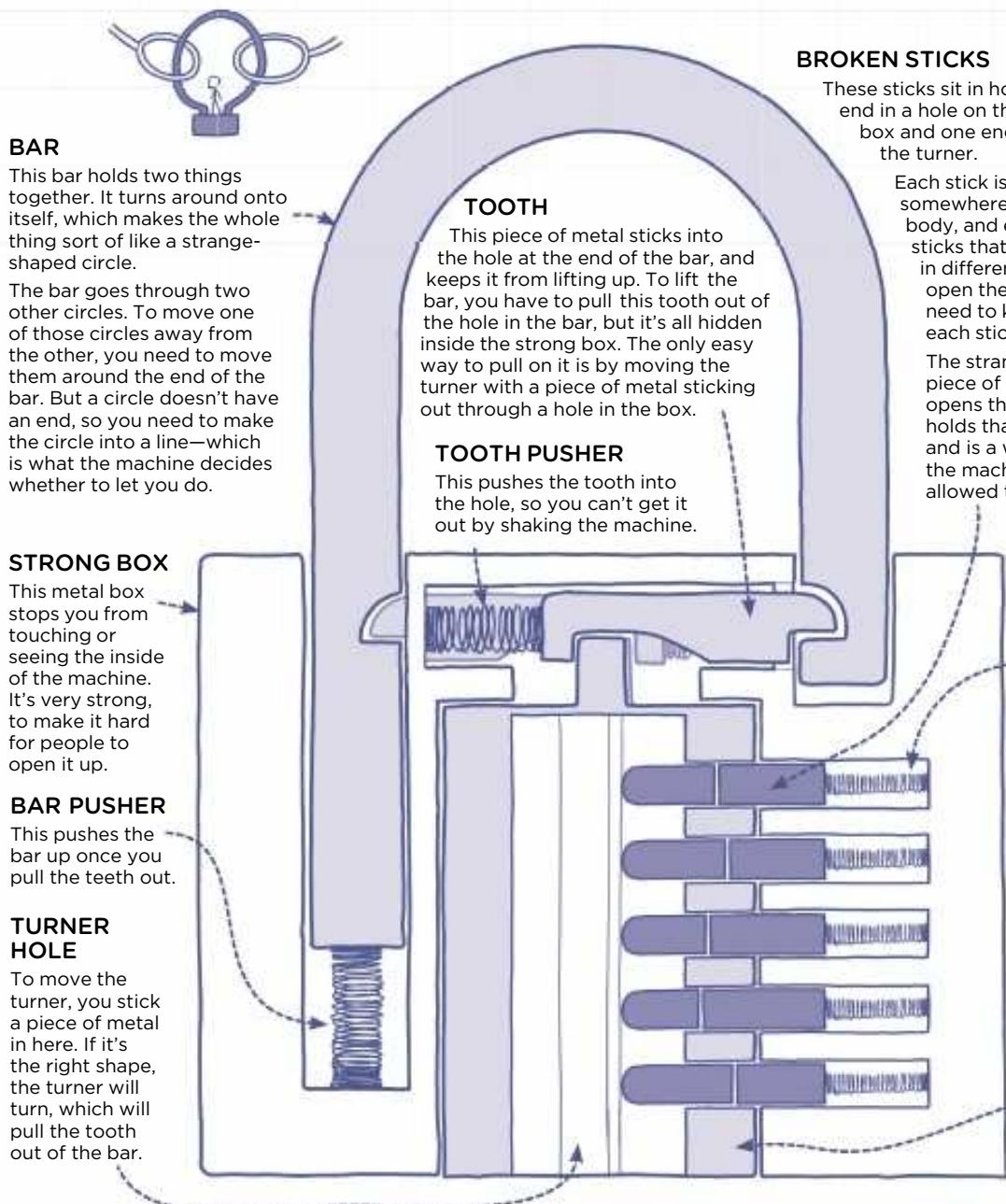


SHAPE CHECKER

This machine checks whether you have a piece of metal with a certain shape. If you do, it lets go of whatever it's holding on to. People put these machines on boxes, doors, and cars to try to control who can open or use them.

What's interesting about these machines isn't really the machine itself. There are lots of different kinds that work in different ways, but they're all the same in one way: They try to put people into groups.

By checking whether someone has a piece of metal that's the right shape, this machine is really a way to try to tell whether people are who they say they are. It's an idea—about which people should be allowed to do something—brought to life in metal.



OTHER CHECKING MACHINES

There are many other kinds of machines for checking whether someone has something (like a piece of metal or special information) and only opening if they do.

OTHER SHAPE CHECKERS

Some kinds of machines need different kinds of metal shapes. This kind uses a circle shape, but the idea of how it works is about the same as the one shown above.

NUMBER CHECKERS

Other machines check numbers instead of shapes. If you know the right numbers, you can make the machine open.

These usually work using metal wheels that turn. When the wheels are all lined up in the right way, the bar opens, but you have to know which way to line the wheels up.

One problem a lot of these machines have is that by turning them and listening and feeling very carefully, you can sometimes figure out how the wheels fit together.

And even if you can't, you can always just try all the numbers. If you're willing to wait, you can open most simple number checkers that way in a few hours.

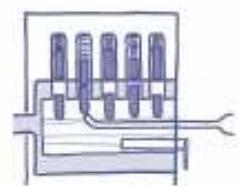
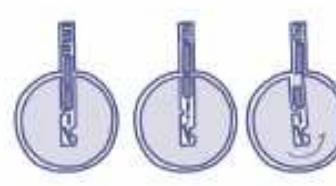
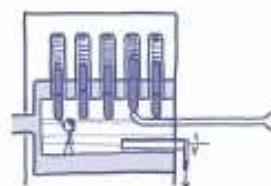
LYING TO THE CHECKER

You can make a machine like this open even if you don't have the right shape. Here's one way to do that:

You start by pushing a thin piece of metal into the hole and gently turning.

While turning it, you reach in with a second piece of metal, and use the end to push on the broken sticks one at a time. If you lift a stick while using your other hand to turn the turner, the broken spot can get caught on the turner's edge.

As long as you keep trying to move the turner, the stick will stay stuck. When you get each of the sticks stuck against the turner, there will be nothing left to stop it, and it will turn and pull out the tooth.



In some places, carrying these pieces of metal can get you in trouble even if you don't open anything with them.

That's sort of a strange law, since there's nothing wrong with using metal to turn a piece in a machine. Lots of people use these to learn how shape checker machines work.

But carrying these pieces of metal can make people worried for the same reason the machines are interesting—because they're not really machines. They're a way of telling people what you want to let them do. And that means these pieces of metal are also seen as messages—the idea that you don't care what other people want.

So it makes sense that people worry about them, even if you just want to learn about cool shape checkers.

And, of course, if you really need to open one of these machines, there are simpler ways to do it.



LIFTING ROOM

A lifting room is a box that carries people up and down in a building.

Today's cities wouldn't make sense without lifting rooms. If we had tall buildings without them, everyone would want to stay on their own floor, because going up or down would take a lot more work than going the

same distance to the side. Tall buildings might have to join up with each other, and people would mostly move between them while staying on their own floors.

Most lifting rooms go straight up and down. A few go to the side while going up and down, to take people to the top of a hill.

There are also lifting rooms that *only* move side to side; those are called trains.

Lifting rooms are safe; there's almost no way they can fall. There are a lot of different parts that help lift them, and each part is made to stop the room—instead of letting it go—if something goes wrong.

LIFTER

These lifters usually sit in a machine room above the top floor the lifting room can visit. They use power to turn a big wheel that pulls a line running between the room and a weight.

WEIGHT

This weight makes it easier for the puller to lift the room. It hangs down on the other end of the line holding the room, so when the puller at the top lifts the room, it's also lowering the weight.

PULLING LINES

Lifting rooms are held and lifted by a big group of metal lines. There are usually around four to eight of them, but it can be more or less than that.

These lines are very strong. Usually, even just one of them would be enough to hold the whole room on its own, but we use more just to be safe.

METAL STICK

LIFTING ROOM

PRETEND CONTROLS

There are controls on the inside of a lifting room that you use to tell it where you want to go. Some of these controls, like the one marked "DOOR CLOSE," don't always seem to do anything.

Some people say that those controls don't even go anywhere, because the lifting room's computer knows when to open and close the door better than you do.

This is half true. On some new lifting rooms, the DOOR CLOSE control might not normally do anything. This is different in different buildings; it's up to the person who owns the building to decide whether to make these controls work.

But the DOOR OPEN control *is* always joined to the lifting room's systems, in case fire fighters need to take full control of the lifters—by putting a special key into the control place—to use them while fighting a fire.

LINE STOPPER

This thing listens to the different parts of the machines, sometimes with the help of a computer, and grabs the line if anything goes wrong.

The line stopper also grabs the line when the room stops at a floor to make sure it doesn't move while people get on and off. It's made so it will keep holding on if the power goes out.

FALL FEELER

This wheel is joined to the room's stopping grabbers by a line. As the room moves up and down, the wheel turns.

If the room starts going down fast, the wheel starts spinning fast, and the little arms in the middle of the wheel swing out and catch onto the teeth around them. This makes the wheel stop turning, which makes the room suddenly pull on the line—setting off the room's stopping grabbers.

GRABBERS

If the fall feeler pulls on the line, these grab the metal stick really hard and stop the room from moving.

WEIGHT LINE

This line is used in the lifting rooms in tall buildings to help keep the weight on the puller even.

When a room is all the way at the top or bottom, the lines holding it add to the weight on one side. When that happens, most of the weight of this line hangs on the other side, which keeps things even.

CATCHER

If a lifting room does fall, these catchers hit a metal plate on the bottom of the room and make the landing a little softer.

There's a second catcher for the weight.

POWER FROM BUILDING

Lifting rooms use a lot of power, but the lights and air systems in the building use even more.

TALL HALLWAY

The lifting room sits inside a long hallway that goes up and down instead of to the side. It can be longer than any of the normal hallways in the building, but most people never see it.

POWER LINE

This line brings power for the lights and controls in the lifting room. It sometimes runs to the top of the hallway, where the pulling machines are, or sometimes to the side of the wall part of the way up the hallway.

DOORS

These doors line up with the doors on the room. When the lifting room stops, both doors open together.

EMPTY ROOM

Lifting rooms are usually empty. People don't put chairs or tables in them except to move those things to other floors. If you tried to use one of these rooms as an office, someone would probably yell at you.



BOAT THAT GOES UNDER THE SEA

We've always had boats that go under the sea, but in the last few hundred years, we've learned to make ones that come back up.

At first, we used those boats to shoot at other boats, make holes in them, or stick things to them that blew up.

Later, we found a new use for these boats: keeping our city-burning machines hidden, safe, and ready to use if there's a war.

WORLD-ENDING BOAT

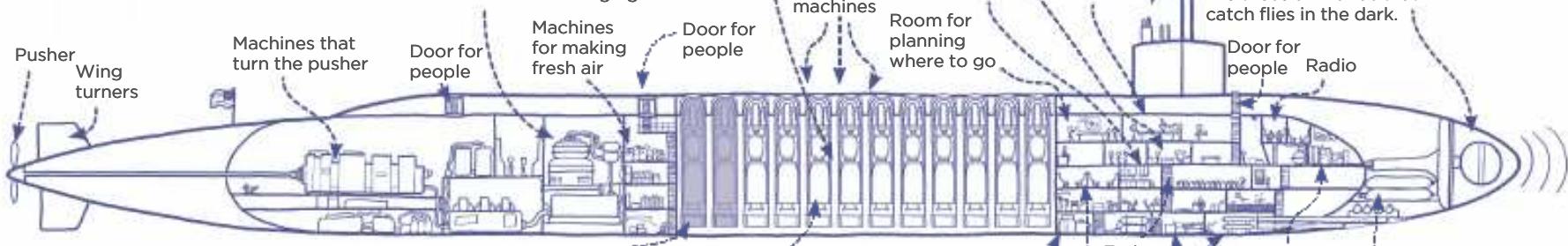
The boat shown here carries up to two dozen city-burning war machines. People have added up the power used during the Second World War—all the machines that blew up, all the guns that fired, and all the cities that burned. It's a lot of fire power. Each of these boats carries several times that much.

SPECIAL SEA WORDS

Most of the time, if you call a really big boat a "boat," people who know a lot about boats will get mad at you. But boats that go under the sea are really called "boats."

HEAVY METAL POWER MACHINE

These boats are powered by heavy metal, just like some power buildings. This means they can stay hidden for a long time without running out of power. Any time heavy metal is used for power, people worry about something going wrong. Of course, given what these boats are built for, people worry even more about the idea of one of them working *right*.



EMPTY ROOMS

A while ago, everyone decided the world didn't need so many city-burning machines. This country agreed to turn off four of the two dozen flying machine carriers in each boat, leaving only twenty.

MACHINES FOR BURNING CITIES

Each of these rooms has a flying carrier full of city-burning machines. While hiding under the water, the boats can shoot the machines into space. Any of these boats can send a machine anywhere in the world in under an hour.

BREATHING STICK

This brings fresh air into the boat, but the boat can also make its own air by breaking water into the parts it's made of. This takes a lot of power, but the boat is powered by heavy metal, so it has enough power to do whatever it wants.

SLEEPING ROOMS

The normal people on the boat sleep on either side of the city-burning machines.

MIRROR LOOKERS

When the boat is hiding under the sea, it can come near the surface and use these sticks with mirrors in them to let the people inside see out of the water.

SOUND LOOKERS

Light can't go far under water, so these boats "see" with sound. The boat makes sound, which hits things and comes back. By listening carefully, the people in the boat can tell what's around them without seeing—just like those skin birds that catch flies in the dark.

OTHER BOATS THAT GO UNDER THE SEA

These are some other boats, drawn to show how big they are next to the world-ending boat above.

WORLD WAR BOAT

This was used by one country in the Second World War. It was called an "Under-Sea Boat."

THE FIRST ATTACK BOAT

This boat was used over two hundred years ago to stick burning things to ships and blow them up.



NEVER-USED BOAT

These were built over a hundred years ago, but kept hidden and never fought. (That's not too strange; today's world-ending boats also hide and have never fought.)

DEEP GOER

Two people used this boat to visit the bottom of the deepest place in the sea.

BOAT FINDER

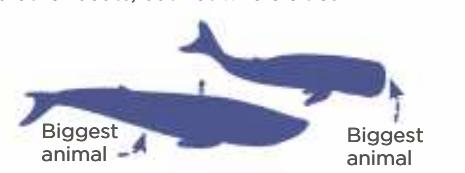
This was used to find a huge boat that had hit some ice long ago and fallen to the bottom of the sea.

MOVIE MAKER DEEP GOER

A man made a movie about the huge boat that hit some ice and broke, then used the money to buy this boat and take it to the deepest part of the sea. (He didn't go there to make a movie. He just likes the sea.)

SMALL ATTACK BOATS

These boats are big, but smaller than the ones that carry our city-burning machines. They carry machines that blow up houses, streets, and other boats, but not whole cities.



HOW DEEP THEY GO

The sea is very deep. Most boats can't go very far down or their walls will break under the weight of the water. To go to the bottom of the sea in most places takes special boats.

PEOPLE

Most of the time, even with the help of metal air holders, people can't go deeper than a few hundred feet (at least, not if they want to come back up).

People *without* extra air sometimes also go that deep and come back up, but those people die a lot.

FIGHTING BOATS

Most fighting boats can only go a few times farther down than they are long. That's not very deep; when a boat is hiding under the sea, the water below it can be ten or even a hundred times deeper than the water above it.

But where they go is deep enough to hide and be safe, so they don't need to go any deeper.

ANIMALS

The large air-breathing animal with teeth can go far, far down into the sea. They go there to eat animals with many arms.

Sometimes the air-breathing animals come back up covered in little cuts and holes, so the animals with arms must fight back, but no one has ever seen it happen.

THE DEEP SEA FLOOR

Only three people have ever been there—two in the deep goer and the movie maker.

BOX THAT CLEANS FOOD HOLDERS

This box is a machine that cleans plates and cups by throwing water at them. The water is full of cleaning stuff, which helps the water stick to the food and pull it off.

If you fill a cleaning box the wrong way, it may not clean well. After people see this happen a few times, they can get strong

ideas about the right way to fill a plate cleaner. When people with different ideas about these machines start living together, this can even lead to fights.

Some ideas are clear to everyone—like that you should always point cups down, so they don't end up full of food water. There's

more, but you don't need to fight over it! There's a book that goes with your plate cleaner, and it shows how you should fill it. (If you've lost the book, you can usually read it for free using a computer.)

TOP HOLDER

The top holder usually has its own thrower, although older cleaners often used one in the middle.

ROLLERS

These let you roll the plate holders in and out.

WATER FOR TOP THROWER

CLEANING STUFF

This is a little cup in the front of the door where you put cleaning stuff.

Once the box is full of water, the door opens and then drops the cleaning stuff into the box.

PLATES

These should go on the bottom, with some space between them so the water can get in.

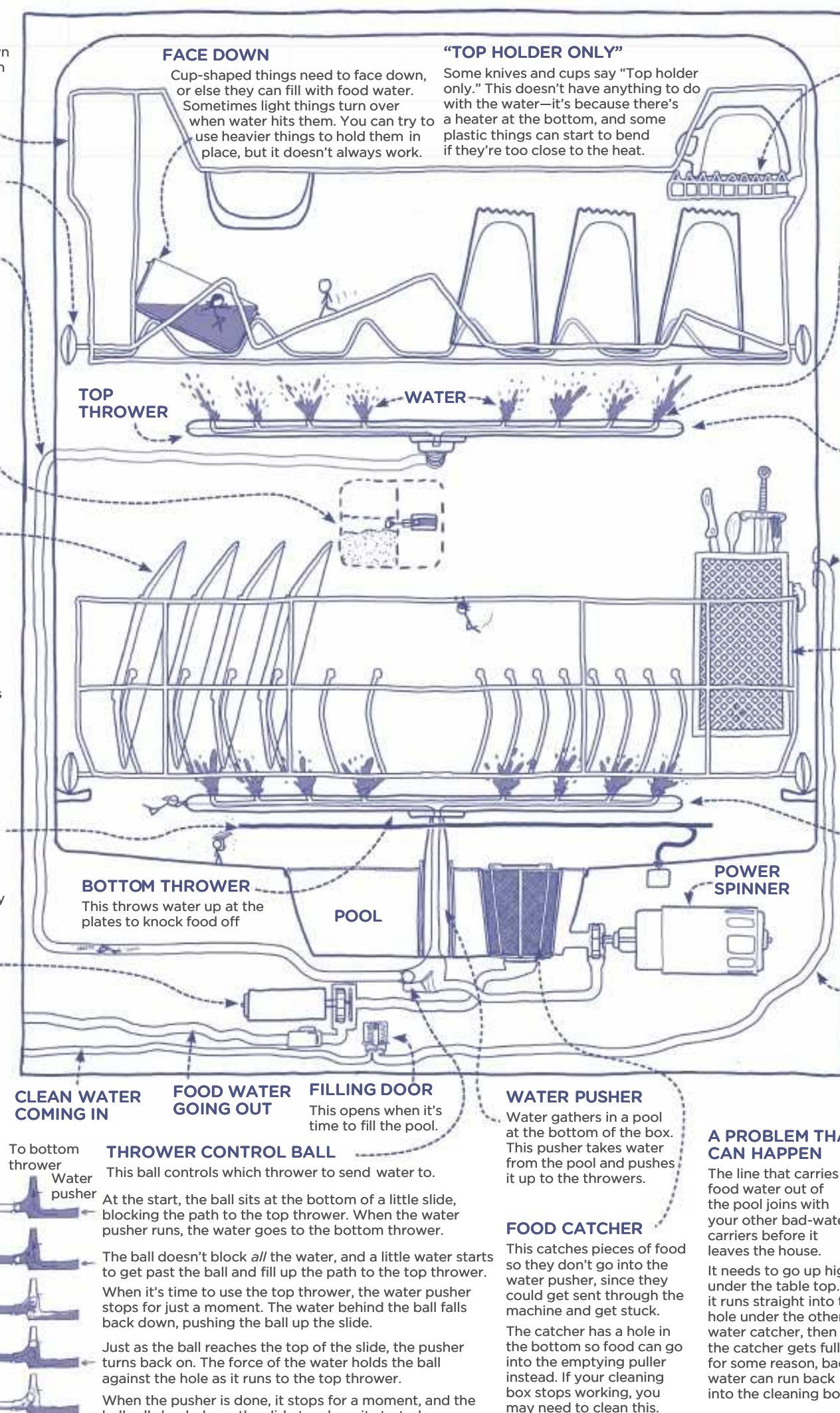
HEATER

This heats the water so it cleans better, and also heats the air at the end so the plates dry faster. A lot of people have pointed out that this heater is hot enough to heat fish in your plate cleaner to make dinner, although no one ever explains why you would want to do that.

EMPTYPING PULLER

When the cleaning is done, the pool at the bottom is full of food water. This machine pulls it out and sends it away.

IN DIFFERENT CLEANING BOXES THIS WORKS IN DIFFERENT WAYS, BUT I LIKE THIS KIND BECAUSE IT'S A COOL IDEA I WOULD NEVER HAVE THOUGHT OF.



SMALL CUP HOLDER

This holder is for small cups, or knives, or anything that fits.

If you have something light that turns over a lot, you can put it under this holder.

TURNING

Throwers have holes that point a little to one side, so when the water goes out that way, it will push the thrower in the other direction. That's what makes them spin around.

DON'T BLOCK THIS

If you put a tall knife in the knife cup, it can block the top thrower from turning. If it can't turn, the water won't reach all your plates.

FILLER HOLE

Clean water comes in here.

KNIFE CUP

This cup holds knives and other pointy things. You should always point sharp knives down, so if you trip and fall on them, they won't hurt you.

DON'T BLOCK THIS, EITHER

If you put a knife here, instead of the knife cup, it can fall through and stop the lower arm from spinning.

FILLER LINE

This line brings in hot water from the house and pours it into the box at the start.

A PROBLEM THAT CAN HAPPEN

The line that carries food water out of the pool joins with your other bad-water carriers before it leaves the house.

It needs to go up high under the table top. If it runs straight into the hole under the other water catcher, then if the catcher gets full for some reason, bad water can run back into the cleaning box.



BIG FLAT ROCKS WE LIVE ON

The surface of the Earth is made up of big flat rocks moving around. The rocks under land areas are usually thick, slow-moving, and last for a long time, and the ones under

seas are thin, heavy, and move fast. (Fast for a rock, that is. They move about as fast as the things on the ends of your fingers grow.) When a sea rock hits a land rock, the

sea rock is usually pushed under it, down into the Earth. Areas where this happens often have deep seas right near land, lines of mountains, shaking ground, and big waves.



DEEP PART

The sea floor is deeper here because the sea rocks are getting pushed down as they run into the land rocks.

LOW AREA

These low areas between mountains sometimes have water in them, and the ground there is usually good for growing things, so people like to live there. Sometimes hot rocks come out of the mountains and cover everyone's houses. But that doesn't happen very often, so people try not to worry about it too much.

SEA FLOOR

LAND FLOOR

SEA ROCKS

Sea rocks are heavy. They slide along like a moving road, and they move fast! Not as fast as a person, but faster than most kinds of land.

When sea rocks hit land rocks, the sea rocks usually get pushed back down under the land rocks, down into the Earth, where they break down. Because most sea rocks run into land and disappear after a while, most parts of the sea floor aren't as old as the land floor.

DEEP ROCK

This part of the world can be hard to understand. Sometimes people talk about it like it's watery, but sometimes they talk about it like it's hard.

The real truth is that it's very hard. If you touched a piece of it, it would feel very hard. (You shouldn't touch it, though, because it would also set your hand on fire.) It's harder than the hardest metal, glass, or even stones in a marriage ring. That makes it sound a lot like rock, not water.

But in some ways, it also acts like water. It's sort of like the big rivers of ice that slide slowly down from mountains. The ice is hard up close, and you can walk on it and break pieces off. But if you look at it from far away, and wait a very long time, you'll see that it moves like water.

DEEP ROCK

The reason the sea floor moves is that these rocks are heavier than the deep rock below them, and their weight pulls on the sea floor as they fall down into the Earth.

The land rocks move too, even though most of the time they stay on top and don't fall into the Earth. We don't understand exactly what pushes them.

It's strange to think that all these things are under you right now.

DEEPER ROCK

HOT ROCK MOUNTAIN

The rocks that get pushed into the Earth get hot and watery, and some of them come up through holes in the rock above them. They come out of those holes and cool down and turn into mountains.

Small Soft, the company that makes Windows®, is in a city like this.

ROCK MOUNTAIN

Not all the mountains in this kind of place are made from hot rock. When a sea plate goes under a land plate, it can make mountains by pushing up on the land plate. If two land plates hit, it can make very big mountains. The biggest mountains on Earth right now were made this way.

LAND ROCKS

These are like big rock boats that drive around on top of the hotter rocks under them.

WHEN THE EARTH SHAKES, SOMETIMES THERE ARE BIG WAVES. THIS IS THE KIND OF SHAKING THAT MAKES THE BIGGEST WAVES:



There's a place in my country on the edge of the sea. (They once made a game for kids about trying to get to this place. You had to cross rivers and shoot animals for food and sometimes people in your family died. It was supposed to teach you about the past, but I just played the shooting part and never learned very much.) Right by the water, there's something very strange: dead trees in the sea. There are lots of dead trees in the sea. But what's strange about these trees is that they're

not lying down. They're sticking up from the sea floor, like they grew there. That shouldn't be possible, because those trees can't grow in sea water. The sea rises and falls, but the trees only died 300 years ago, and the sea hasn't risen enough to explain how these trees grew there.

The answer is that the sea didn't rise. The land fell. On the other side of the sea, 300 years ago, there was a big wave. People who saw it wrote about it. They also wrote that they didn't feel the ground shake before the wave.

The reason they didn't feel the ground shake is that the shaking didn't happen near them. It happened far away, across the sea, in the place from the kids' game. And by the edge of the water, the ground went down a little bit, and the sea came in and covered the trees.

WHERE DO ROCKS GO AFTER THEY DIE?

We used to think that when rocks fell into the Earth, they broke up right away from the heat. And even if they stayed together for a little while, it didn't really matter, since they were hidden away forever. That part of our history was gone.

But it turns out they're not quite gone. When the world shakes, we can listen to the sound go around and through the world. By listening very carefully, we can hear the sound hitting things inside the Earth, and learn what it's like in there.

By listening to the Earth, we've learned that the rocks don't all turn to water right away. We can keep track of them, even when they're out of reach of our eyes, as they fall down, down, down into the Earth.

I think that's really cool.

CLOUD MAPS

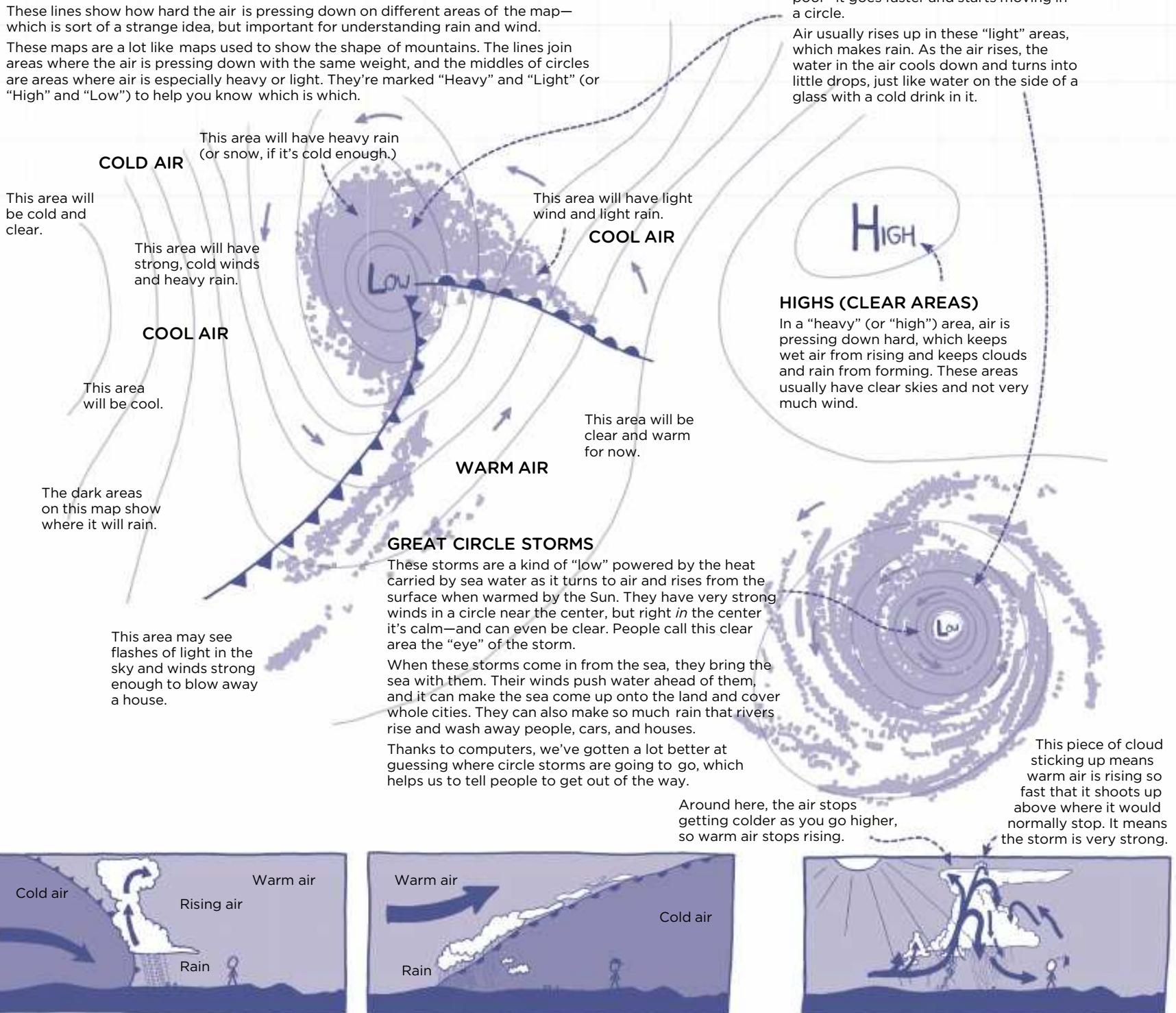
The air changes every day. Every day, clouds move around, rain comes and goes, and winds change. And every day, people all over the world try to figure out what the air is doing and where the rain will go next.

To make maps of the sky, we use space boats looking at clouds from above, radio waves looking at clouds from the side, and people all over the world looking at clouds from below.

HIGHS AND LOWS

These lines show how hard the air is pressing down on different areas of the map—which is sort of a strange idea, but important for understanding rain and wind.

These maps are a lot like maps used to show the shape of mountains. The lines join areas where the air is pressing down with the same weight, and the middles of circles are areas where air is especially heavy or light. They're marked "Heavy" and "Light" (or "High" and "Low") to help you know which is which.



LOWS (RAIN MAKERS)

Areas with lighter air over them are called "lows." Air moves across the ground toward those areas, and—just like water moving toward a hole in the bottom of a pool—it goes faster and starts moving in a circle.

Air usually rises up in these "light" areas, which makes rain. As the air rises, the water in the air cools down and turns into little drops, just like water on the side of a glass with a cold drink in it.

HIGHS (CLEAR AREAS)

In a "heavy" (or "high") area, air is pressing down hard, which keeps wet air from rising and keeps clouds and rain from forming. These areas usually have clear skies and not very much wind.

THINGS YOU SEE ON RADIO MAPS AND WHAT THEY MEAN

Sky-watching stations point radio waves at clouds. If there are big drops of water in the clouds, the radio waves hit them and come back. By pointing the radio in different directions, the people in the stations can make a map of all the rain and snow in clouds around them. Here's how to understand some of the shapes you see on those maps:

RAIN

Big shapes like this mean rain. It will probably last a while and be light sometimes and heavy other times.

SOUND STORM

This shape means a storm is coming, which may bring light, sound, and strong wind.

WIND STORM

This shape means a storm with lights and sound is coming, and the wind ahead of it might be even stronger than normal.

SPINNING WIND

This shape, like a bent finger, means a spinning cloud is touching the ground, and may be tearing up trees and houses. Sometimes, if you look at the shapes made by the radio, you can see the stuff the storm has picked up. It looks like a small ball in the middle of the bent finger shape.

SKIN BIRDS

This circle shape isn't rain—it's hundreds and hundreds of little skin birds all flying out of a big hole to eat flies when the Sun sets. Sometimes other animals, like normal birds or flies, show up on these maps too.

TREES

When there's no rain to see, sometimes the map shows little lines of noise from the radio waves hitting the tops of trees and houses.

GROUND

This shape happens when the radio waves hit clouds, then a pool of water on the ground, then come back. That makes them take longer, so it looks like there's rain far away.

TREE

GROWING UP

Trees grow taller only by making the ends of their branches longer. The spot where a branch joins the main part of the tree is never lifted higher.

POINTY CAT

This animal walks around slowly, climbing trees and eating leaves and sticks. It's covered in sharp points that can stick in your skin, so most animals don't bother it.

QUIET NIGHT CATCHER

These birds fly very quietly and have big eyes to catch animals on the ground in the dark. People think of them as knowing a lot of things, although that may just be because they're quiet and have big eyes.

TREE-EATING FLOWERS

This flower makes holes in trees and steals food and water from inside them. If the flowers get big, they can kill the branches they're growing on, or even kill the whole tree. When people stand under this flower at a party, other people tell them to kiss.

SKIN BURNER

These leaves have stuff on them that makes your skin turn red. It gives you a really bad feeling, like you need to rub your skin with something sharp, but doing that only makes it worse. This leaf-flower grows in long lines across the ground or up trees. Sometimes it grows into the air like a small tree of its own. Like many things, its leaves come in groups of three.

ANIMAL HILL

This is the dirt the walking flies took out of the ground while making their holes.

DOOR

LOUD JUMPERS

These two kinds of tiny animals make loud noises and are known for jumping. One has bones.

STORM BURN

When flashes of power from storms hit a tree, they can burn a line in the wood.

BROKEN BRANCH HOLE

When a tree gets hurt, like if a branch breaks off, the place where it got hurt grows differently, just like when skin gets cut. Sometimes animals get in through these spots and make the hole bigger.

DIRT BRANCHES

Trees grow branches down into the ground, like the ones in the air. The air branches get light from the Sun, while the ground branches get water and food from the dirt. They spread way out—often farther than the air branches—but usually not very deep.

TINY DOG



WALKING FLIES

These tiny animals live in big groups and make holes. Most of them don't have babies; each family has one mother who makes all the new animals for the house. They usually don't fly, and they're not much like house flies. They're in the same group with the kinds of flies whose back end has a sharp point that can hurt you.

LEAVES

Trees make power from the Sun's light using leaves. The green stuff in leaves eats light (and the kind of air we breathe out) and turns it into power (and the kind of air we breathe in).

GRAY TREE-JUMPER

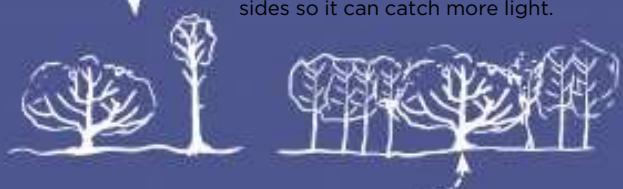
These little animals sleep in big round houses made of sticks and leaves high up in the branches.

BIRD HOLES

Some birds make holes, but a lot of them just use holes other birds make.

TALL AND WIDE TREES

The same kind of tree can grow tall or wide. If there are other trees around, they'll grow mostly up, each one trying to get above the others to reach the Sun's light. If a tree is growing alone in a field, it will spread branches out to the sides so it can catch more light.



DRINK HOLES

These were made by a head-hitting bird looking for tree blood to drink.

FIELD TURNING INTO FOREST

When people cut down a forest, sometimes they leave a few trees—to make a cool shadow area, or because the tree looks nice—and those trees will grow out into the new space.

If the forest grows back, the new trees—fighting with each other as they grow—will be tall and thin.

If you find a forest of tall thin trees with one wide tree with low branches in the middle, it might mean the forest you're in was someone's field a hundred years ago.

HEAD-HITTING BIRD

This kind of bird hits trees with its head, making holes in the wood with its sharp mouth. They make holes to find things to eat, and some also make holes to live in.

OLD METAL

When people use metal to stick signs to trees, sometimes the tree grows around the metal and eats it up.

Then, many years later, if someone needs to cut down the tree, their saw can hit the metal and send tiny sharp pieces flying everywhere.

TREE-FOOD STEALER

Instead of growing dirt branches of their own, these flowers grow onto the dirt branches of other trees and steal food from them. Some of these little flowers don't even have green leaves and can't make their own food from light.

LITTLE HOLE-MAKERS

BIG HOLE-MAKERS

LONG-HOLE MAKERS

LONG-BITERS WITHOUT ARMS OR LEGS (SLEEPING)

These long thin cold-blooded animals don't usually hang out together, and sometimes eat each other. During the winter, though, lots of different kinds come together and sleep all wrapped up together in big holes under the ground where it's warmer.

DIRT-BRANCH LIFE

Most trees and flowers have life growing on their dirt branches. This life helps them talk to the other trees and flowers around them. They can even use this life to share food or attack each other.

If something tries to eat one tree, it can tell other trees through messages carried by this ground life, and the other trees can start making bad water and other things to make themselves harder to eat.

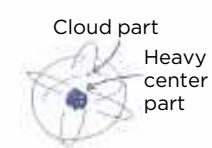
MACHINE FOR BURNING CITIES

At the end of the biggest war in history, less than a hundred years before this book was written, some people figured out how to make a small piece of heavy metal heat up like the Sun. They could make the metal get so hot that it would blow up with enough light and fire to burn a whole city, and send up clouds of dust that made people sick. Two of the machines were used in that war, and each one burned a city and killed many, many people.

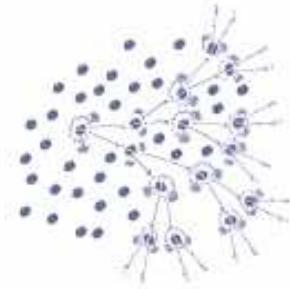
THE FIRST RUN-AWAY FIRE

Everything is made of tiny pieces. Around the start of the Second World War, we learned that the pieces of a few special heavy metals could be made to break in half. We also learned that when they break, they let out a little flash of heat and some tiny fast pieces.

THE PIECES EVERYTHING IS MADE OF



Cloud part
Heavy center part



RUN-AWAY FIRE

When the heavy center of one of the metal pieces breaks in half, it lets out heat and some pieces. If those pieces hit another center, the same thing happens, letting out more heat and pieces. Soon, the whole piece of metal can become a run-away fire.

ENOUGH METAL

If the piece of metal is too small, the little pieces from the broken center can fly out without hitting any other centers.

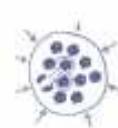
For a run-away fire to start, there needs to be enough metal to make sure the flying pieces hit other centers instead of flying out.



HOW MUCH IS "ENOUGH"?

The size of a piece of metal it takes to make a run-away fire is different for different metals and different shapes, but it can be a piece small enough for a person to pick up.

(Don't do this.) Even if a piece isn't big enough, pushing it into a small space can make it blow up, because when the centers are closer together, there's less room between them for the fire to get out.

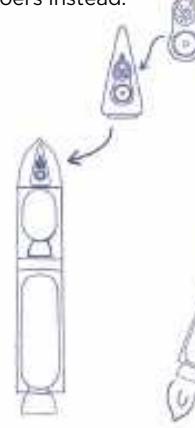


HOW WE SEND THEM

The first city-burning war machines were dropped from sky boats. Later, we learned to put them on fast up goers instead.

City-burning machine carriers work a lot like the up goers that fly people up to space.

In fact, some of those people carriers are just city-burner carriers without the city-burning part at the end.



GOING TO SPACE (BUT NOT FOR LONG)

The city-burning machine carrier flies up to space. Like most up goers, the machine carrier drops parts once they're used up, so it can go faster and faster. It goes almost fast enough to stay in space and go around the Earth.

Almost, but not quite.



After the war, we learned to make the fire from the machines even bigger and hotter, and built flying carriers that could send them anywhere in the world in just a few minutes. There was no way to stop these machines, so many countries built them, and hid them under the ground, so that no one could attack them without getting attacked back.

Everyone worried that a new war would start at any minute. We spent many years like that, each side waiting for the other to attack and start the war that would end the world.

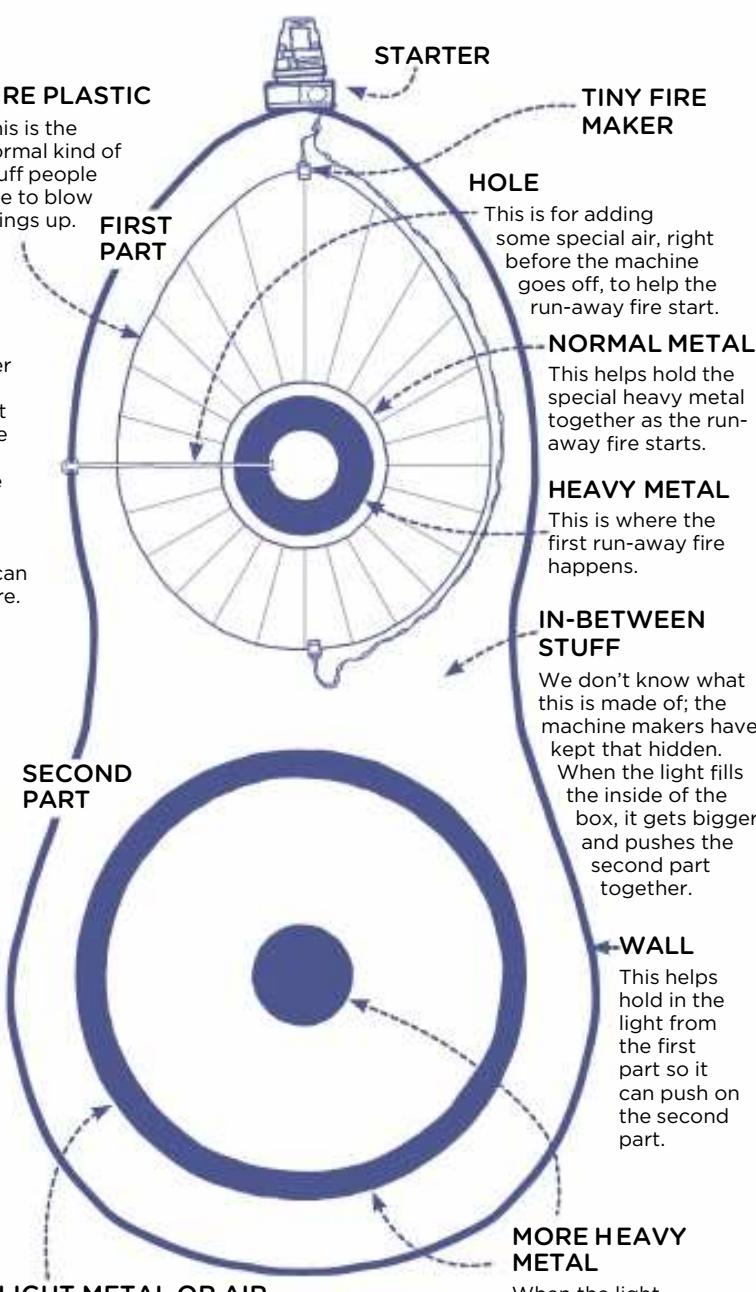
We're less afraid now, and most people don't think that war will happen. But we still have the machines.

THE MACHINE

The first machines had one part that blew up, but a few years later, we learned to make the fire a lot bigger by putting two parts together.

The top part uses a normal fire to start the run-away fire in the special metal. Then the bottom part uses that special fire to start an even bigger run-away fire in a light air or metal. That second fire is the kind that powers the Sun.

The light metal's run-away fire can let out even more power than the heavy metal kind, but it takes so much heat and force to get it started that we can only do it with the help of a run-away fire in a heavy metal.



LIGHT METAL OR AIR

This stuff can also burn in a run-away fire, but it has to be pushed together really hard first.

THE SECOND RUN-AWAY FIRE

Here's how the first run-away fire sets off the second one.

First, a message goes down a line and starts some tiny fires.



The tiny fires set off the fire plastic, which starts to blow up.



The blowing-up plastic pushes the heavy metal together.



When the metal gets small enough, the run-away fire starts.



As it burns, the metal puts out a bright light—brighter than anything but a dying star.



The light heats up the in-between stuff, making it push the second part together hard.



That starts a run-away fire in the light metal.



This fire makes the other fire even worse, and the whole thing blows up.



After the first run-away fire begins, the whole thing happens in the time it takes light to go a few hundred feet.



By adding more and more steps like this, we found we could make the fires as big as we wanted, and at first we built the machines larger and larger.

But then we stopped making the machines larger, and started making them smaller, instead. We didn't stop because we didn't want to burn larger cities. We just realized you could burn a city more easily with a few small machines than one big one. Soon, we had enough small machines to burn as many cities as we wanted.

We stopped making the machines larger because the ones we had were big enough to burn everything. There was nothing larger to burn.

WATER ROOM

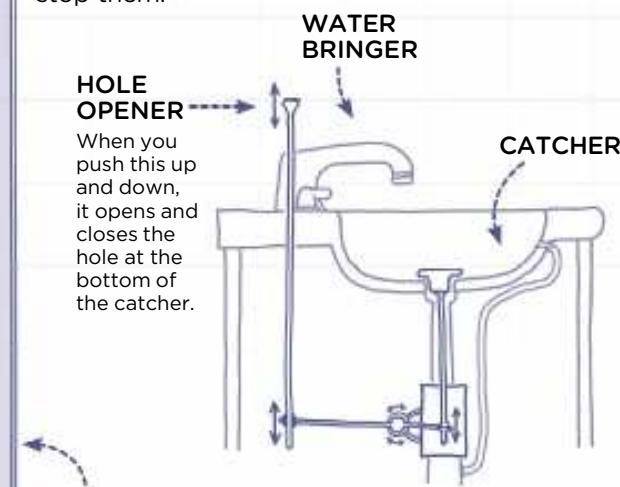
This is one of the best things humans have ever built.

Over the past few hundred years, we've learned a lot about why people get sick. We've learned how the things travel that make us sick, and we've learned ways to stop them.

We've learned that often, when we get sick, it's because a kind of life has gotten into our bodies and is trying to grow in us. Our body can often fight this off, but while we're fighting it, it uses the things that come out of our body—often, by helping more of them come out—to spread itself to other people.

By learning how to bring water into our buildings, and how to make it carry things away from our bodies without touching others, we've found a way to fight back against the things that have killed so many of us.

This is an important room!



AIR HOLE TO ROOF

There's usually some air in the smelly water that's going out of the room. This carrier lets that air rise up and out a hole in the roof, instead of coming back up through the hole in your room and making everything smell bad.

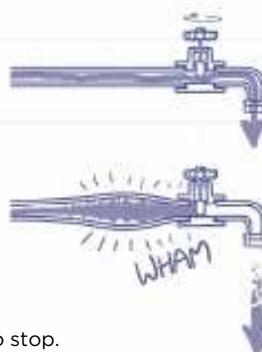
WALL SOUNDS

Sometimes, when you turn off the water in an old house, you hear a loud sound from the wall, like a big rock hitting something. That's the sound of water hitting a stopper.

When you turn on the water bringer in a house, there's a long train of water all moving together toward the hole where it's coming out. When you turn it back off, all that water has to stop.

Water moves around a lot, but it can't really get smaller. When the front part of the water train hits the stopper, since it can't get smaller, there's no place for it to go. It all has to stop right away. The force of the water train all stopping at once hits the metal around it really hard, making a loud noise.

OLD HOUSE:

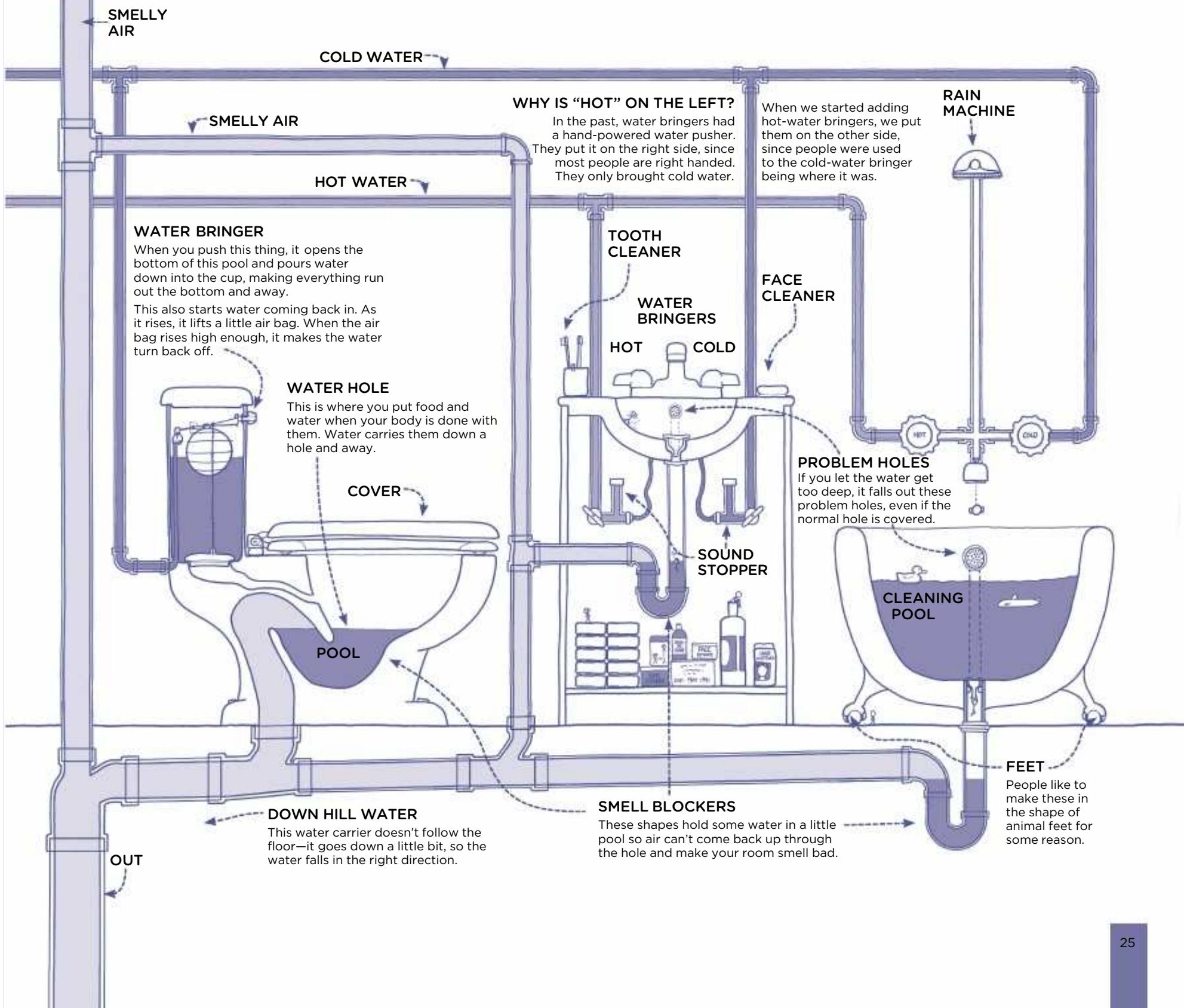


NEW HOUSE:



HOW WE FIXED THEM

Newer houses fix this by adding a piece to the water bringer. The piece is a dead-end area, above the water, which is full of air. When the water stops, it can go up into the dead end. The soft air in the dead end acts like a spring, slowing the water down gently so there's no loud noise.



COMPUTER BUILDING

When you use a computer to listen to songs or watch movies, sometimes they're on your computer, but often they're "in the cloud."

"The cloud" is just a lot of buildings owned by big companies. They're full of rows of computers, information boxes, and lots of confusing colored lines everywhere joining everything together, carrying information

and power in and out of the computers. When you use things like Short Bird Talk and Face Book, your computer is talking to computers in buildings like this.

Some computer buildings were built by companies to hold all their own computers. Some very big companies do this. Other computer buildings sell space to people

who have computers but need somewhere to put them. Some let you use their computers if you pay. Many have computers, and if you pay them, they use their computers to do things for you. But the computers in all these buildings usually look about the same.

FIRE-STOPPING AIR

If something catches fire in a computer building, the building's systems will often open up boxes full of heavy air. Fire needs stuff that's in our air so it can burn. If you put another kind of air in its place, the fire stops.

(The special air fires need to burn is the same kind of air we need to breathe, so if you're in the room when they send in the other air, you can die. But at least you won't be on fire.)

WAIT CONTROL

If there's a fire, and the building starts to fill itself with fire-stopping air, press this control. It tells the building, "Wait, don't change the air yet! I'm still here!"

COOLERS

Computers make heat. One of the hardest things about running a computer building is keeping it cool. A lot of the power these buildings use goes for running blowers in every room, pushers to move cooling water up to the roof and back, and running the big coolers on the roof that cool the cooling water down.

COLD AND WARM HALLS

Floors are laid out in rows, with cold halls and warm halls between them. The cold halls are on the side where computers pull air in, and the warm halls are on the side where the air is blown out of the computers. That way, computers aren't blowing hot air into other computers on the side where they're pulling air in.

SPECIAL ROOMS

If you have your own computers and computer holders, you can pay for a room to yourself. You can bring any computers you want and join them up with the building's systems.

MEET-ME ROOM

(That's the real name.) Sometimes, different companies have computers in the same computer building, and they want to send things to each other. Normally, they would have to send stuff out of the building into the world, and then pay information-carrying companies to bring it to the other company's computers—even if those computers were in the same building where it started. Some computer buildings have a room where different companies can all join up their computers and share stuff with each other without having to go outside or pay other companies to carry their messages.

NORMAL AIR

INFORMATION LINES

The lines to and from the computer rows sometimes run along the ceiling and sometimes along the floor.

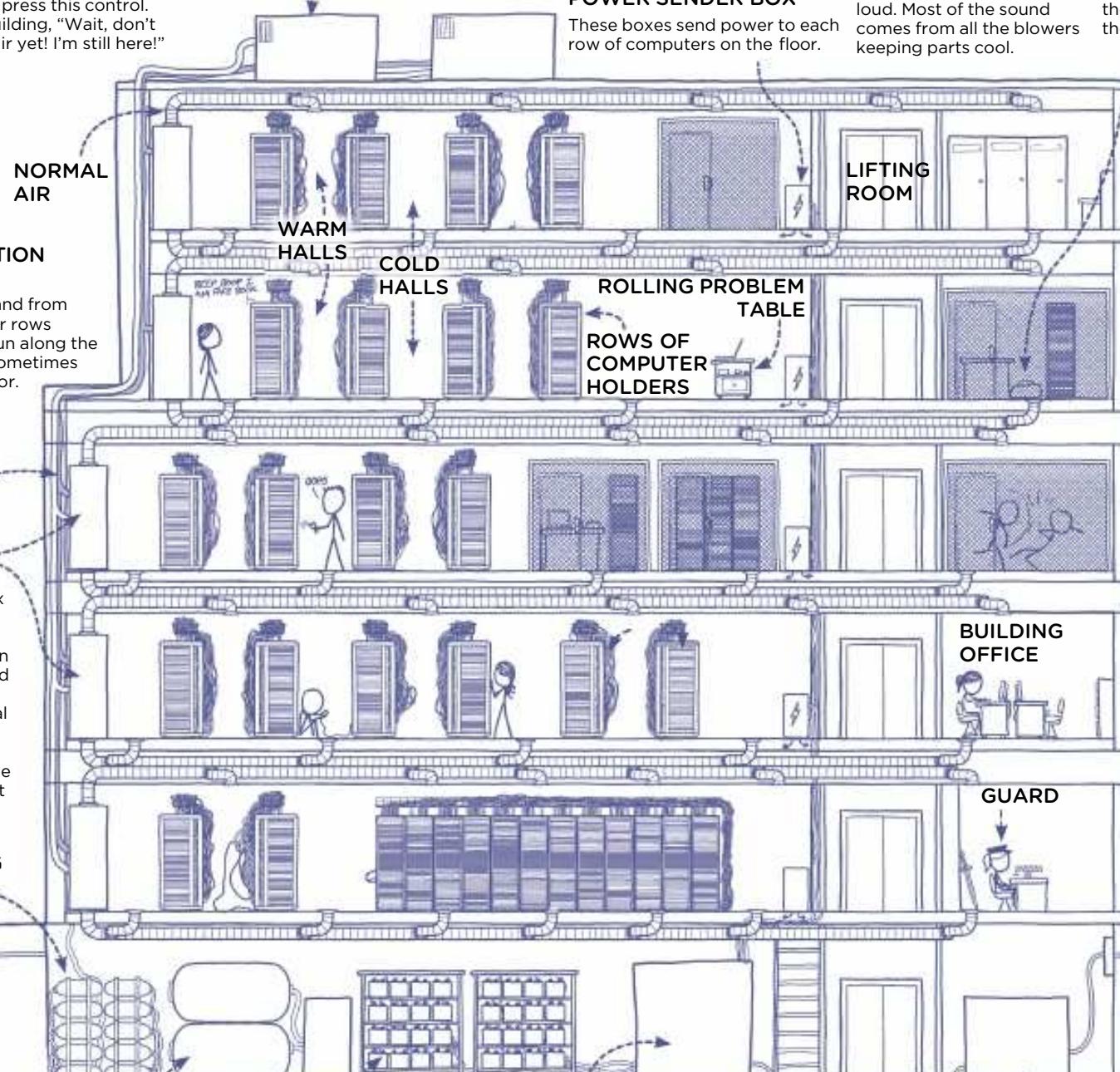
COOLING WATER CARRIER

There's a box like this on each floor. It feels the air in the room, and if it's too hot, it uses special cold water from the coolers on the roof to cool it down.

FIRE-STOPPING AIR

OUTSIDE LINES

These join the building with the world's computer and phone systems. The lines are made of glass, instead of metal, which lets them carry more information.



KEEPING THE POWER ON

The people who run computer buildings worry a lot about the power going out. They usually have lots of power boxes to keep themselves running for a short time if the power dies, and some machines for burning fire water to make power if the power stays off for a long time.

POWER WATCHER

This machine decides where to get the power to send up to the computer floors. If the outside power dies, the machine changes over to using the power boxes without letting anything turn off.

POWER CHANGER

Computer buildings use a lot of power, so the kind of power they get from the power company isn't like the power to a house—that kind is too hard to send a long way. Instead, they get the kind of power that runs through those long lines that you sometimes see hanging from tall metal things high above the trees out in the country. These boxes change that power into the normal kind of power computers need. They make things a lot easier, except when they blow up. But most days they don't blow up.

BLOWER SOUND

Computer buildings are loud. Most of the sound comes from all the blowers keeping parts cool.

PART FIXER BAG

This was left here by the people who own the room.

LOCKS

Computer buildings usually have at least two doors with machines that only let certain people in.

People who own computer buildings worry about this a lot, because if someone stole stuff from them, no one would want to leave their computers there anymore.

PERSON CATCHER

People have to close the outside door before opening the inside one. This keeps people from walking in behind you while the door is open.

FINGER CHECKER

These machines have pictures of the lines on the fingers of everyone who's allowed in. When you touch them, they check the lines on your fingers and only open if the lines make you look like one of the people who's allowed in.

COMPUTER

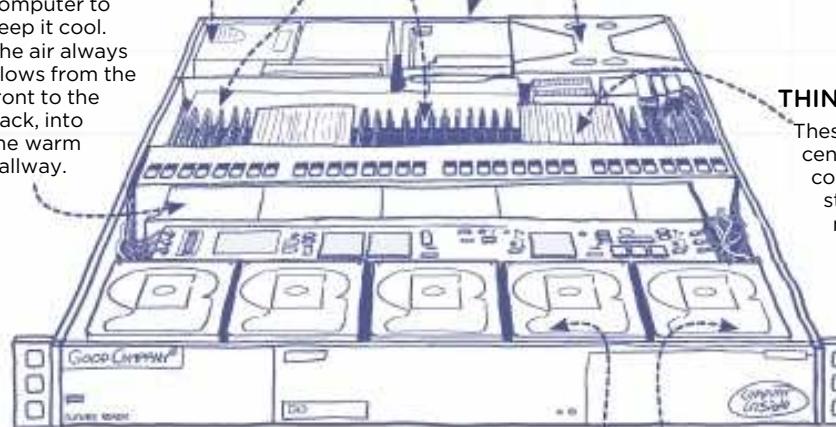
Computer buildings use a special kind of computer that fits well in a holder. It's about the size of the back of a chair.

POWER SENDER

This takes power from the outside and sends it to different parts of the computer.

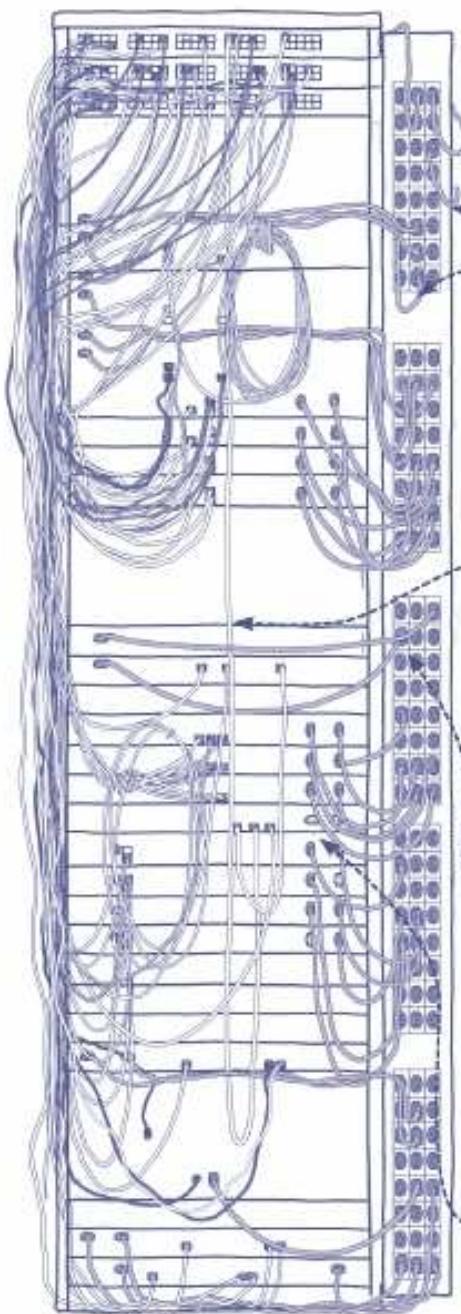
BLOWERS

These blow air through the computer to keep it cool. The air always blows from the front to the back, into the warm hallway.



FRONT

This part usually has some lights to tell you how the computer is doing, and a little sticker with a name or picture that tells you what company made the machine. Since you're usually seeing it because you're fixing a problem, the sticker just tells you who you should be angry at.



MEMORY STICKS

These hold things the computer is thinking about, like information it's sending or pictures it's looking at. If the computer turns off, this goes away.

BACK

If you want to add a line into the computer, you usually run it in through a hole here.

CARD-HOLDER

These are spaces where you can put in a few more smaller add-on computers. These might do things like talk to other computers faster than normal, or do special work with numbers.

THINKING BOXES

These are the main centers where the computer follows steps and moves numbers around.

GRABBERS

These join the computer to the computer holder.

INFORMATION BOXES

These boxes remember things even when the computer turns off.

TALKING CENTER

Lots of lines run up here. Other lines run from here out into the world. Sometimes, to carry more information, those lines are made of glass, and use light instead of power.

POWER LINES

Each computer has two power lines, which can look a lot like the information lines. If they used the same kind of ends to join to the computer, there would be a lot of problems, but they don't.

INFORMATION LINES

Each computer usually has three different information lines. One is to talk to computers in the outside world and another is to talk to other computers in the building that are owned by the same company. The third is a special computer building system used to do things like turn the computer on and off or change how it works.

PROBLEM

Someone is probably going to fall and pull this out.

ANOTHER PROBLEM

These lines are really confusing. They always start out nice and clean, and then over time the whole thing becomes a wall of color that makes no sense.

ANOTHER PROBLEM

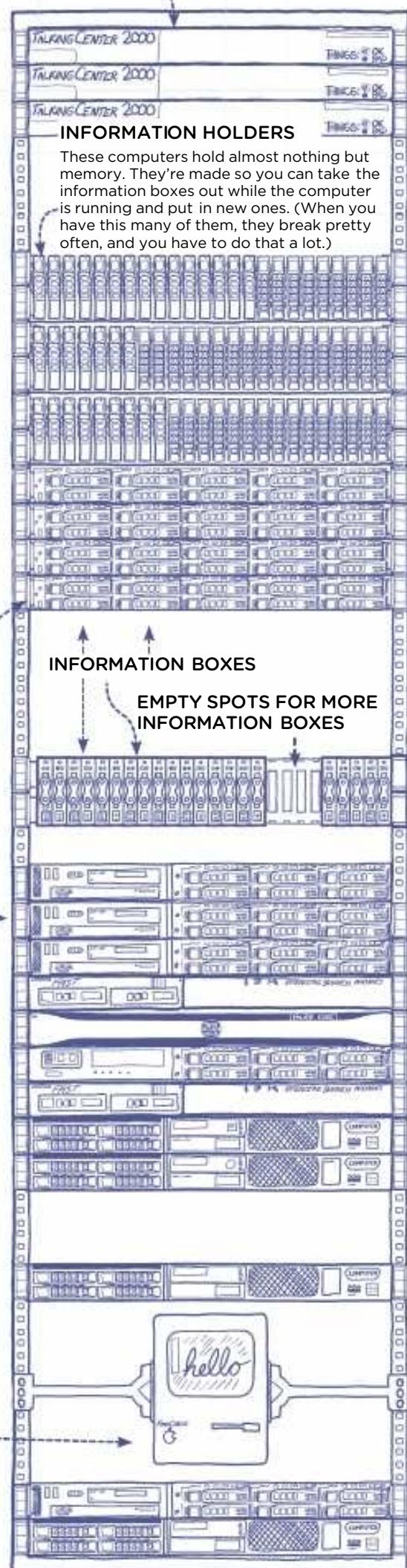
Someone forgot the power lines to this computer, which is probably why your phone has no service right now.

HOLDER

Computer buildings keep all their computers in these holders. A holder can hold all kinds of computer parts; anyone can easily put any kind of computer in any computer building.

TALKING CENTER

A few spots on the holder hold the talking center, which is where the lines from all the other computers go so they can talk to the outside world. This usually goes at the top.

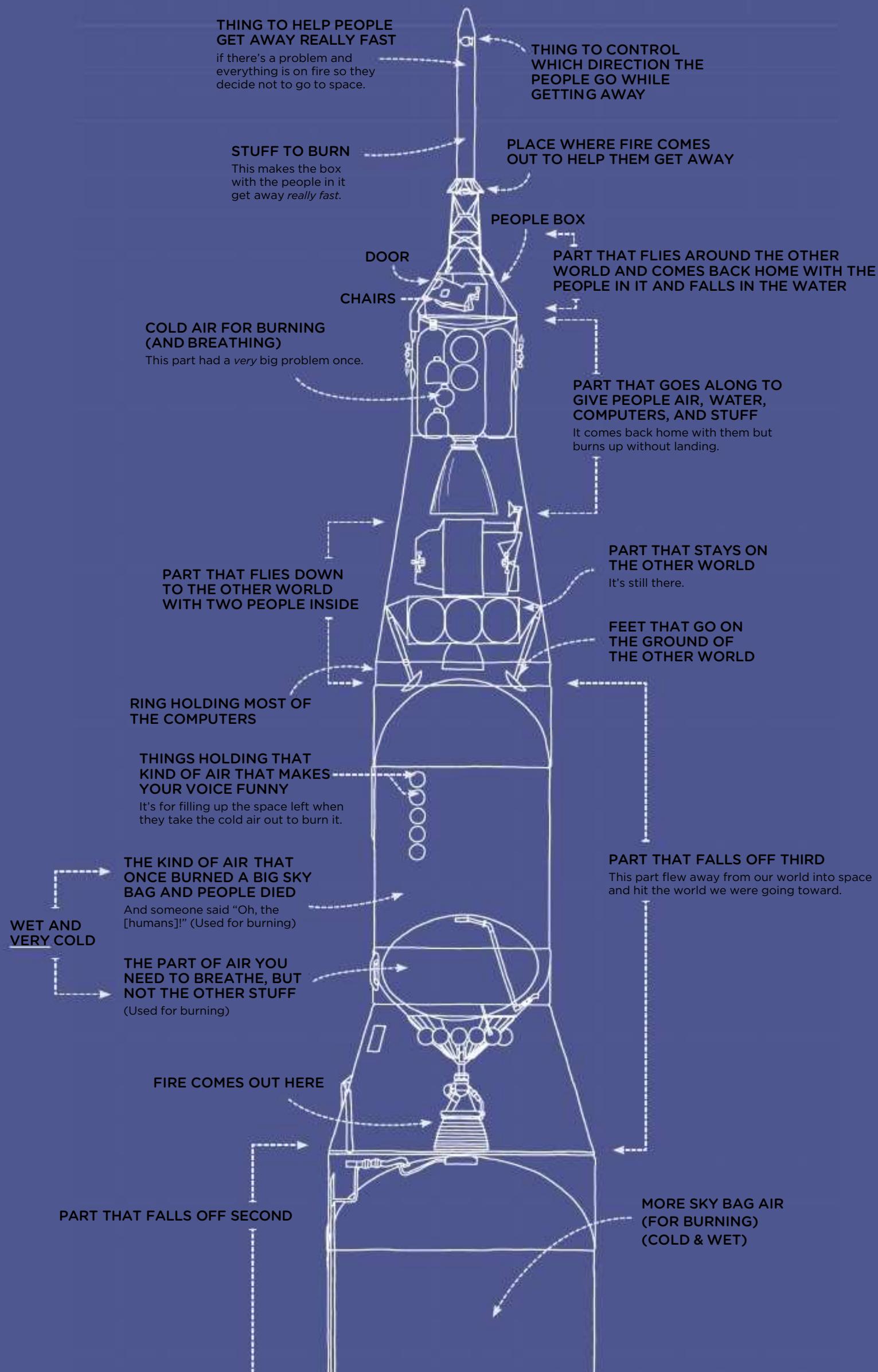


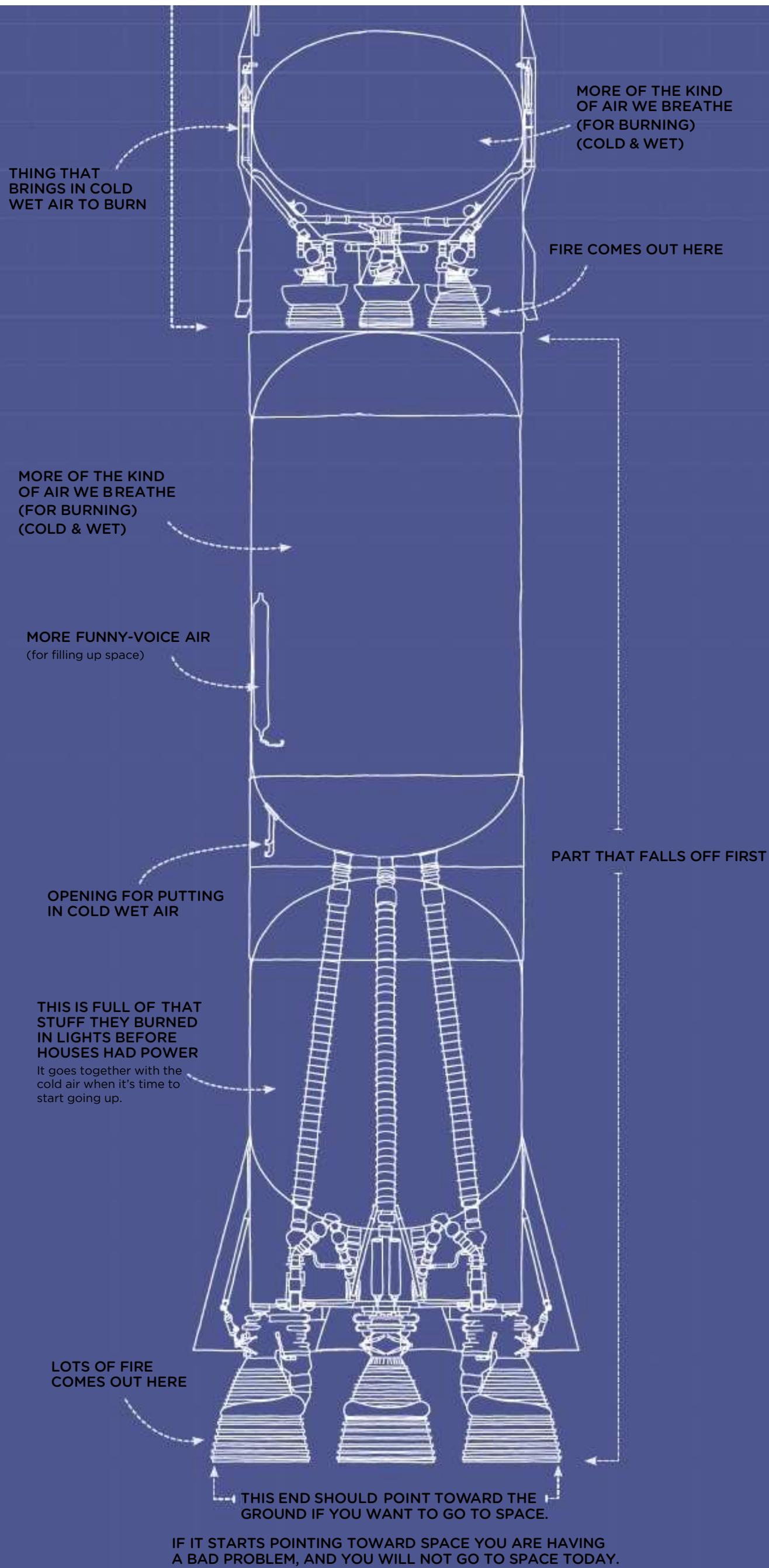
US SPACE TEAM'S UP GOER FIVE

This is the only space boat that's landed people on another world. People landed on the Moon with it six times, all about half a hundred years before this book was written.

After those visits to the Moon, we stopped using this space boat to go to other worlds. The US Space Team used the boat, one last time, to send up their first space house.

After people visited the house a few times, it fell back down. Pieces of it landed in a small town. The town told the US Space Team to pay a fine for dropping stuff on the ground.





SKY BOAT PUSHER

Sky boats, like cars and sea boats, are pushed by machines that burn fire water. Fire water needs air to burn, and sky boat pushers use special blowers that use the air they're moving through to feed their fire.

Most machines that burn fire water use these four steps: **First**, pull air in. **Second**, push the air together. **Third**, burn fire water in the air, heating it and making it get bigger. **Last**, use that growing air to push on something.

Sky boat pushers use the force from the hot air in two ways: They let it fly out the back, pushing them like a space boat, but they also use it to turn their own blowers, pulling in more air and keeping themselves running.

KINDS OF PUSHERS

Small sky boats and large ones all work by pushing air, but different kinds of sky boats use different kinds of pushers.

SIMPLE PUSHER

These are fun to play with, but if you try to push any kind of boat with them, your arms get tired.

POWERED PUSHER

These are even more fun to play with (though you probably want to put them on a sky boat first).

FIRE PUSHER

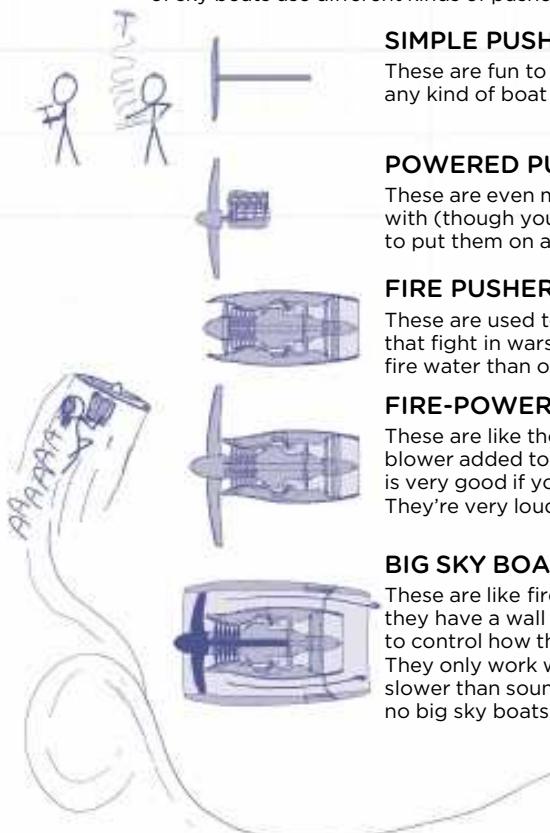
These are used to push fast boats, like the kind that fight in wars. They go fast, but use more fire water than other kinds.

FIRE-POWERED BLOWER

These are like the fire pushers, but with a big blower added to the front. This kind of pusher is very good if you don't want to go too fast. They're very loud.

BIG SKY BOAT PUSHER

These are like fire-powered blowers, but they have a wall around the whole thing to control how the air goes through. They only work well when you're going slower than sound, which is why almost no big sky boats go faster than that.



STEP ONE: GET AIR

Air comes in from this side, the first step in making power.

STEP TWO: PUSH

These blowers push the air into a smaller and smaller space, which will help the fire burn faster and hotter.

STEP THREE: BURN

The air from the pushers comes into this burning room, where little drops of fire water are thrown into it and set on fire. The fire water and air get hot and blow up. The walls make it hard to blow up in any direction except out the back, so that's where the burning air goes.

BLOCKER

If there's stuff in the air, like sticks or rocks, it gets pushed through here so it doesn't hurt the blowers.

POINT

This thing helps to start pushing the air together before it goes inside.

BIG BLOWER

The fire in the back turns this big blower using the stick in the middle. This blower is what really does most of the work of pushing a big sky boat; everything else is just there to turn it.

Not all sky boats have a big blower like this. Some of them just use the hot air itself, which works well for very fast boats. But for boats going slower than sound, it turns out that using the hot air to power big blowers takes less fire water than using the air itself as a pusher.

SPIN STOPPERS

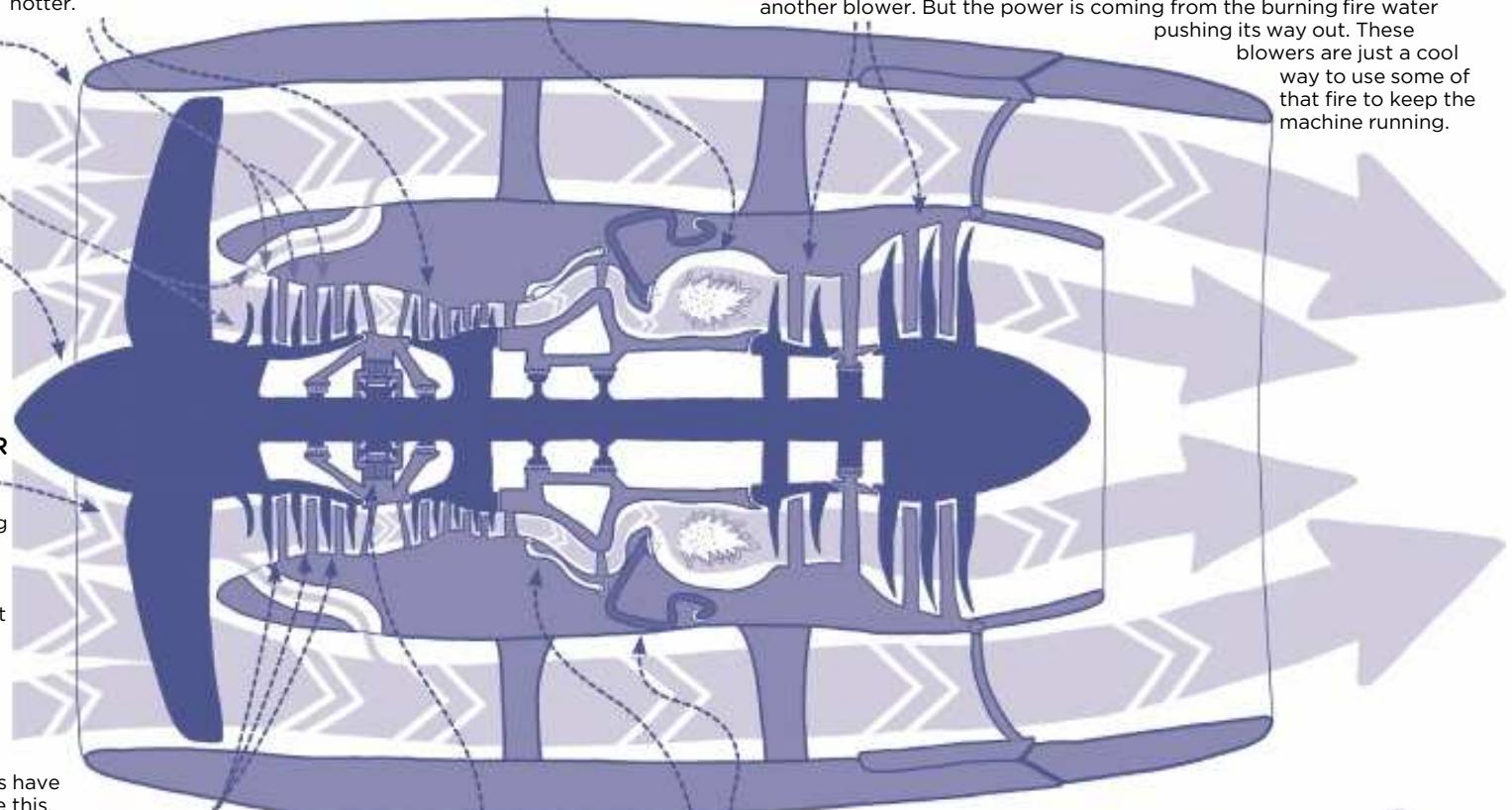
The blowers that push the air together all work by spinning, but since they're all spinning in the same direction, they can start the air spinning around instead of going toward the burning room. To keep that from happening, there are little wings in between each blower to make the river of air go straight and keep it from turning too much.

POWER MAKER

This machine uses the turning stick to make a little extra power for the rest of the sky boat to use (for things like lights and computers).

STEP FOUR: MAKE POWER

The force of the air coming out would help push the sky boat on its own, but sky boat pushers do something cooler: They put extra blowers in the path of the air. Instead of turning those blowers to push air, they let the air turn the blowers. The blowers turn the stick in the middle of the pusher, which turns all the blowers at the start, powering the machine. That might seem like it shouldn't work, since it's using a blower to power another blower. But the power is coming from the burning fire water pushing its way out. These blowers are just a cool way to use some of that fire to keep the machine running.



HOW DO THEY WORK?

To understand how air pushers work, it can help to start by looking at space pushers.



To make a fire, you need air and something to burn. Space boats pour fire water and air into a little room that's open on one side. Then the water and air is set on fire. The fire blows up and flies out the hole, pushing the boat.



Since there's no air in space, but fires need air, a space boat has to carry air with it. Sky boats can use the air around them, so they only need to carry the fire water. They can take in air, add fire water to it, and burn it.



You can make the pusher better by using a blower in the front to force more air together into the burning room. If there's more air, the fire can burn faster and hotter.



Running the blower in front takes power. You could get that power by burning fire water in a different machine and running power to the blower with power lines. But it's better to just use a little of the power from the fire you're already making.



If you put a blower in back, in the path of the fire, it can turn a stick that turns the blower in the front. This blower slows down the burning air so it doesn't push you as well. But the blower makes the fire work so much better that it more than makes up for it.



There's one last idea that makes this work better. Instead of just using the hot air to power the blowers that press the air into the burning room, you can also use it to power a big blower.



This big blower (which sometimes has a wall around it) is what really pushes the sky boat. Once you add this blower, all the rest of the parts are just there to get lots of air together, start a fire, and get power from it.

WAIT A SECOND!

One thing a lot of people wonder is "How does the force from the fire know to go out the back? Why doesn't it push on the blowers in front just as much, and slow them back down?"

The answer is that the shape of the room and the size of the blowers make it so the easier way out is through the back. It just has to push through a few blowers on the way.



BACK PUSHER

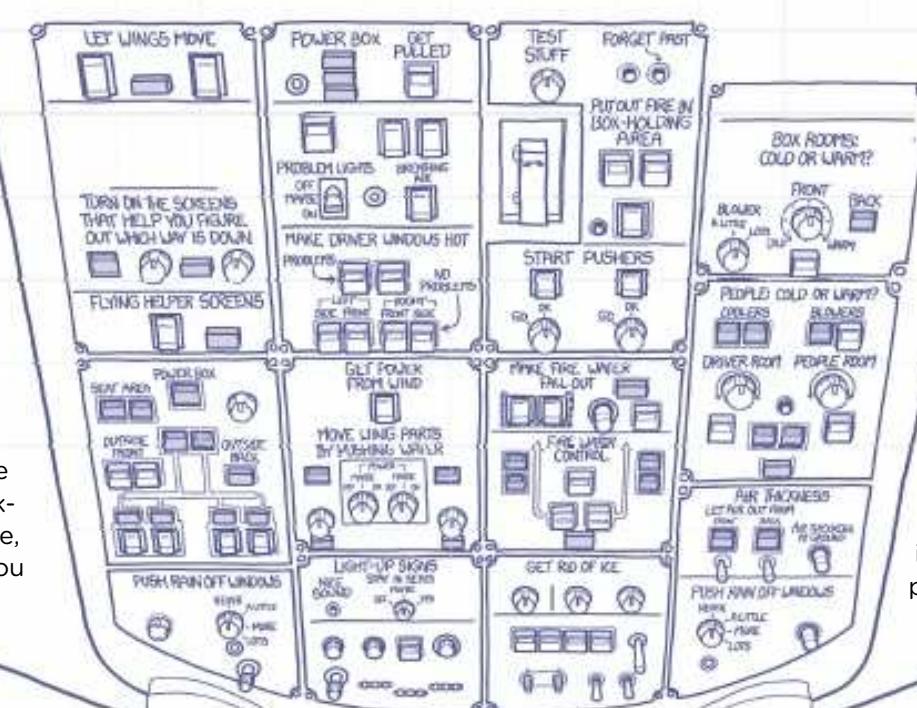
If the sky boat needs to stop, it can use these doors to send the air out the sides and toward the front, which makes it push back instead of forward.

STUFF YOU TOUCH TO FLY A SKY BOAT

A sky boat has a room in front with two chairs. Drivers sit in them and tell the boat where to go.

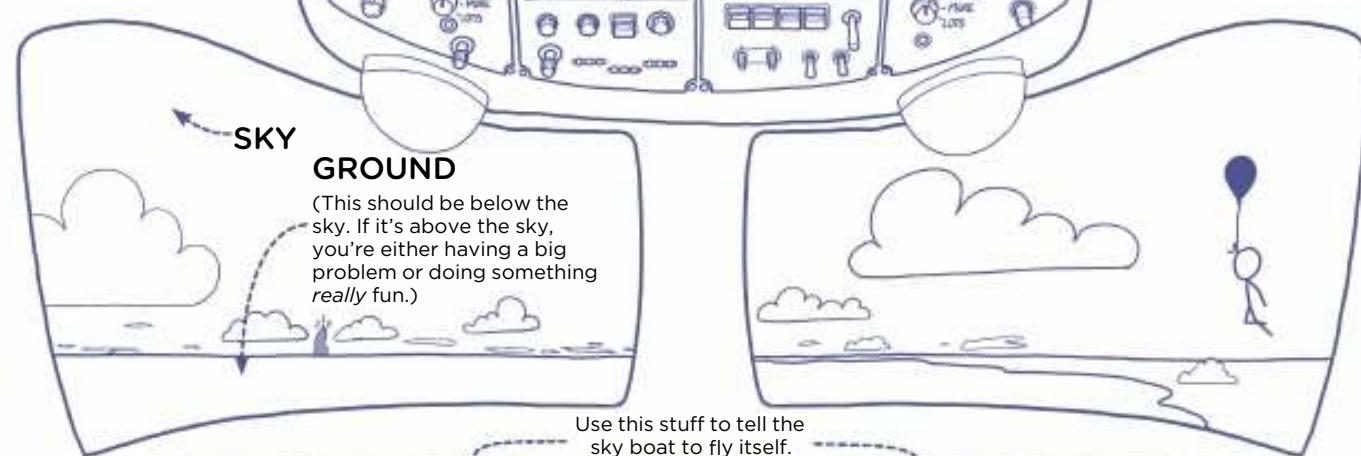
The room has some windows, but most of it is taken up by screens, keys, and little lights that change color to tell you how each part of the boat is feeling.

Sky boats have computers in them, and the computer can fly pretty well, if it has a plan for where to go. A lot of the keys and screens are for asking the boat what its plans are, and giving it new ones if you don't like what it says.

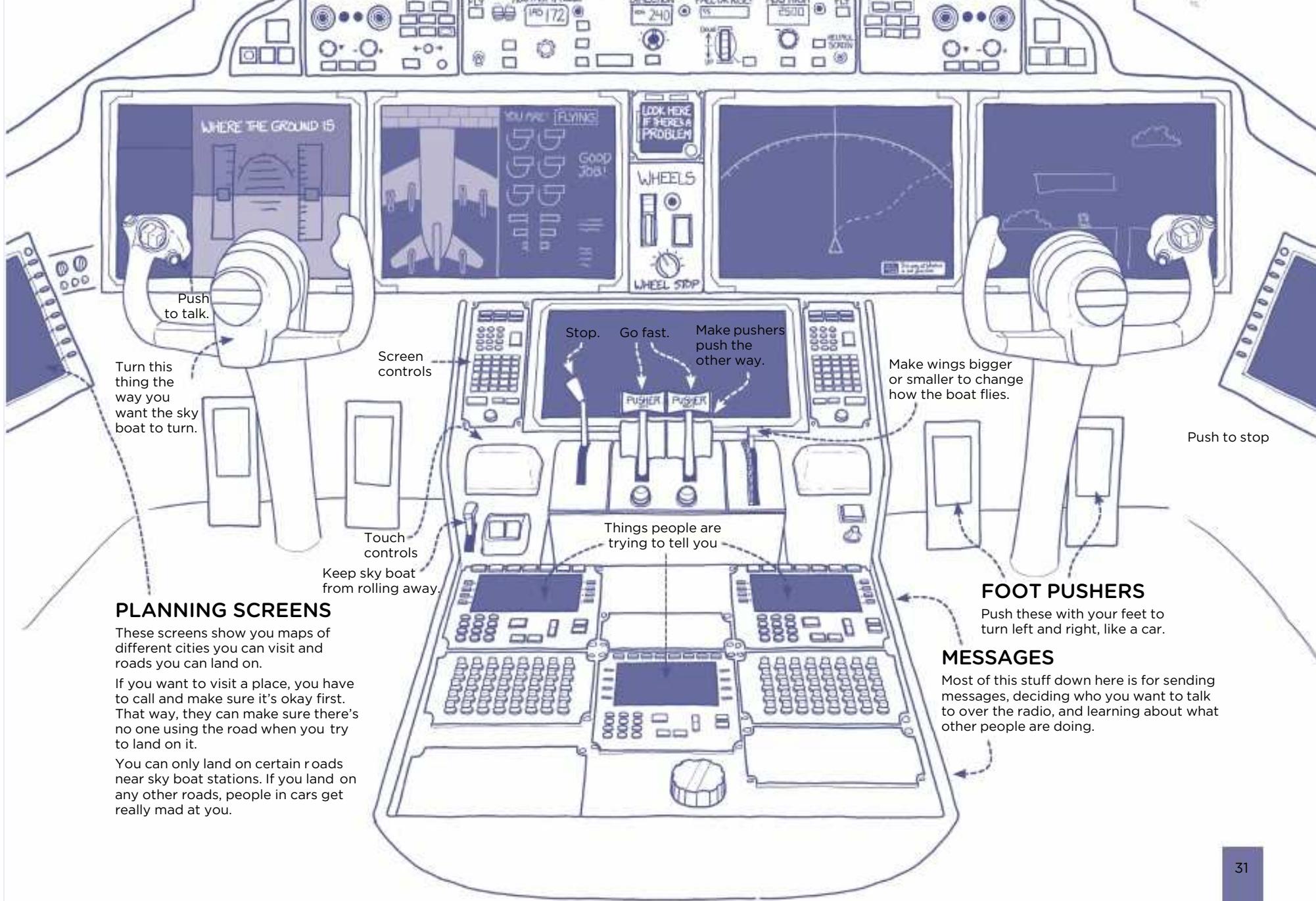


Most of the lights and keys are simple; they just do one thing, like turn a light on and off. Some of the big rows of keys and screens between the seats are for sending messages to people or looking at maps and making plans.

The hardest parts of flying are taking off and landing. The middle part of the trip is easier. During the middle part, the computer often does all the flying, and the drivers are just there to watch over it and make sure there are no problems.



Use this stuff to tell the sky boat to fly itself.



PLANNING SCREENS

These screens show you maps of different cities you can visit and roads you can land on.

If you want to visit a place, you have to call and make sure it's okay first. That way, they can make sure there's no one using the road when you try to land on it.

You can only land on certain roads near sky boat stations. If you land on any other roads, people in cars get really mad at you.

FOOT PUSHERS

Push these with your feet to turn left and right, like a car.

MESSAGES

Most of this stuff down here is for sending messages, deciding who you want to talk to over the radio, and learning about what other people are doing.

BIG TINY THING HITTER

Tiny thing hitters are machines that hit tiny things together really hard. To explain why anyone would want to do that, it might help to imagine a story about boats.

Say you and some friends are on a boat moving over a sea. The sea is covered in clouds, so you don't know what it's like. You think there's water—but what's *in* the water? Is there ice? Big biting fish? Or is it really a sea of beer instead of water? Or sand, or plastic balls?

To figure out what's in the sea, you could throw things over the edge and see what

flies back up. If you throw something heavy, a few drops of water might fly up. If you throw something down harder, the wave might toss a piece of ice into the air. You can learn a lot this way!

Now, imagine that you notice that your boat is moving. You don't have any wind sheets, so you wonder what's pushing you along.

You and your friends also notice that you sometimes hear strange sounds against the side of the boat. After thinking it over, you and your friends decide that maybe the boat is being pushed by big biting fish

hitting the side. So you get an idea: If you throw something heavy enough into the sea, one of them will throw up a big ball of water with a biting fish in it.

But to have a chance of lifting a fish into view, you need to build something that can hit the water *really* hard. Doing that will take a lot of work (and money), but you and your friends think that if it can get answers about what's going on in the water, maybe you should give it a shot.



BIG TINY THING HITTER

The Big Tiny Thing Hitter is the biggest and most high-power tiny thing hitter ever built. It's the size of a city, and most of it is hidden under the ground.

HOW DO WE LEARN FROM IT?

This machine works by throwing pieces of air down a hallway so they hit together really hard. The air hits with so much power that the pieces break in strange new ways, as if it shakes the air—and space itself—so hard that things fall out.

Most of these pieces only last for a moment, while space is being shaken really hard, and disappear as quickly as they appear. But by watching what flies out from the place where the air hit, we can figure out what we shook out.

WHY DID WE BUILD IT?

We're like boats, trying to understand the space we're moving around on. We can't see that space, but if we hit it hard enough, pieces fly out that tell us something.

These machines have helped us learn about space, time, and what everything is made of. We built this hitter to try to figure things out about our new ideas—about what those pieces themselves are made of, how they push on each other, and why things have weight.

WHY IS IT UNDER THE GROUND?

Space is everywhere, so we can do the hitting anywhere we want. Putting the hitter under the ground keeps it safe from things—like tiny flashes of light from space—that could make it harder to see what's going on.

START

The air starts here, in a bottle, and is pushed down this hallway to get going fast.

HOW DO YOU PUSH AIR?

These hitters use a kind of air that can be pushed by a force from power lines, or by the kind of pulling metal used to stick pictures to a kitchen cold box. Turners are built that push the air with that force.

FAST CIRCLES

From the first hallway, the air gets sent into these hallways that go in a circle. While it's going around, they push it faster and faster.

NOT THAT DEEP

This is shown deeper than it really is, to make it easier to see. It's really only about as deep as a tall building, but as big around as a large city.

HALLWAYS

The air flies through these hallways, one in each direction. To keep the fast air from hitting other air and slowing down, the hallways have all the air taken out before they start the machine. The hallways of this machine are emptier than any other place near any of the worlds around the Sun.

TURNERS

This machine makes the force that keeps the air in the middle of the hallway and pushes it around the circle. It works by running power through very, very cold metal. Cold metal lets power run through it very fast, and that power makes a force that pushes hard on the air.

COLD METAL

The metal in here is only a little warmer than the coldest that anything can be.

INSIDE A HALLWAY

AIR GOING ONE WAY AIR GOING THE OTHER WAY

HITTING ROOMS

There are rooms around the hallway where people can make the air going one way hit the air going the other way. When it hits, machines in these rooms watch what flies out.

AIR POCKETS AND CLOUDS

In this machine, people watch for flying pieces using sheets of computer-controlled feelers. In older machines, though, they used some stranger things, like air pocket pools and cloud boxes. Air pocket pools are big pools of really hot water, right on the edge of turning to air. When a tiny piece flies through the pool, it makes tiny pockets of water turn to air and start to grow. Each thing that goes through leaves a track of air pockets behind it, and they make beautiful pictures.

Cloud boxes are like air pocket pools, except instead of water right on the edge of turning to air, they use air right on the edge of turning to water. When things fly through, they leave a line of water drops in the air.

You can build one of these cloud boxes in your house, and see lines left by tiny things from space! (Or from heavy metal, if you have any, which you probably shouldn't.)

COOLING AIR

The outside of this carrier has a layer of air so cold it turns to water. (They use the kind of air you can breathe in to make your voice sound funny.)



LIGHT THROUGH THE EARTH

By hitting pieces together, this hitter makes many strange things. One of the things it makes is kind of like light, except it goes right through almost anything without touching it. There's a building in another part of the world where they have machines to look at this light and learn about it.

To send the light to the building, they just point it there—right through the Earth. It's so good at going through stuff, it barely notices the Earth.

AN AIR POCKET POOL



These lines are the paths of tiny things flying through water. Some of them go in circles because there's a pushing field that makes the flying pieces turn. Seeing how much they turn helps tell us what they are.



HOLE-MAKING CITY BOAT

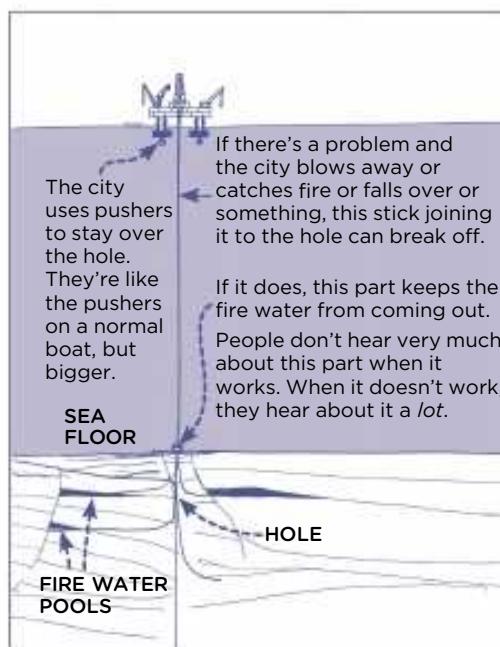
Deep in the Earth, there are pools full of the fire water and fire air that power cars and sky boats. Some of these pools are under land, and we've worked hard to get the fire water from them.

Many of the pools are under the sea floor. It's harder to reach these pools, but since you can sell the stuff in them for so much money, people have built big city boats all around the world to try anyway.

CITY BOATS

Sometimes these cities sit on top of the water like normal boats, but some of them stand on the bottom on legs the size of tall buildings.

The ones in deep seas usually sit on top of the water. When they're done making holes in one area, they can drive to another.



ROCK-EATING STICK MACHINE

We push this stick into the ground, and wheels at the front covered in teeth turn to cut the rock into tiny pieces and push it back up the hole.

BENDING PART

We used to make our holes straight down, because anything else was too hard to keep track of.

Now, with the help of computers, we can point rock-eaters very carefully even deep under the ground. This lets us make longer holes with many branches and get more stuff out of the ground.

The diagram shows a stick standing vertically. A dashed line extends from its top end to represent the axis of rotation. A small circle at the top indicates rotation around this axis. The stick is labeled 'STICK' at the top left and 'LE' at the bottom left. A label 'Water being pushed down to the end of the stick to help carry broken rocks away' is positioned to the right of the stick. Another label 'Water back & broke' is also present. At the bottom, a box contains text about a gyroscope: 'Machine for feeling how much the stick is turning so the computer can tell it where to go. (There's one of these in your phone to tell which way you're holding it.)'

FIRE WATER GETTERS

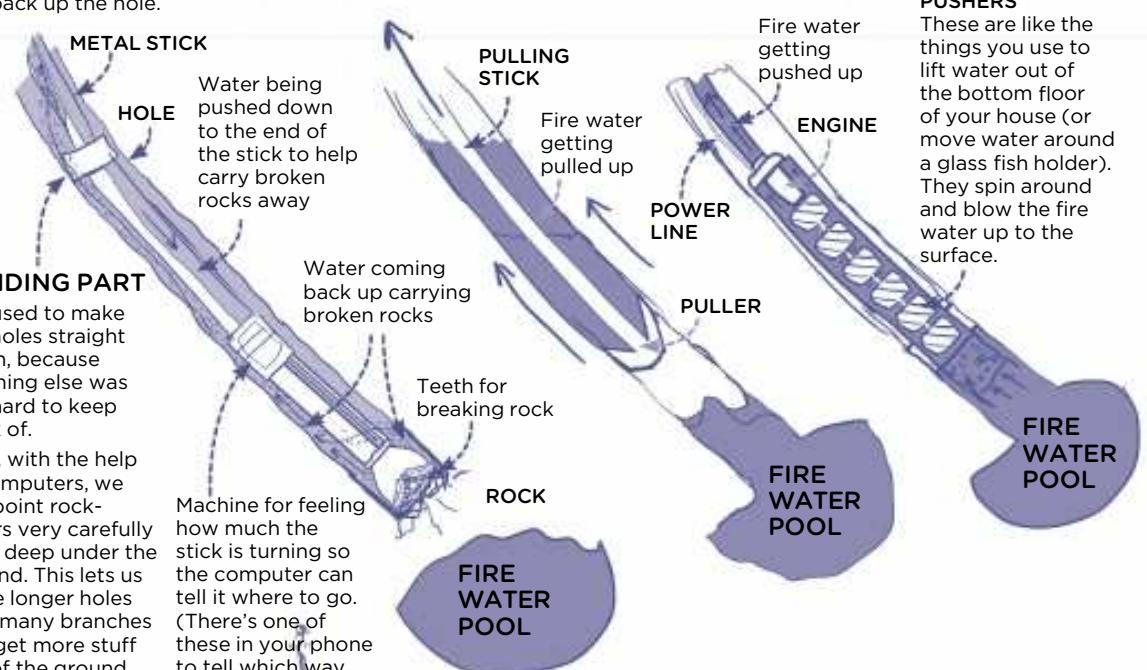
These things get the fire water either by pulling it up with a metal stick or pushing it up with a machine.

Workers on a city boat spend about half their time on the boat and half the time back on land. They usually go out to the boat for a few weeks at a time. While they're on the boat, they spend half their hours working.

Sometimes the fire water comes up on its own because of the weight of the Earth pushing down on the hole it's in. Most of the time, that's nice, but sometimes it can be a very, *very* big problem.

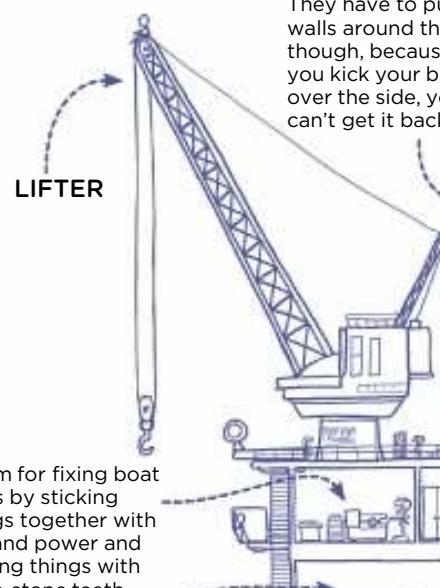
SPINNING WATER PUSHERS

These are like the things you use to lift water out of the bottom floor of your house (or move water around a glass fish holder). They spin around and blow the fire water up to the surface.



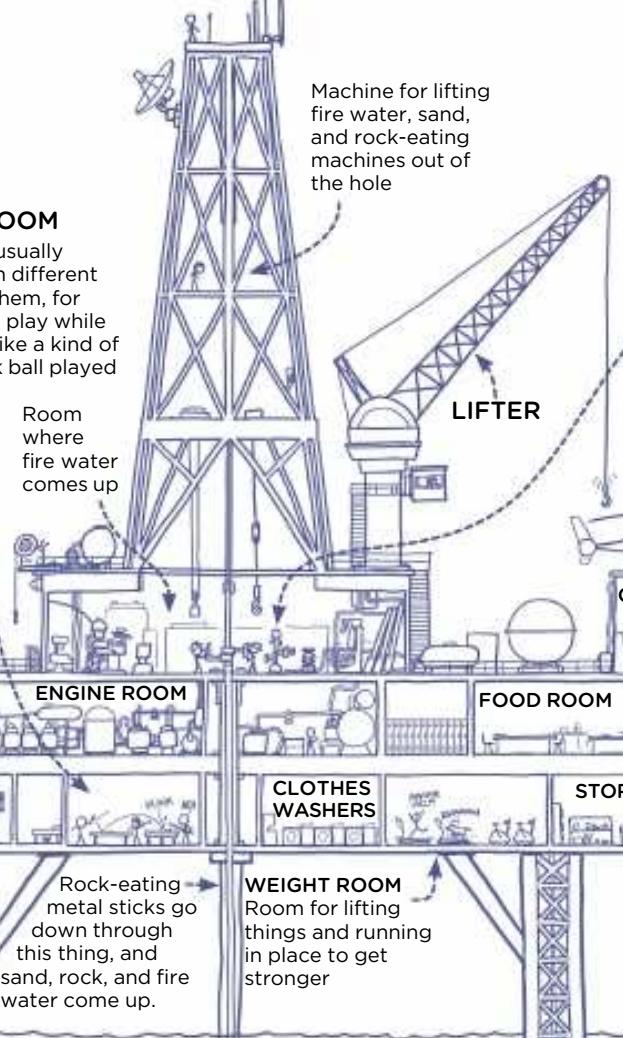
PLAYING FIELD

Some city boats have fields for playing games. They have to put walls around them, though, because if you kick your ball over the side, you can't get it back.



GAME ROOM

- There are usually rooms with different games in them, for workers to play while they rest, like a kind of circle-stick ball played on a table.

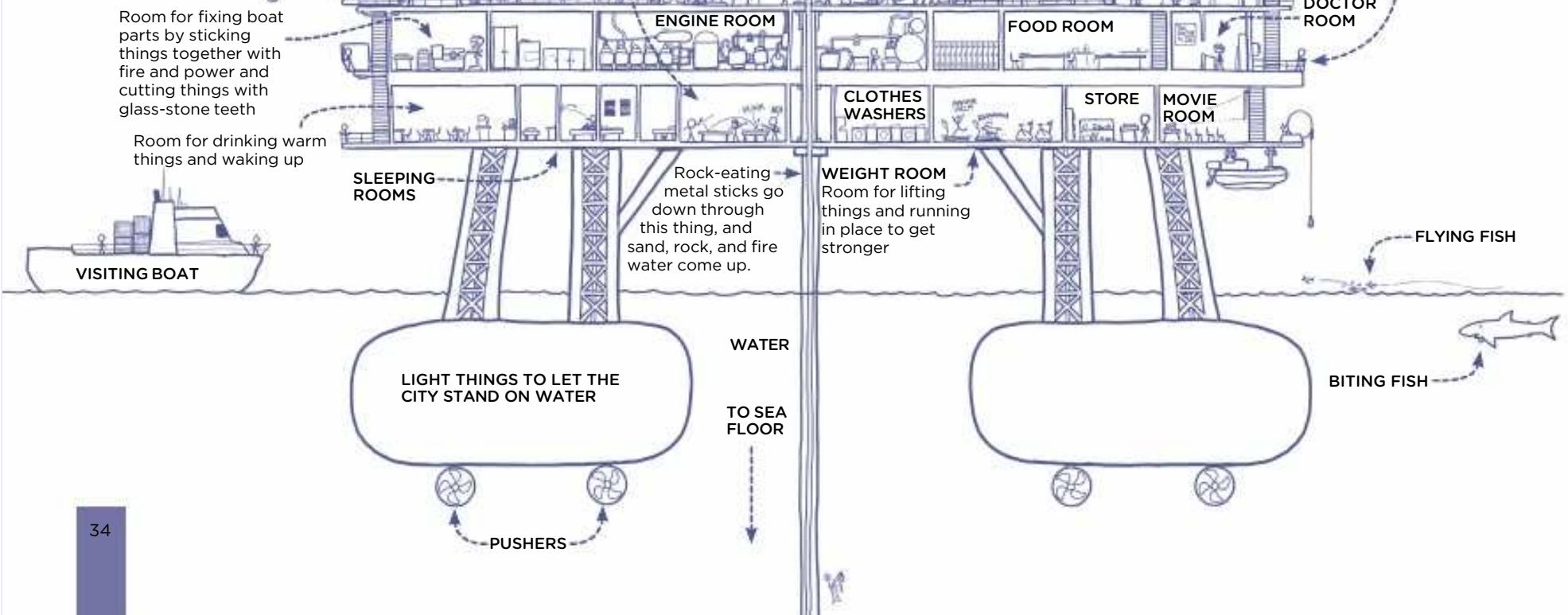


These things sit on top of the hole and control what kinds of air and water go in and out. They're named after those winter family trees (the kind with boxes under them) because people say they look like one.



FISH WATCHER

Some workers like to stand near the edge and look for cool fish.



STUFF IN THE EARTH WE CAN BURN

Almost all living things are powered by the Sun. Some living things get their power straight from the Sun's light—like trees, and some things that grow in the sea. Most living things that don't eat the Sun's light eat other living things to get *their* power. In the end, the power comes from the Sun.

When things die, some of that power is left in their remains, which is why you can get power out of dead trees by burning them.

Sometimes, if dead things don't burn or get eaten, they go into the ground with that

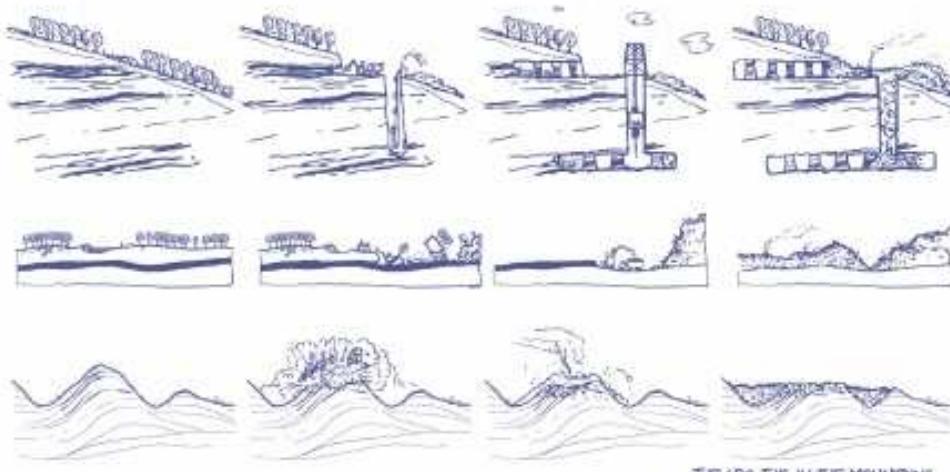
power still inside them. Over a long time, under the weight and heat of the Earth, huge numbers of these remains can change into different kinds of rocks, water, or air . . . but even as they change, they hold on to their power. When we find these remains, we can burn them, and get all that power—gathered from the Sun over huge stretches of time—at once.

When we first built machines powered by fire, we burned wood from the forests of our time. When those weren't enough, we started burning the forests of the past.

One day, those will run out, too, and we'll have to get power somewhere new—like straight from the Sun, or the Earth's heat.

But we may have to change the kind of power we use soon, before we finish burning all the stuff in the ground. It turns out burning that stuff is changing our air, in a way that's making the world hotter. If we use up all the black rocks, fire water, and fire air, the problem it makes may be too big for us.

HOW WE GET BLACK ROCKS OUT OF THE GROUND



THEY DO THIS IN THE MOUNTAINS NEAR WHERE I PLAYED AS A KID.

This kind of work leaves pools full of heavy metals and strange kinds of water that was used to get the black rocks out. Sometimes you can notice the bright colors of these pools from the air. When companies are done making holes, they often leave the pools behind. People worry about whether the stuff in the pools could be bad for us. Sometimes birds land in the pools and die.

HOLES

HOW DEEP?

We can only get black rocks easily if they're not too deep in the ground. The biggest problem is that deeper in the Earth, rocks are hotter. It's hard to get a lot of rock up out of the ground, and if the rocks are too hot, that makes everything so hard that it's not worth it.

There are other problems. You need to cut big rooms into the ground to get black rocks out, and it's hard to hold the roof up when there's so much rock piled up on it. Sometimes the roof falls and people die.

One reason we make holes that bend is so we can reach under cities without bothering people.

STRANGE SHAPE

When a sea dries up, it leaves lots of this white stuff behind. Sometimes, the stuff gets covered in dirt and sand.

When the layers above the white stuff get heavier, it can make the white stuff start to rise up and push through the layers above. It looks like paint drops falling from a ceiling, but going up.

ROCK BREAKING

Big, easy-to-reach pools of fire water are getting harder to find, so we've been trying new ideas for getting it from the ground. We've found that sometimes, rock has fire water or air you can burn stuck in it. To get it out, we push water into the ground so hard that it makes the rocks break. Then we push in small rocks or glass to hold the breaks open, and the fire water and fire air comes out through the openings.

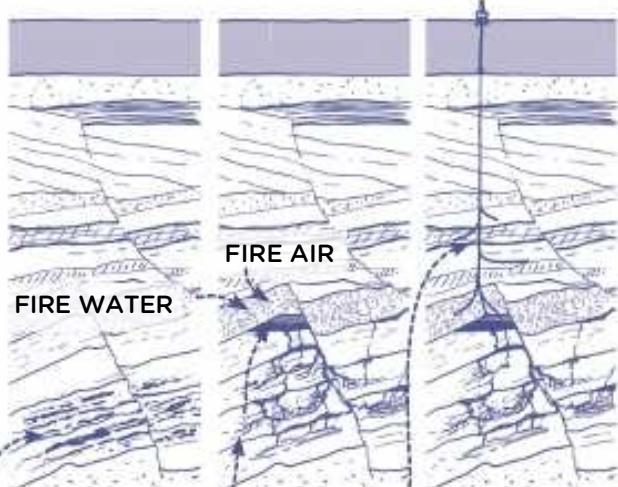
Making all these holes in the rock might mean that when we drink water, we'll also drink whatever stuff they use to get fire water out, since everything can run through the new holes in the rock.

If the rocks aren't very deep, we can make holes under the ground and carry them up with machines. This is how we used to get most of the rocks we burned.

As we built bigger earth-moving machines, we learned to just move all the trees and land out of the way to get the rocks.

Some rocks are inside mountains, so some companies have started blowing up the tops of the mountains so they can get the rocks out more easily.

HOW WE GET FIRE WATER AND FIRE AIR OUT OF THE GROUND



Over time, some dead things slowly turn to fire water and fire air.

These are both lighter than rocks, and rise up through tiny holes. When they reach a rock with no holes, they form pools, with the lighter air on top.

We make holes looking for places where lots of things died. When we find a pool, we push a stick down and pull up all the fire air and fire water.

WHITE STUFF

This is white stuff, like what we put on food to make it better (although we mostly get the kind we eat from drying out sea water). We make holes like this to get white stuff out, then we put it on our roads to get rid of snow and ice.

We sometimes use the spaces we leave behind to hold stuff, like fire water or fire air that we want to save to burn later.

Layers of rock from different times

DEEP POOLS

We can get fire water and fire air from much deeper places than we can get black rocks. Since it forms pools and can run through small holes easily, we only need to make a very thin hole to get it out, instead of having to move all the rocks around it.

HOLES

FIRE WATER

Places where the ground broke

FIRE AIR
(on top of the fire water)

VERY DEEP HOLES

TALL ROADS

The Earth's pull holds people to the ground. We like to walk around, but sometimes the ground goes places we don't want to go, like under a river or into a deep hole. We can't get past those places because we have

to follow the ground. (Birds don't, since they can fly by pushing on the air. Someone in a movie once sang, "If birds fly over the sky, why can't I?" The answer is, "You are too big and don't have wings.")

If we want to go somewhere, we can make a road that goes straight across, high above the ground. Making short roads over holes and rivers is pretty easy, but making long ones can be very hard.

HOLE



Sometimes, you want to walk somewhere, but you don't want to go where the ground goes.

ROAD



If the hole is small enough, you can put a board over the hole to make a new road. Then you can walk across the board.

LONG ROAD



If you find a bigger hole, you can try to find a bigger board. Bigger boards are longer and stronger, but they're also heavier—and bigger things get heavier faster than they get stronger.

LONGER ROAD



All boards bend a little, and longer boards bend more. A long enough board will break under your weight, and a very long board will break under its own.

BENDY ROAD



You can cross a larger hole with a road that's allowed to bend. If you tie many small boards together and let it hang, bending won't hurt it, and that will let it hold more weight.

This kind of road gets stronger the more you let it hang down, but it also gets harder to walk across. If it hangs down *too* far, it's no better than just walking down into the hole.

THICK ROAD



You can cross a bigger hole if you make the board thicker. Thicker things are harder to bend, so this kind of road is stronger.

TALL ROAD



It might seem like it would make more sense to put the extra-thick part below the road, because it's "holding" the road up, and we usually hold things from below.

But if it's strong mostly because it's thick, then it works just as well if you add the thickness above the road.

ROAD HANGING UNDER A STRONGER SHAPE



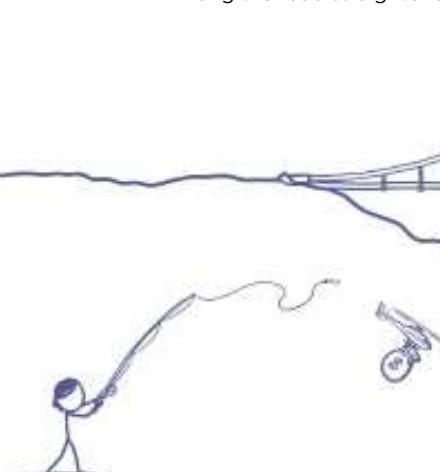
Since all this stuff you're adding is just there to hold the road up, that stuff doesn't need to be near the road. You can make a strong metal piece that goes high up over the hole—which gives it a stronger shape, but would be harder to walk on if the road went that way—and then use strong metal lines to hang the road straighter across under it.

HANGING ROAD PROBLEMS

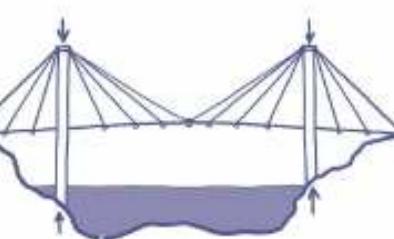
When you hold up a road by hanging it, you have to be very careful. These tall roads keep the road from being moved by the Earth's pull—which is always straight down—but wind can make the road swing side-to-side.

Some roads have fallen down because the builders didn't understand wind well enough.

VERY TALL ROAD



ROAD HANGING FROM STICKS



Another way to hold up a road is to build very strong sticks, then hang the road from the top ends of the sticks. The lines need to be a little stronger than the lines in the other hanging road, and the sticks need to be *really* strong. On the other hand, there are only two sticks, so that can make building easier.

Strong line
Smaller lines

THIS IS THE BEST KIND OF TALL ROAD.

That's not really true. Different tall roads are good for different things. But a lot of the time, when you need to cross a big hole, this kind of shape will let your road reach farther than any other shape would.



TALL ROADS ON OTHER WORLDS

A very bright person (who was known for calling the Earth a "pale blue point") once said something interesting about these kinds of roads in one of his books.

He pointed out that everything about the shape of very tall roads is decided by the laws of space and time—the laws that say how a world's weight pulls things—and those laws are the same everywhere. That means that if there's life on other worlds, the

road shape that works best for them should be the same one that works best for us. Our tall roads may look familiar to them.

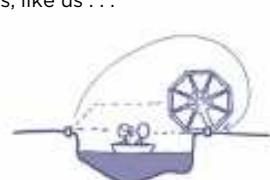
Maybe that's true; maybe it's not. We don't know if there's life on other worlds, and if there is, maybe they don't build roads at all. Maybe their way of living is different from ours in ways we can't even think about.

But if they have holes they need to get across . . .
... and if, in their world, they build things out of different shapes, like us . . .

. . . and if they have problems with holding their roads up . . .

. . . then they very well may build tall roads that look just like ours.

I like that idea, because now, when I look at one of these tall roads, I always feel a little happier. It makes me think about how maybe, somewhere far across space and time, there's someone looking at another tall road, thinking about how the shape might be found across many worlds, and—maybe—wondering about me.



BENDING COMPUTER

HOW TO OPEN A COMPUTER

KEYS
You can press these to put words in the computer.

OUTSIDE
(plastic or metal)

TOUCHING BOX
You can touch this to point at things on the screen. Some computers can feel when you touch the screen itself, so you don't need to use this box—but even on those computers, using the box can be easier because you don't have to lift your hand.

BENDER

SCREEN

BOTTOM PIECE

TURNING HOLDERS
(Don't lose these.)

INSIDE

STICKERS THAT YELL AT YOU
These are put here by the company that made the computer. They tell you that if you open the computer and then it breaks, they don't have to fix it.

POWER HOLE
This is where you join the computer to the wall so the power box doesn't run out.

POWER CHANGERS
These all help change one kind of power into another kind. The more of these they use, the calmer the power that comes out is.

THINKING BOX
Lots of parts of a computer "think" in different ways, but this is what we usually call the "thinking" part. It's a machine for quickly following a set of steps that are written down as numbers.

Following steps might not be "thinking." But it's hard to say for sure. That's one of those things where not only do we not know the answer, we're not sure what the question is.

THOUGHTS RIGHT NOW
This is a kind of memory that holds things the computer is thinking about right now. The thoughts go away when the computer turns off.

Thing that tells the air blower how hard to blow

AIR BLOWER
Computers get hot inside. This pushes air out of the computer so it doesn't get too hot and break.

LITTLE POWER CIRCLE
This circle is a power box. These used to be here to keep a small part of the computer from sleeping, so it could keep remembering who it was and what machines were joined to it.

Most computers can now remember that stuff even when they're turned off, so they don't need an extra power box for that anymore. They still use these power boxes, though, so a part of them won't sleep and can keep track of time. That way, when the rest of the computer wakes back up, it won't be confused about what day it is.

Hole where you can put a card with memories on it (like pictures from your camera) if you want the computer to have them

HOW TO OPEN A COMPUTER EVEN MORE
Different computers open differently. Some open from the top, by lifting the keys away, and some are really hard to figure out.

Note: If you're trying to use your computer, you probably don't need to do this. Just open it the normal way, like in the first picture.

If you open it like this, you might not be able to use it for a while, or maybe ever.

HOLES FOR YOUR OTHER MACHINES

SOUND BOX

Thing that knows how to talk to other machines through the holes in the computer's side

Timer for helping control how fast the computer talks to those machines

MACHINES THAT FIGHT CHANGE
These are shown on part maps with this picture:

Power runs through them, and they keep it from changing too quickly. This way, if there are any little jumps or stops in the power, it doesn't break things.

Part that remembers the steps for waking up the other parts

Place where power comes out of the power box

BABY COMPUTER
This is a very small box with all the parts of a computer in it—the parts that think, the parts that remember, the parts that send power around, and more.

It does a few different kinds of work. It controls how bright the screen is, watches to see if any keys are pushed down, and watches for finger touches on the touch box.

MEMORY HOLDER
If you write a story or put a game on your computer, it goes here.

If you take this part out and put it in another computer, it will have your stuff on it. (But it might also get confused.)

POWER BOX
This holds power so the computer can run for a while even when it's not getting power from the wall.

More than any other part, you shouldn't try to open this one. If you open the other parts, they can make the computer stop working. If you open this one, it can make you stop working.

HOLES FOR YOUR OTHER MACHINES

SOUND BOX

✓
✗
✗
✗

DARK WORLDS

Out past the cold wind world, there are lots of little ice worlds moving very slowly around the far-away Sun.



BIG WORLD BOAT

This boat visited the big world and its moons. Once it was done with its job, we told it to fly into the huge air world so it would burn up in the air, just like old space boats sometimes do on Earth.

We did that because we were worried that if we didn't, it would hit one of the other worlds and spread Earth's tiny animals there. We don't know if there are any other animals on those worlds, but if there are, we don't want our animals to eat them before we can look at them.

OLD CIRCLE-COVERED MOON

This moon got hit by lots of rocks once, which left it covered in circle-shaped holes, just like our Moon.

BIG MOON

This is the biggest and heaviest moon near the Sun.

These two worlds are huge balls of air and water with some rocks in the middle.

BIG WORLD

This is the biggest world around the Sun. It's mostly made of air. Some of its moons are almost as big as our world.

ICE WATER MOON

This world has ice on the outside, but it's warmer on the inside, and there's water under the ice.

Since there's warm water, lots of people want to go there to look for animals. We don't know if there are animals there, but if there are, we want to know about them.

THE MOON

Other moons have names, but our moon is just called the Moon. Some people visited it once.

We're not sure where it came from. We think another world probably hit our world when it was very young and lots of pieces flew off, and then the pieces fell together and made the new baby world. But we don't know for sure yet.

HOT SKY WORLD

This world is about as big as our world, but it's much hotter. One reason it's hot is that it's closer to the Sun. The other reason is that it has more air than our world, which keeps it warm, sort of like a thick coat around the whole world.

People used to think this world would be nice to live on. But if you visit this world, you will have lots of problems.

The air is really hot. If you land there, you will be on fire, and you will not come home. The air is really heavy. If you land there, it will be like you're deep under the sea. The sky will press down on you and make you get smaller, and you will not come home. The air isn't the kind of air humans breathe. If you try to breathe it, you will not come home. The air is also full of a kind of water that's bad for your skin. If it touches you, you might come home, but without your skin.

BIG TRIP TAKER ONE

We were so surprised when an earlier boat saw clouds around the cloud moon, we told Big Trip Taker One to change plans and fly past the cloud moon for a closer look. This took it off the road to the other worlds, and it headed out into space. It's now traveled farther from home than anything humans have built.

These two air worlds are smaller than the ring world and the huge air world. They have more kinds of water in their air, which makes them more blue.

COLD AIR WORLD

BIG TRIP TAKER TWO

Big Trip Taker Two is the only boat to visit the two outer worlds.

This world is far from the Sun. It has the coldest air and the fastest winds.

COLD WIND WORLD

LOST WORLD

This world is strange because it used to go around the Sun alone, but one day it came too close to the cold wind world and now it lives there.

RING WORLD BOAT

This boat visited the ring world to learn more about it—and to get a closer look at the cloud moon.

CLOUD MOON

This world is very strange—it's the only moon covered in thick clouds. The air there is even thicker than Earth's.

It would be nice if it were the kind of air we can breathe, but it's not.

SMELLY YELLOW MOON

This world has lots of color, but the color doesn't look very nice. It looks kind of like fire, but even more like food that came out of someone's mouth. It's covered in stuff that smells like old food.

SPECIAL ENGINE BOAT

This boat visited two of the little worlds between the red world and the huge world. It's pushed by a special engine that's powered by the Sun. It was the first boat to visit two different worlds and stay for a while at each of them.

LITTLE RED WORLD

RED WORLD SPACE CAR

OUR WORLD

There are animals and trees and a blue sky here. You probably live here, too; it's very hard to leave.

SMALL ROCK WORLD

This world is hard to see because it's right next to the bright Sun. It turns very slowly, so the day side gets very hot and the night side gets very cold.

THE SUN

The Sun is a star. It looks bigger and brighter than other stars because it's much closer to us. But it turns out it really is bigger and brighter than other stars.

For a while, we thought it was smaller than other stars, because most of the stars we looked at turned out to be bigger than it. But it turns out there are lots of stars that are less bright; they're just harder to see.

WORLDS AROUND THE SUN

The Sun is the biggest thing near us. Our world and everything near it goes around the Sun. Some of the worlds that go around the Sun are big enough that they have their own moons—little worlds that go around them as they all go around the Sun.

All of our history happened in this picture. Most of it happened on the third world, counting out from the Sun. You're somewhere in this picture right now!

. . . probably. But sometimes, books last a very long time. Maybe you're reading this

hundreds of years after I wrote it. Maybe you're on a boat or a world that's somewhere outside this picture.

If you are, then I'm wrong. But I'm happy to be wrong for such a cool reason! I just wish you could tell me what you've seen.

THE LITTLE RED WORLD

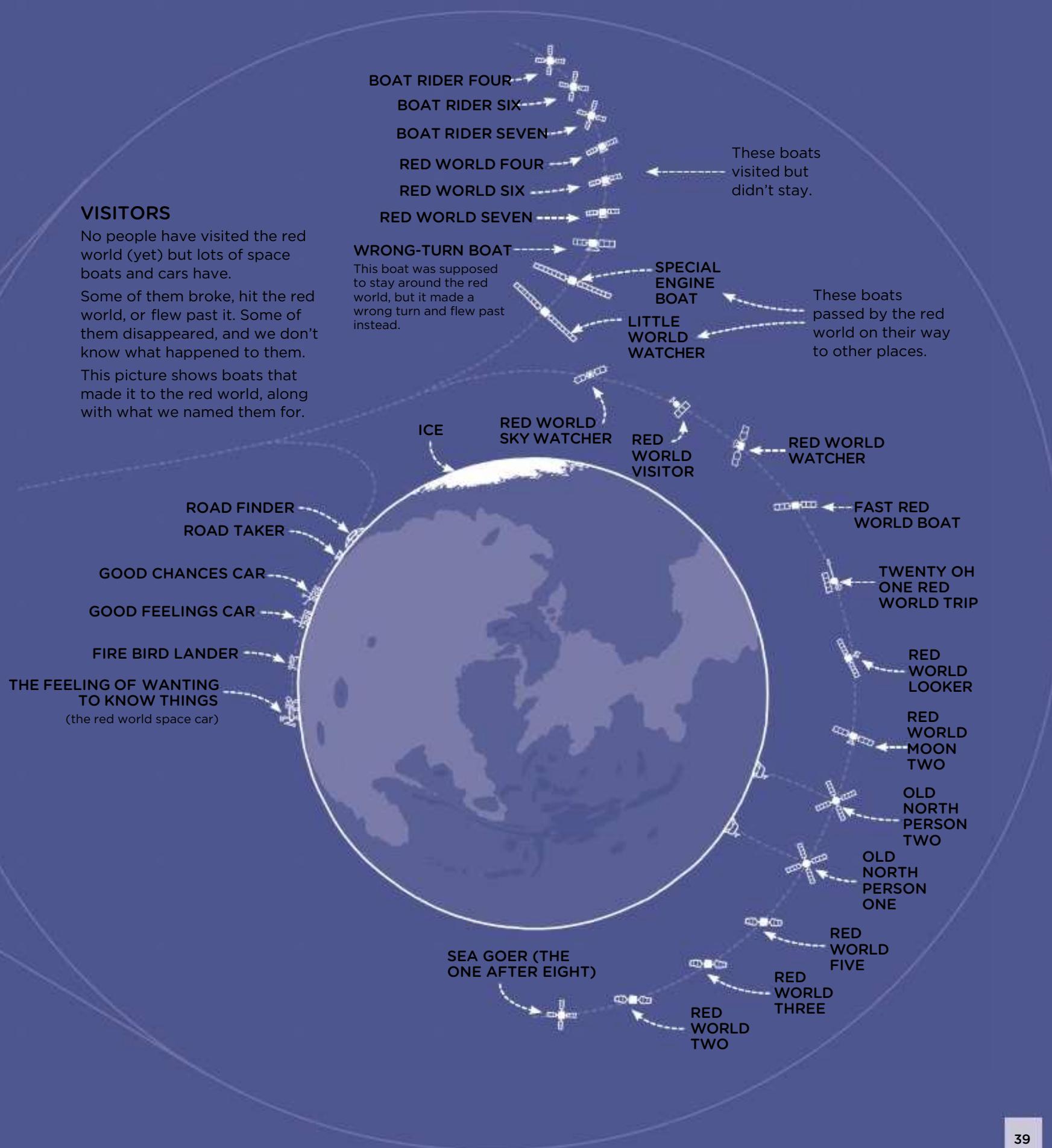
This world had seas on it when it was very young, but now it's cold and the seas are gone. It's called the red world because there's metal in the sand, and it turned red over time, for the same reason that old keys or trucks turn red on Earth if you leave them outside for a long time.

VISITORS

No people have visited the red world (yet) but lots of space boats and cars have.

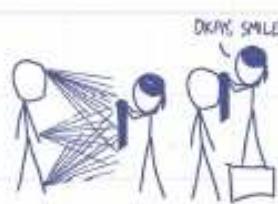
Some of them broke, hit the red world, or flew past it. Some of them disappeared, and we don't know what happened to them.

This picture shows boats that made it to the red world, along with what we named them for.



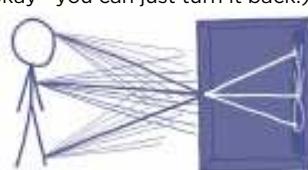
PICTURE TAKER

When you look at something, the light from it goes into your eye and makes a picture inside your head. The picture gives you an idea about the thing's shape and color.



SHAPE

To make a picture of something, you need to control the light so that each part of the paper sees light from just one part of it. One way to do this is by blocking almost all the light paths using a wall with a hole in it. (This makes a picture that's turned over, but that's okay—you can just turn it back.)



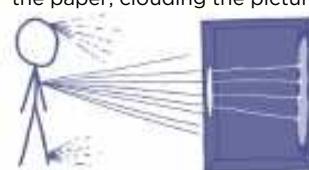
LIGHT PAPER

Some kinds of paper change color when light hits them. Picture takers used these for a long time. This paper alone isn't enough to make a picture, though. When you hold the paper up to someone, light from every part of them hits every part of the paper, so your whole page will be all one color. (Unless you hold the paper so close to the thing that each part of the paper only sees light from one part of the thing, but that doesn't work very well.)

MORE LIGHT

The hole idea works, but a tiny hole doesn't let very much light through, so it takes a long time for enough light to hit the paper to make a picture.

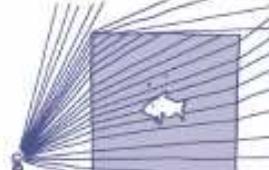
To let in more light, you could make the hole bigger, but then the light from one spot starts to spread out on the paper, clouding the picture.



BENDING LIGHT

To make the picture less clouded, we need to bend lots of light from each part of the thing toward the spot on the picture that goes with it.

We can do this by using things that bend light—like water and glass.



A few hundred years ago, we started making machines that turned light straight into pictures. These made it easier for anyone to make pictures, and picture making has become a big part of how we talk and share.



SPECIAL SHAPES

By cutting glass into the right shapes, we can make light benders that catch lots of light and send the light from each direction to a different part of the picture. This machine is good enough to take a simple picture, but it will be a little clouded and not very sharp or bright. To take a clearer picture, we have to add more benders to control the path the light takes more carefully.

Most picture takers use glass, since it's easier to cut it into a shape than water. Some people are trying to build computer-controlled benders that use water, which would let the benders change shape to control the light without using as many parts.



BIG PICTURE TAKER

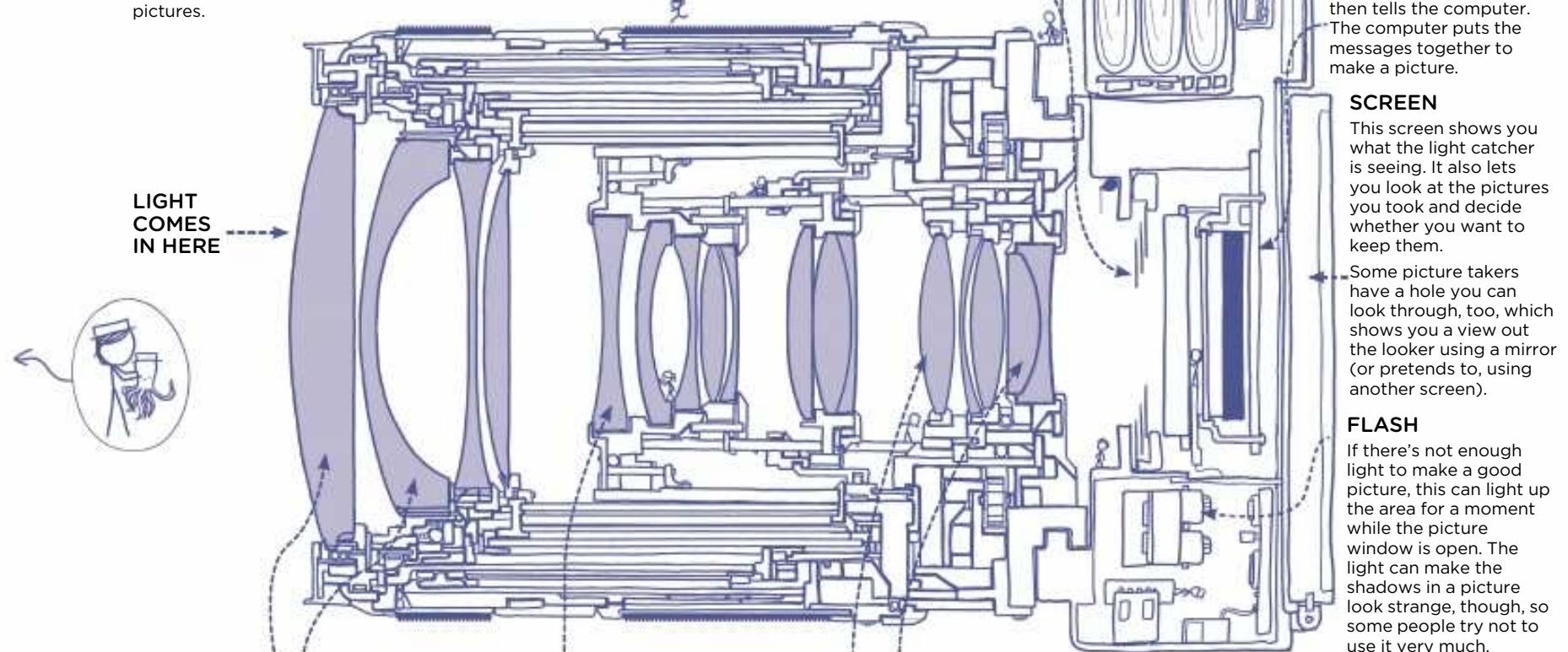
This machine is used to take sharp pictures, even of things that are small or far away. Our eyes are better than most picture takers at seeing small and far-away things, but thanks to its very large benders that take in lots of light, this kind of picture taker can see even better.

LOOKER

The whole front end of the picture taker is for gathering light. The whole thing can come off, so you can use different lookers for different kinds of pictures.

PICTURE WINDOW

This window opens and closes to let light through to the light catcher and take a picture. It has two sheets. When it starts taking a picture, the bottom sheet pulls down out of the way. When it's done gathering light, the top screen comes down to cover it. It uses two screens; if it used a screen that came up and then pulled back, then the top half of the light catcher would spend more time catching light than the bottom.



FRONT BENDERS

These grab all the light and start bringing it together so the other benders can do things with it.

FROM YOUR PICTURES, WE FIGURED YOU WERE JUST BAD AT USING CAMERAS.



CLOSE-OR-FAR BENDERS

These benders control how close up or far away the things in the picture look. They slide forward to look at small things far away, and back to see a wider view of the whole area.

DUST SHAKER WINDOW

Even a tiny piece of dust stuck to the picture window can make the machine take bad pictures. In small picture takers, the picture window is locked inside and safe from dust. But on ones where you can take the big looker off to put on a different one, dust can get in.

To keep dust from being a problem, there's a window in front of the picture window with a shaker on it. The shaker shakes the window very fast, throwing off any dust that sticks to it.

PICTURE BENDERS

These light benders are the ones that bring the light together to make a picture on the light catcher in the back.

NO MIRROR

Nice picture takers used to have a mirror here, so you could look through a hole in the top and see through the looker, to see what would be in the picture. The loud "picture-taking sound" is the mirror moving out of the way to let light reach the back.

Now, more and more picture takers are using screens to show you the view instead.

CHANGING SHAPE

Picture takers have changed shape over time. The back parts are smaller, but some of the front parts of good picture takers have stayed big. The jobs done by the back parts, like saving pictures and storing power, are now being done by small computers. The front parts bend light, and computers can't do that yet.



Soon, people might just use their hand computers as the back part, sticking them to a looker to take nice pictures.

WRITING STICKS

People used to write all their words using sticks. Now, they write words by pressing keys, which is usually a lot faster. Even though we're writing more words every day than we used to, we're using writing sticks less and less.

Some people still use sticks like these for things other than writing. People who draw pictures for a living might not use paper anymore, but most of them still use sticks to control where lines go.

(The pictures in this book weren't drawn on paper, but they were still drawn with a stick.)
Someday, we may stop using sticks for making pictures, too.

WOOD KIND (makes lines you can change)

PROBLEM FIXER

This used to be made from tree blood, but now it's usually made from a kind of plastic (which is made from very old dead things).

WOOD PART

Most of the wood for most writing sticks comes from one kind of tree. Writing-stick makers like that tree because the wood smells nice and doesn't break off into little pieces that get stuck in your hand.

WRITING PART

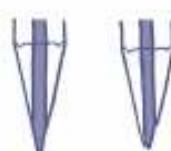
This used to be made from a kind of heavy metal, long ago, but now it's made from black rocks that we found in the ground. Most of those rocks come from very old dead things. It turns out a lot of the parts of writing sticks come from dead things.

POINTS

This kind of writing stick gets less pointy as you use it, so you have to keep cutting it to make a new point.



Sometimes you get a nice sharp point, but sometimes it's hard to get right:



When this happens, it can make you decide the thing you were writing wasn't very important after all.

WOOD KIND

(makes lines you can change)

SOUND

You push down on this part to make the end of the writing stick come out. It makes a loud sound when you do this, and some people press it over and over again. They don't always think about the sound when they're doing this, but the people around them do.



YELLOW PAINT

Although we haven't used heavy metal in the writing part in the center for hundreds of years, until not too long ago, we *did* use it to make the yellow paint on the outside. We finally learned how bad that metal was and stopped using it for yellow paint, so now you probably won't get sick from biting your writing stick.

Empty space where you can hide a piece of paper if you want to send someone a note

PUSHER

This is the bottom end, where the writing water comes out slowly. Sometimes it comes out very fast, and colors your clothes. Then you have to buy new clothes, unless you like the new colors.

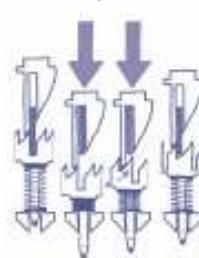
WATER KIND (makes lines you can't change)

(makes lines you can't change)

If you write something wrong with these, it will always be wrong. (Unless you write over it with the same color as the paper, so it's hidden.)

HOW THE END THING YOU PRESS WORKS

If the bottom end of the writing stick, where the writing water comes out, is inside the stick, pressing the top end makes it go out. If it's out, pressing again makes it come back in. The writing stick does this by using several strangely shaped parts that all push on each other in different ways, and it's hard to understand even when you can see it happening. It's a very cool idea.



END HAT

This is made of plastic, like most of the parts of this writing stick. If you take this off, the writing water won't fall out, but it will make the writing stick look less nice.

WRITING WATER

This is the stuff that goes on the page. We used to get it from sea animals that have many arms.

Now—like almost every other part of these sticks—writing water is often made from black rocks and fire water, which are themselves made from long-ago dead trees and sea life. Some writing water, like the kind used to write news on paper each day,* is made from a kind of food we grow (it's a kind of food people use to make pretend animal parts to eat instead of real ones).

*If you're reading this in the future, this is a thing we used to do.

ANIMAL WE GOT WRITING WATER FROM

HUMAN



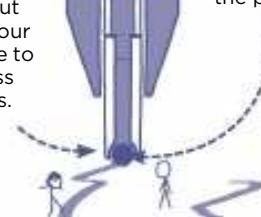
ARMS	2 +2 OTHERS	8 +2 OTHERS
BONES	206	0
BIG BRAIN	✓	✓
WRITING WATER BAG		✓
CAN DRIVE CAR	✓	
STRANGE	✓	✓

When the ball dries out, you have to move it around for a while before it gets covered with writing water again.



BALL MADE OF VERY, VERY HARD METAL

The ball at the bottom end rolls around as the writing stick moves over the paper. The top side of the ball gets covered with writing water, and then it rolls over and leaves the water on the paper.



HAND COMPUTER

These machines began as radios for talking out loud to people who were far away. Over the years, they slowly became more and more like computers.

As these machines turned into computers, they started taking the place of a lot of things we used to carry around—like picture takers, music players, and even books.



FACE CHECKER

This turns the screen off if your head is near it, so you don't press keys with your face while you're talking.

HOT SPOT TALKER

This lets the hand computer talk to people through a little radio in your house, instead of the big radio run by the phone company, which can save you money.

EXTRA MEMORY HOLDER

If your phone is storing too many memories for you (like pictures, sounds, and games), you can put a card here to give it more space.

As computers and radios get faster, companies are holding more and more of your memories on their computers, and only sending them to you when you ask for them.

LOUD CONTROLS

These controls make the sound in your ear louder or quieter.

TINY POWER GATE

Like other computers, almost every part of a hand computer is full of many different kinds of power gates.

This picture is used in maps of parts to mean "power gate":



These gates take in power from one line, and listen to another line to decide whether to let the power through or not. Computer brains are built by sticking these gates together.

There are as many power gates in a computer as there are people on Earth. Some of them are big and easy to see, but most of them are tiny and control very little power. The gates, I mean, not the people.

RADIO FEELER

This part listens to the thin pieces of metal along the outside of the hand computer. When a radio message comes in, it makes power move in the metal. This thing listens to how the power is changing and turns it into words.

It also listens to words that the hand computer wants to send back out, and turns them into power changes to send down the metal.

FRONT CAMERA

SOUND MAKER

BIG CAMERA

EAR PIECE HOLE

POWER KEY

You can push this to make the computer sleep or wake up.

POCKET MOVER

This piece of metal turns very fast to make the phone move. That way, it can get your attention without making too much noise. (Unless it's sitting on a hard table; then it can make a *lot* of noise.)

JOINERS

Different parts of the hand computer, like the screen and the radio feelers, join up with the rest of the phone here when it gets put together.

CARD HOLDER

This holds the card that lets the phone talk to the world. The phone works by using a radio to talk to a company that you pay to carry your messages. It uses this card to tell them which hand computer they're talking to.

SOUND UNDERSTANDER

RADIO TALKER

This tells the hand computer how to understand the words the company's radios send.

DIRECTION FEELER

FAST MEMORY

This part of the phone holds stuff the hand computer is thinking about right now, like pages you're looking at or games you're playing. The memory goes away when the phone turns off.

BIG SOUND MAKER

This thing makes noise that you can hear even when your ear is far away from the phone.

LISTENING BOX

This is a special thinking box that just listens for words. Since it only does one thing, it can do it without as much power as the main thinking box would need. If a phone has this, you can make it listen for your voice all the time, not just when you press a key.

POWER CONTROLLER

This thing pays attention to what different parts of the computer are doing, and makes sure each part gets sent the power it needs.

POWER BOX

POWER HOLE

COLORS OF LIGHT

Light is made up of waves, and we see longer waves and shorter waves as different colors. When it rains, the Sun's light hits tiny drops of water and bends as it goes through them. Some colors of light bend more than others, so different colors reach your eye from different parts of the sky.

These sky colors are sorted by how long their waves are, from the shortest waves, blue, to the longest waves, red. But the kinds of light don't stop there! Those are just the shortest and longest waves that our eyes can see.

HOW LONG ARE THESE WAVES?

- A big country
- A small country
- A city
- A small town
- A building
- A truck
- A dog
- A finger
- A computer key
- These two black spots:
- A hair (the short way)
- A single bag of water from your blood

WHAT ARE THEY?

LONG WAVES

RADIO

Radio waves and light are the same stuff. Radio is just longer. Our eyes can't see light that long, but we can build machines that can.

NEWER RADIO

Cars use space radios for a few different things, like . . .

- ... finding where they are . . .
- ... and playing music
- Phones
- Computer hot spots

"SMALL" WAVES

Food-heating boxes are named after these waves (see page 16). They use this color.

WARM LIGHT

Everything gives off light because everything is at least a little warm, and warm things give off light. Warmer things give off more light made of shorter waves.

Our bodies give off these colors of light because we're kind of warm, but not warm enough to give off light you can see. If you wear special computer glasses that help you see these colors of light, you can see where people are in the dark using the light from their bodies.

LIGHT WE CAN SEE

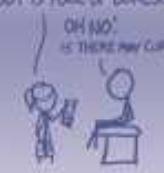
RAIN COLORS

People say those rain lights in the sky show all the colors, but they don't really; there's no deep pink.

The more you learn about color, the more you find that almost everything people say about color is only sort of true.

FROM THESE IMAGES, IT LOOKS LIKE YOUR BODY IS FULL OF BONES.

OH NO! IS THERE ANY CURE?



LIGHT CARRYING A LOT OF POWER

These very "short" colors of light aren't really like waves at all. They're more like tiny rocks going very fast.

Not very many things make this kind of light.

This picture shows what other colors you would see if the rain colors kept going. (The picture isn't in color, but that's okay—they're not real colors, anyway!)

In real life, even if you could see longer and shorter light waves, you wouldn't see these colors spread out like this in the sky. There are three reasons for this.

First, the Sun gives off most of its light in colors that we can see, and light that's a little shorter or longer. In colors that are *much* shorter or longer, the Sun is pretty dark!

Second, lots of these kinds of light don't go through water, so they wouldn't go through the rain.

Third, the colors are sorted from long to short because short waves (blue) bend more than long waves (red). But there are some colors, kinds we can't see, where it goes the other way! That means that these colors wouldn't be spread out like they're shown here; they'd be laid in sheets over themselves—some parts top to bottom and other parts bottom to top—all in the same area of the sky.

CAN THEY REACH US FROM SPACE?

This side shows which kinds of light can get through Earth's air.

These long waves go through normal air, but can't get through a special layer of air near the edge of space. The air in that layer acts kind of like a mirror for radio, which is why you can pick up some kinds of radio messages from other parts of the Earth.

These radio waves go through air just fine. We use them for looking at stars and talking to our space boats.

These colors are stopped by the water in the air. Light from the Sun can get through air. That's good, since we need it to see.

The Sun gives off light in these colors. The colors our eyes can see are right in the middle of that, which makes sense; eyes grew to fit the Sun's light.

A special layer stops some of the light that burns your skin. A while back, we learned that we had made a hole in that layer. We didn't mean to. We're fixing it.

FAR-AWAY FLASHES

About once every day, our space boats see flashes of very, very high-power light from somewhere far off in space.

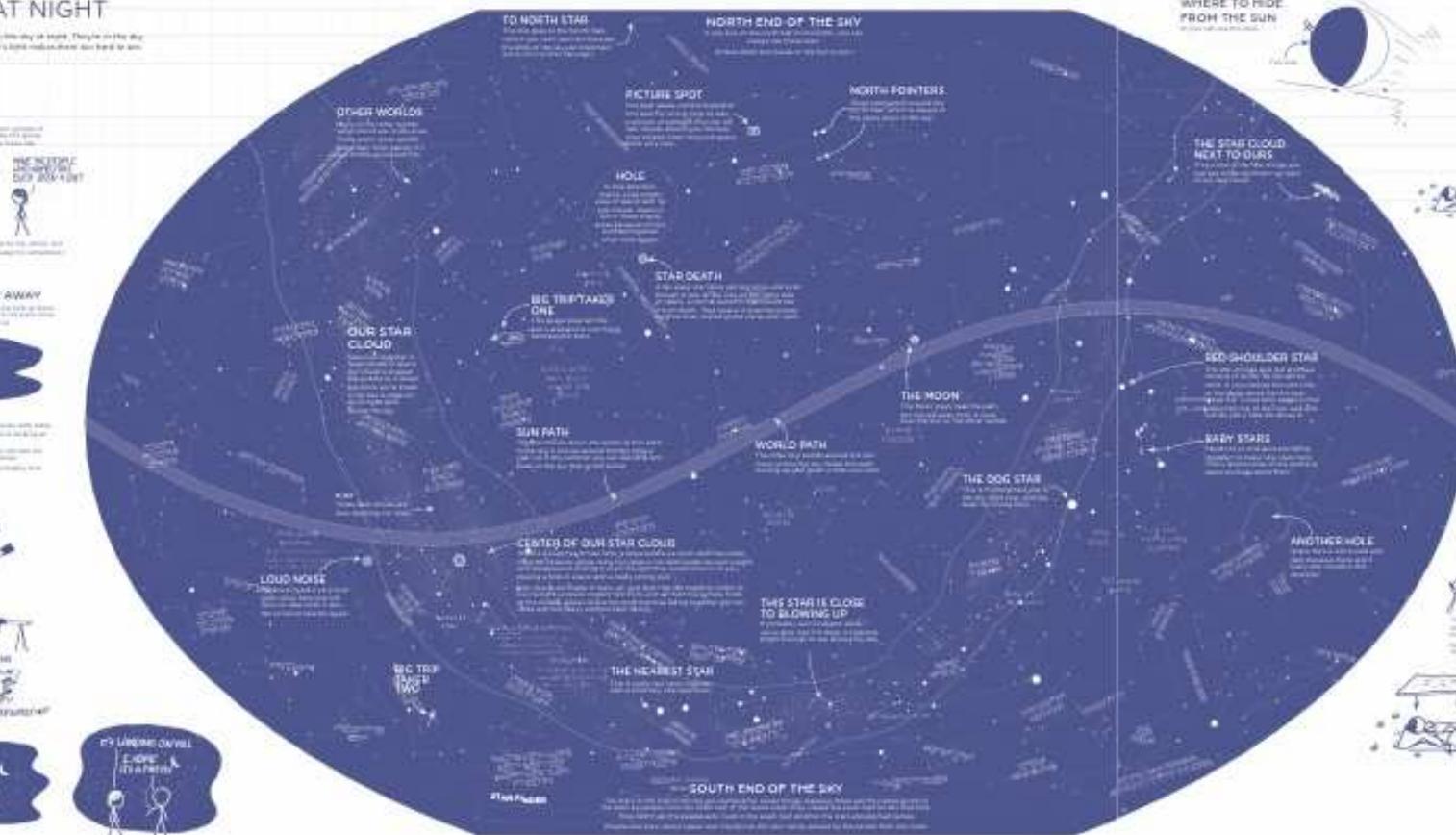
We're pretty sure they come from huge stars dying, but we aren't sure exactly what happens in the stars to make the light.

THE SKY AT NIGHT

This map shows parts of the night sky in a variety of ways. They're in the sky, but even this map has lots of things that aren't stars or constellations.

LINES

Lines are the boundaries between different regions of the sky. They're not stars, but they're in the sky. You can see them in the sky, but they're not stars.



STARS ARE FAR AWAY

Stars are far away. They're in the sky, but they're not stars. They're not stars, but they're in the sky.

HOW TO USE A LOOKING GLASS

How to use a looking glass. You can look at the stars through a looking glass. You can look at the stars through a looking glass.

It's like looking at the stars through a looking glass. It's like looking at the stars through a looking glass.

WHERE TO HIDE FROM THE SUN

Where to hide from the sun. You can hide from the sun.

HOW TO LOOK AT SPACE

How to look at space. You can look at space.

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THE PIECES EVERYTHING IS MADE OF

People used to think that everything around us was built from four kinds of stuff: like light) are made from these pieces earth, air, fire, and water. They were almost right—but instead of four kinds of pieces, there are more like ten dozen.

All the things we can touch (but not things like each other, we've found so far, but there are probably more.)

EARTH METALS

These things are called "metals," but a lot of them are more like rocks or dust. They often burn easily.



PIECES OF PIECES

These pieces are made of other pieces. Different kinds of pieces have different numbers of those smaller parts. There are three main kinds of these smaller parts—two heavy ones and a light one.



Over the past hundred years, we've learned that the idea of "where" doesn't always work well for very small things.

THE METAL IN YOUR PHONE'S POWER BOX

DON'T BREATHE THIS STUFF AS DUST OR YOU MAY DIE.

PART OF THIS

LIGHT METAL THAT BURNS VERY HOT AND BRIGHT

STUFF YOUR BRAIN USES TO TALK TO THE REST OF YOUR BODY

THE STUFF TEETH ARE MADE OF

SOME TIME COUNTERS WORK BY WATCHING HOW FAST PIECES OF THIS STUFF SHAKE AROUND.

METAL WHOSE HEAT WAS ONCE USED TO POWER LIGHTS THAT HELP SEA BOATS IN THE FAR NORTH

WHEN A HEAVY METAL POWER BUILDING BLOWS UP, THIS STUFF IS A BIG PROBLEM.

STUFF YOU DRINK SO DOCTORS CAN LOOK INSIDE YOUR BODY

STUFF THAT LASTS FOR TWENTY MINUTES

THIS

TABLE SHAPE

The boxes in this table are in order from left to right and top to bottom. It has the same shape because pieces are in groups with other pieces that are a lot like them.

(The reason those groups are like each other has to do with the number of light parts around the outside of the piece—which is mostly the same as the piece's center number—and the way different numbers of light parts sort themselves around the outside of the piece.)

NORMAL METALS

The pieces in this middle area of the table are what we usually think of as "metals." Most of them are strong, hard, and look a little like mirrors.

SHORT LIVES, STRANGE HEAT

Some kinds of pieces don't last very long, slowly breaking down into other pieces over time by throwing away bits of their centers in all directions, which makes them give off a kind of strange heat.

We count how long a kind of piece lasts by timing how long it takes for half of it to break down. We call this the piece's "half-life."

CENTER NUMBER

We name the pieces by counting how many of one kind they have in their center, and use that number to put pieces in boxes in the table. The other heavy part doesn't matter to the count, so pieces with different numbers of that part may share the same box in the table.

STAR DOCTORS

People who learn about how stars work call everything below this line a "metal," which is a little strange. But stars are mostly made of the two things above this line, so it also kind of makes sense that star doctors wouldn't care too much about the other stuff.

THE STUFF THAT KEEPS KITCHEN GLASS FROM BREAKING WHEN HOT

THIS METAL

THE ROCK THAT MAKES BEACHES, GLASS, AND COMPUTER BRAINS

THE ROCK

BURNING WHITE ROCKS

SMELLY YELLOW ROCKS

AIR USED BY DOCTORS TO MAKE THIN BRIGHTLIGHTS FOR CUTTING EYES

RED WATER

METAL THAT'S NOT VERY INTERESTING

METAL WELL KNOWN FOR BEING VERY STRONG BUT VERY LIGHT

A METAL NAMED AFTER THIS TINY TOWN

METAL THAT TELLS US ABOUT THE EARLY EARTH

METAL NAMED AFTER A GOD, BUT ONLY AFTER A LONG NIGHT OVER WHAT TO CALL IT

METAL WE ADD TO OTHER METALS

METAL ON THIS TAPE THAT BREAKS DOWN WITH STRANGE HEAT

METAL WE DON'T FIND VERY MUCH OF

TWO METALS USED IN CARS TO MAKE THEIR SMOKE CLEANER

METAL USED IN PAINT UNTIL WE REALIZED IT MADE PEOPLE SICK

METAL USED IN POWER HOLDERS

THIS STUFF

METAL USED TO MAKE VERY FAST SKY BOAT PUSHERS

METAL USED TO MAKE SKY BOAT PUSHERS

THE HARD METAL IN THE END OF A WRITING STICK

METAL LAID DOWN A WRITING STICK

A ROCK THAT PEOPLE WILL PAY AS MUCH FOR AS GOLD

A ROCK THAT PEOPLE WILL PAY AS MUCH FOR AS GOLD

GOLD

GOLD

STUFF THAT LASTS FOR AN HOUR AND A HALF

STUFF THAT LASTS FOR A DAY

STUFF THAT LASTS FOR TWO MINUTES

STUFF THAT LASTS FOR ONE MINUTE

STUFF THAT LASTS FOR TEN SECONDS

STUFF THAT LASTS FOR EIGHT SECONDS

STUFF THAT LASTS FOR TEN SECONDS

STUFF THAT LASTS FOR FIVE SECONDS

STUFF THAT LASTS FOR HALF A MINUTE

STUFF THAT LASTS FOR A THIRD OF A MINUTE

STUFF THAT LASTS FOR THREE SECONDS

STUFF THAT LASTS FOR LESS THAN A THIRD OF A SECOND

STUFF THAT LASTS FOR THE TIME IT TAKES YOU TO CLOSE AND OPEN YOUR EYES

STUFF THAT LASTS FOR THE TIME IT TAKES YOU TO CLOSE AND OPEN YOUR EYES

STUFF THAT LASTS FOR ONE FOOT

STUFF THAT LASTS FOR ONE FOOT

If we find any more pieces, they'll go in a new row here.

I HOPE WE DON'T ADD ANY NEW ONES. I LIKE HOW THE BOTTOM ROW GOES ALL THE WAY ACROSS.

NOT METAL

The things toward the top right part of the table are things that aren't metal. Most of these things are very different from metals. Some are even in the form of air. A few of them look like a kind of rock or water instead of air. They usually turn to air easily, and most of them are not very strong.

People don't agree exactly where the line between "metals" and "not metals" is, but it's somewhere around here, and runs down and to the right.

Here are a few of the things these pieces are named after.

The things in this area of the table do a lot of things. When you put them near things from the other end of the table, they can turn to different kinds of water, start fires, or make everything blow up.

The things in this area of the table are pretty quiet. When you put these kinds of air with other things, they usually don't seem to notice.

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OUR STAR

The Sun is a star. It's like other stars, but looks brighter because it's closer. The Sun is so bright that we can only see other stars when its light is blocked by the Earth.

AIR AROUND THE SUN

The Sun has air around it, like the Earth, but it doesn't have a hard surface under that air. It just keeps getting thicker, all the way to the center.

The air around the Sun is even hotter than some of the inside parts, which is very strange. We're not sure why it's like that.

CENTER

The middle of the Sun is where most of the weight is gathered and where the special fire happens. This special fire only starts if you push air together very, very hard. (This is the fire that powers our biggest city-burning machines.)

FIRE LIGHT

Around the center of the Sun, hot air doesn't rise. Hot air only rises when there's cooler air above it, and near the center of the Sun, *all* the air is hot. Instead, the heat is carried through the Sun by light, just like how light carries the Sun's heat to your face.

The light takes a winding path through the Sun's air. The path is so long that it can take a very long time to reach the surface—as long as hundreds of human lives.

DARK SPOTS

Sometimes dark, cooler spots appear on the Sun, caused by power running through the Sun's surface. Big fire storms often come from places with dark spots.

Stars are clouds of air that fell together so hard that they started burning. The Sun's air has been burning since just before the Earth formed, and will keep burning for about that

long into the future. After the Sun runs out of air to burn, it will get very big for a short time, blow out lots of heat, then fall together into a small heavy ball that slowly cools.

HOT AIR

The air on fire at the center of the Sun blows light and heat out in all directions. The air in the Sun is trying to fall toward the center, but the light and heat keep blowing it away.

Near the surface of the Sun, the air shakes and rises and turns over, much like a cup of water when you heat it up.

The fire from the center of the Sun heats the air. The air rises and turns over, carrying heat to the surface, where the heat is sent out to space (most of it as light). Some of the air is blown away too, but most of it—cooler, thanks to its trip to space—falls back down to heat up again.

FIRE STORMS

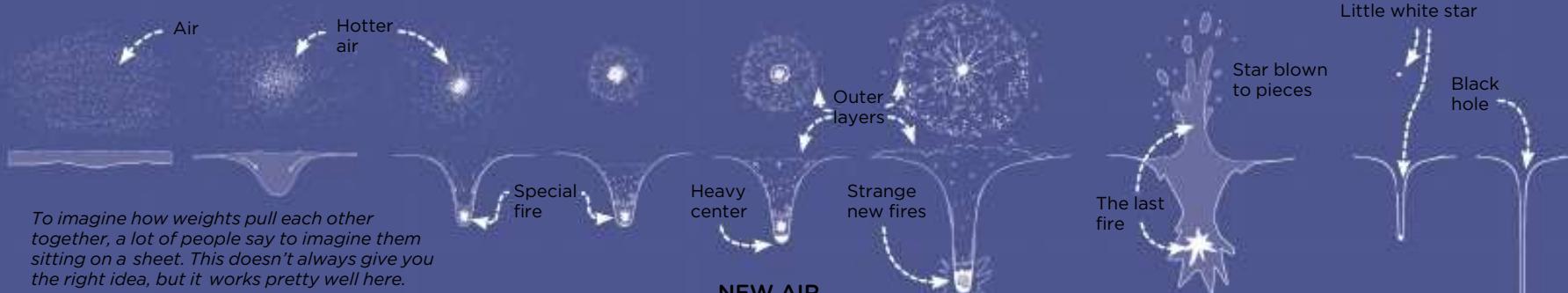
The air in the Sun makes power as it moves (for the same reason that a turning wheel can make power run through metal lines). Sometimes, the power runs through the Sun's surface and blows some of the Sun's fire out into space. These fire storms carry power with them, and if they hit Earth, they can break our computers and power lines.

HOW MUCH HEAT?

Although it's very hot, the fire doesn't actually make new heat very fast. An area of air at the Sun's center makes about as much heat as the body of a cold-blooded animal of the same size.

Even though that doesn't seem like a lot, the Sun is so big—and it has such a thick coat of air around it—that the heat adds up, making it much hotter than any animal.

WHY STARS HAPPEN



To imagine how weights pull each other together, a lot of people say to imagine them sitting on a sheet. This doesn't always give you the right idea, but it works pretty well here.

AIR CLOUD

A star begins as a cloud of air in space. This cloud is always moving, pushing, and feeling waves go through it, like the surface of the sea.

After a while, a pocket of air happens to get close enough together that the pull of its weight becomes stronger than the force keeping it spread out.

As the air falls together, it gets heavier. This makes it pull harder, which pulls in more air.

As air falls together, it also gets hotter. This heat is how the air pushes back against whatever is pushing it together.

But in this cloud, that heat isn't as strong as the pull of the air's own weight, so it keeps getting smaller and hotter.

SPECIAL FIRE

The air seems like it might keep getting smaller and hotter like this forever. But when it gets hot enough, a new kind of heat is made.

When air is pushed together hard enough, the pieces it's made of can stick together. When they do, they let out a lot of light and heat. This is the heat that powers our largest city-burning war machines.

When a cloud of air gets hot enough, this kind of fire starts, and a great heat blows out from where it burns. This hot wind is strong enough to fight the force pulling the air together. The air gets hotter, but stops getting smaller. A star is born.

The force pushing away and the force pushing in stop each other. If the star falls a little closer together, it makes the fire burn much hotter, pushing it back out.

A star like the Sun has enough air to burn for a very long time—long enough for worlds and life to form. But it can't burn forever.

NEW AIR

When the star burns air by pushing it together, it makes a new kind of heavier air. This kind of air doesn't burn as well, so it gathers, not burned, in the center of the star.

The new air's weight pulls the star together, making the fire burn hotter. The wind from this hotter fire blows the outer parts of the star out farther. Over time, the star grows.

When it starts running out of air to burn, the center falls even closer together, lighting new kinds of fire that blow the outer layers farther away from the star. The star gets very, very big... and as the fires begin to die, the force holding back the star's weight disappears, and it starts to fall in on itself.

THE END OF THE EARTH

When the Sun gets very big, its edge will reach the Earth, and Earth will fall in and burn up. You don't need to worry about that now, though. If we want to stay alive past the Sun's death, there are lots of other problems we'll have to face first. Worrying about that one now would be like worrying that one day a tree will grow where you're standing.

THE LAST FIRE

As the dying star falls together, it becomes even hotter than ever before. In this heat, even things that couldn't burn before start to burn, creating new and strange kinds of air. (Much of the stuff we're made of here on Earth comes from a fire like this.)

A lot of heat and light pour out from this last fire, and for a moment, the star can become the brightest thing in all of space.

WHAT'S LEFT

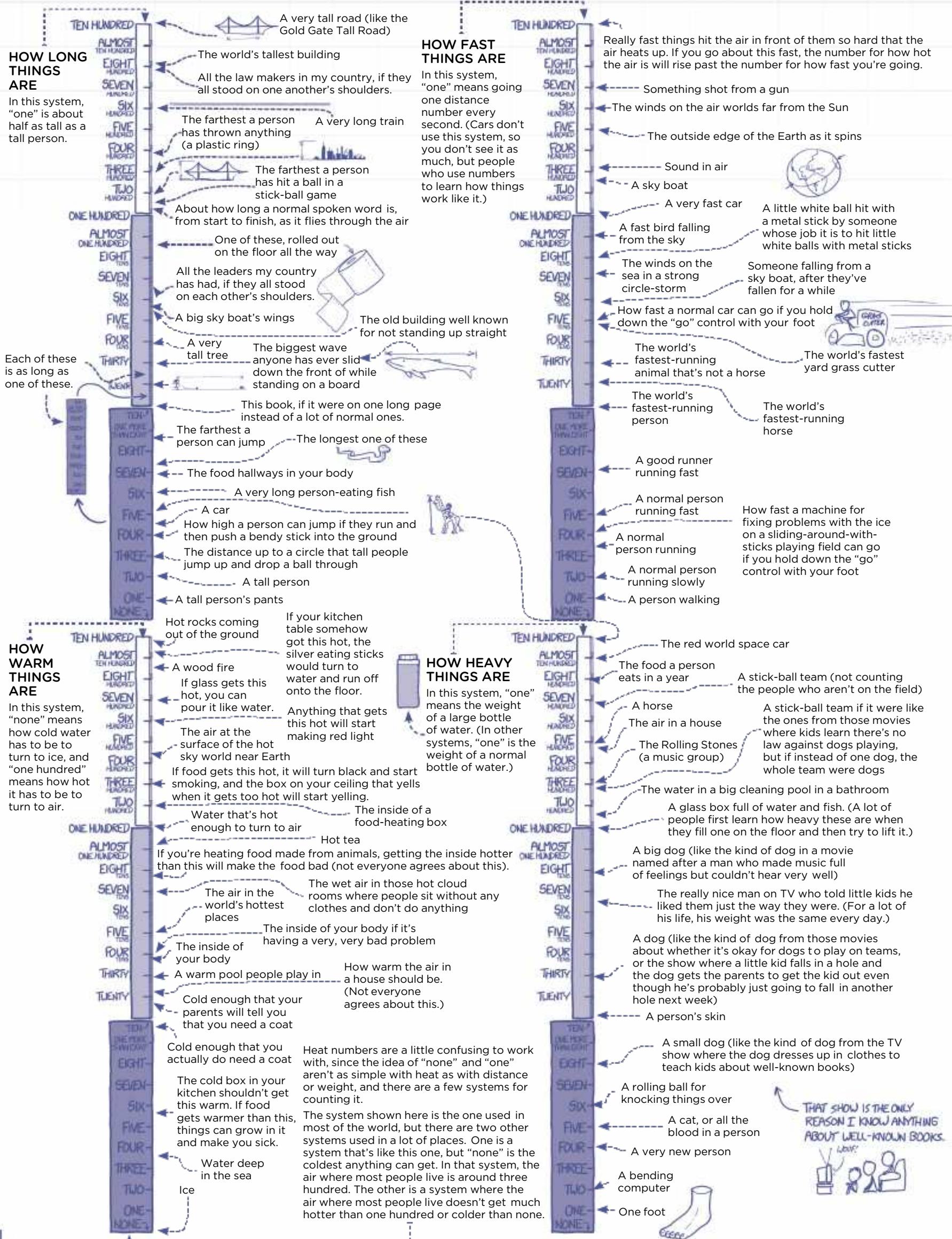
The heat blows much of the star away into space. Sometimes, what's left of the star will fall together until it becomes a bright white ball of hard air that slowly cools. Someday, this will happen to the Sun. If the star is bigger than the Sun, it may have too much weight to stop even there. The weight of the hard ball will make it keep falling in on itself, until it becomes so strong it pulls in even light, leaving behind a black hole in space.

HOW TO COUNT THINGS

To count how heavy things are, we pick a weight to call "one." Then, if you say a weight is "ten," people understand it's as heavy as ten "ones." We do the same for counting other things, like how fast or hot things are.

People don't always agree on how much "one" is, which can cause a lot of problems. A space boat once missed a world because people got confused about which "one" they should be using for weight.

Most countries have agreed to make "one" the same thing everywhere. Here's what numbers from one to ten hundred mean in that counting system.



ROOM FOR HELPING PEOPLE

Little things go wrong in our bodies all the time, but bodies are pretty good at fixing problems. Parts are always breaking, but our bodies make new ones. Tiny living things try to make us sick, but our bodies are full of groups of tiny machines flying all over the

place looking for things that don't belong and getting rid of them. Usually, these problems get fixed without us even knowing!

But just as there are places we can't travel without help from other people and machines—like the Moon, or the bottom of the

sea—there are problems we can't fix without help from other people and machines.

When we're sick, or something goes wrong with us, sometimes we need to visit a room full of machines like these so we can talk to doctors and get the help we need.

WALL AIR

The walls of normal houses have power holes and water holes. The walls in these buildings have those holes, but they also have lots of air holes. If someone is having trouble breathing, the doctors will run a line to their nose or mouth from one of these holes, and the wall will help them get more air into that person.

DROPS

This makes the water fall through in the form of drops, instead of running down in a line. This makes it easier for doctors to see how fast it's moving.

ADDING-TO-BLOOD COMPUTER

Doctors tell this computer how much stuff to add through the hand line.

NOISES

If this machine notices something, it makes a little noise, like a phone getting a message, to make sure the doctors know what it's doing. These noises happen a lot, and can make people worry that there's a problem, but they're normal.

CHEST STARTER

If the blood pusher in your chest stops working, it has to be fixed very fast. This machine sends power through it, which can start it working again.

SPECIAL FOODS TO HELP PEOPLE WHO ARE SICK IN DIFFERENT WAYS

SPECIAL WATER FOR ADDING TO BLOOD

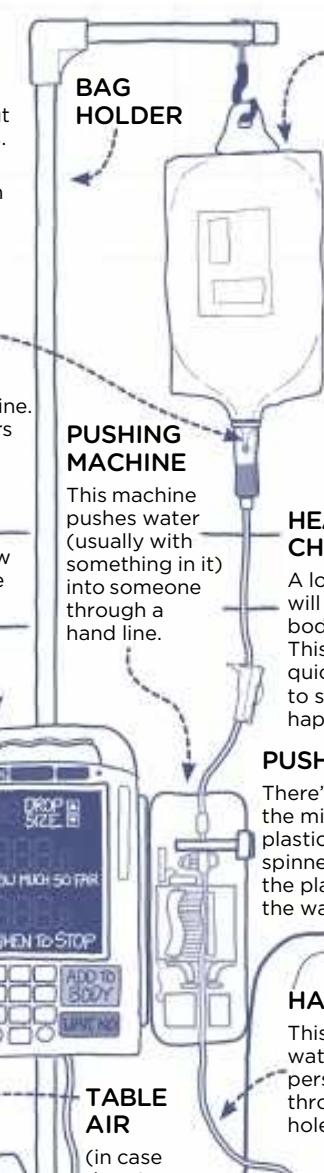
STUFF TO HELP GROWN-UPS BREATHE

STUFF TO HELP KIDS BREATHE (THEIR THROATS HAVE A DIFFERENT SHAPE, SO THEY NEED DIFFERENT STUFF)

STUFF TO MAKE A TINY HOLE IN A SICK PERSON'S HAND SO DOCTORS CAN ADD THINGS THAT HELP THEM GET BETTER

PARTS FOR ADDING STUFF THROUGH HANDS

STUFF FOR CLEANING UP



BAG OF WATER TO ADD TO BLOOD

These bags are used to put water and stuff into people. Sometimes, doctors put things in bodies by having people eat them, but these are used when doctors need to take a shorter path, without going through the food system.

Sometimes, the bags hold special food to make people better. Other times, the bags just give water. They do that if someone needs water but might not be able to drink anything without feeling sick.

HEAT CHECKER

A lot of problems will cause your body to get hot. This lets the doctor quickly check to see if that's happening.

PUSHER

There's water in the middle of this plastic line, and a spinner presses the plastic to push the water down it.

HAND LINE

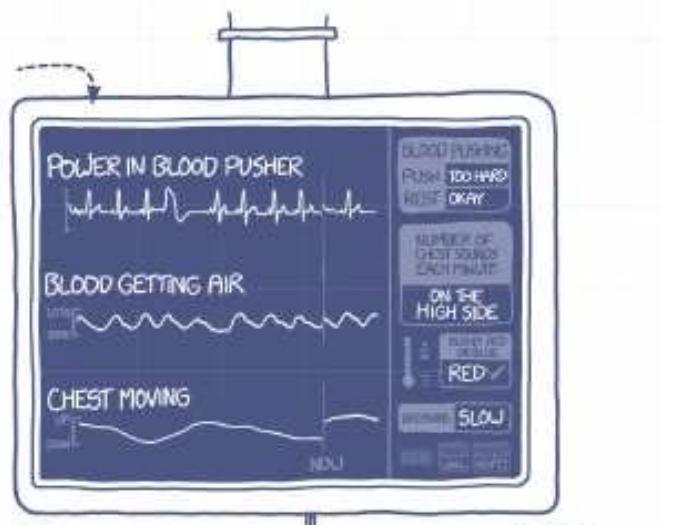
This plastic carries water into the person's blood through a little hole in their hand.

PERSON WATCHER

This machine watches the person in the bed, keeping track of how they're breathing and how different parts of their body are working. It shows this information on a screen so doctors can quickly tell whether there's a problem.

WALL POWER

Visiting one of these rooms can mean a lot of sitting around and waiting. If you're ever stuck in one of these rooms and your phone is running out of power, it's okay to ask the doctors if you can use the wall power! They have lots of these holes and won't mind.

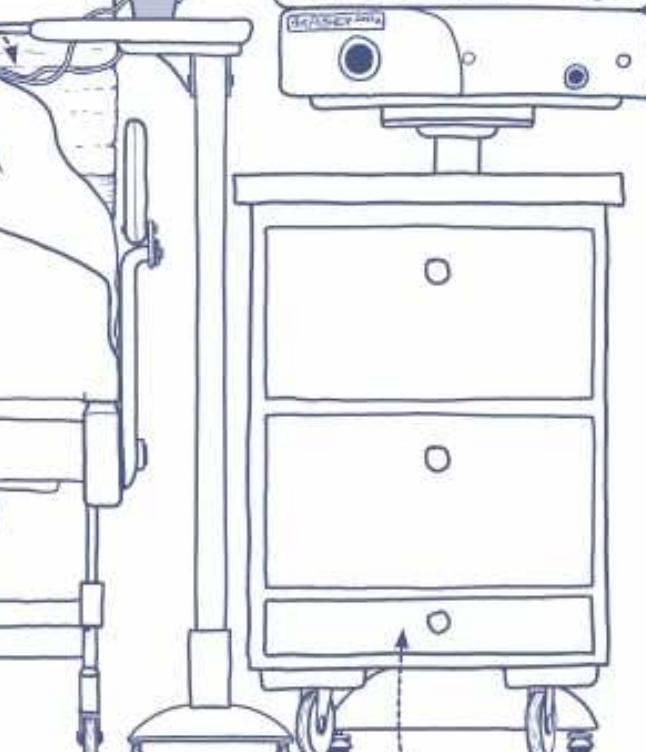


BREATHING MACHINE

If someone can't use their chest to breathe, this machine can move air in and out of their chest for them. It works by pushing and pulling the side of a box of air to push air down a plastic line into the person's mouth or nose.

ARM TABLE

People can keep a cup of water here. Doctors will also bring around food when it's time to eat (unless the people are sick in a way that means they can't eat normal food right away).



HOLDING BOXES

These are usually full of extra clothes and sheets for people who are visiting, but they can also be empty, for visitors to put their stuff in. (If you're visiting, you should ask before using them.)

ROLLING PROBLEM TABLE

If someone has a new problem show up while they're in the room, and there's no time to move them to a place where that kind of problem is normally fixed, doctors will bring one of these rolling problem tables. They're full of things for helping with all kinds of problems that need to be fixed within just a few minutes of when they happen.

WHEELS

These let people move the bag holder around. That way, they can go to the bathroom without having to take out their hand line.

FOOT CONTROLS

Doctors can move the parts of the bed using these foot controls, to make it lie flat like a normal bed or sit up like a chair.

LEG PRESSERS

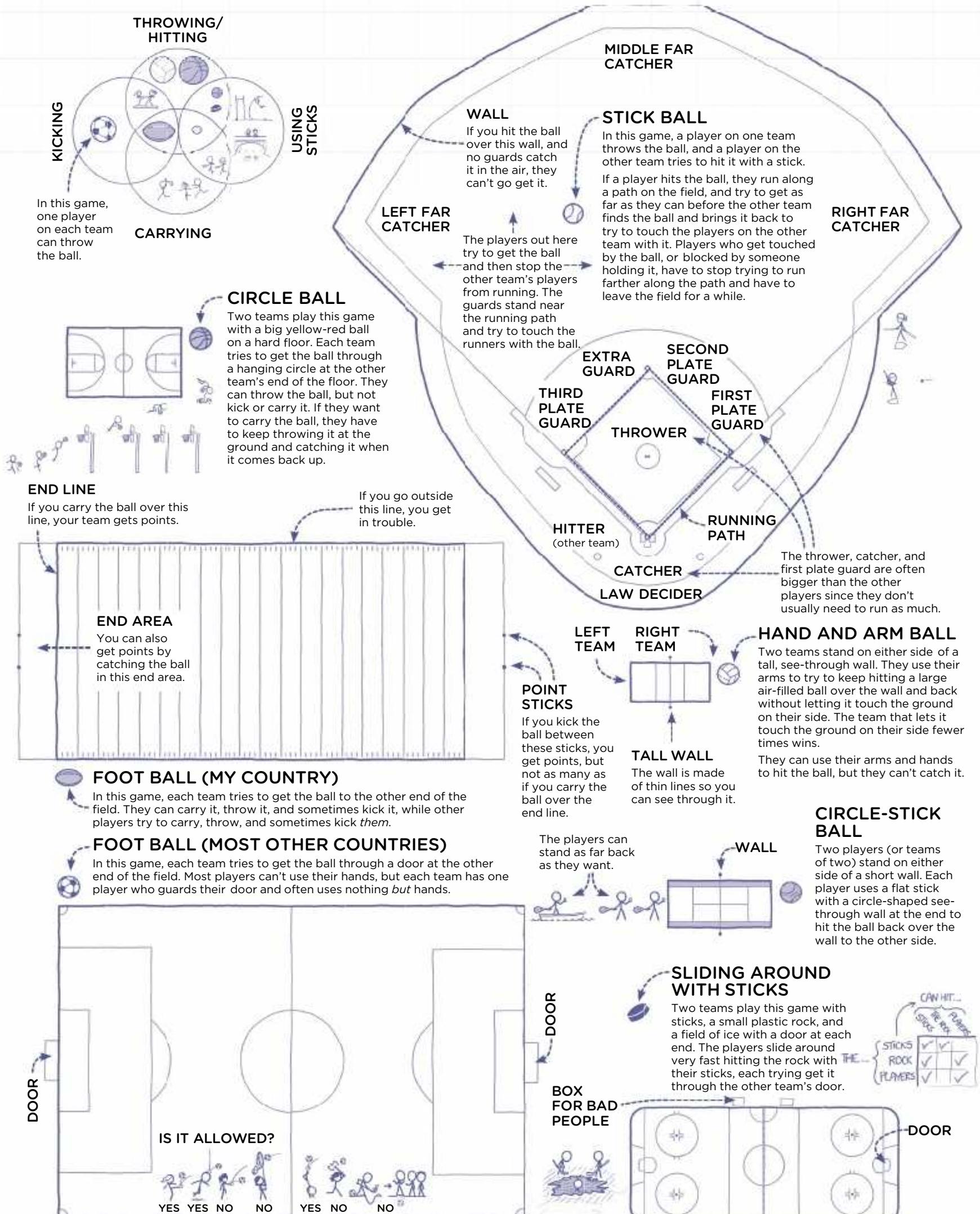
Sometimes, if people have certain kinds of problems with blood, doctors will have them wear special pants that press on their legs. This is to move blood around, to keep too much of it from getting stuck somewhere in their body and causing a problem.

PLAYING FIELDS

And how big they are.

(The real-life fields are all ten hundred times larger than these drawings.)

A lot of games are played by throwing things, kicking things, hitting things, and using sticks. Games put these together in different ways:



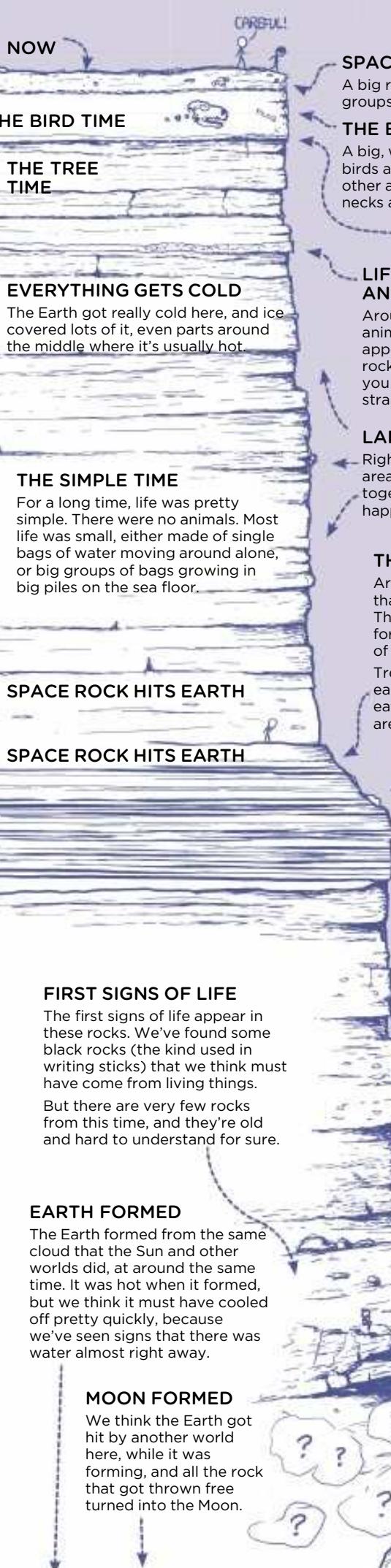
EARTH'S PAST

Everything* that has happened here so far *NOT QUITE EVERYTHING

We learn about the history of the Earth from rocks. Rocks are laid down in layers, and by looking at the layers from different parts of the world, which are all different ages, we can piece together a single history that goes back almost to the start of the world.

This picture shows what it would look like if you could see the whole history of Earth in a single set of layers, with every year as thick as every other. In real life, no single place has all these layers together, and there are no layers at all from the oldest part of the Earth's history.

All of human history, since we first learned to write and build cities, is a layer as thin as a piece of paper.



SPACE ROCK HITS EARTH

A big rock hit the Earth, and lots of the animals died. Some groups lived, like birds, some kinds of fish, and our parents.

THE BIRD TIME

A big, well-known group of animals lived during this time. Today's birds are the only animals from that family alive now, but many other animals came from it in the past—like big ones with long necks and bitey ones with huge teeth.

THE GREAT DYING

Almost everything died here, and we're not sure why. There were lots of strange changes in the air and the sea, and around that time a huge layer of hot rock came up out of the Earth and covered a large part of the land. So whatever happened, it was pretty bad. "The Great Dying" sounds like a name made up to use simple words, but it's not; serious people call it that.

LAND COMES TOGETHER AND BREAKS UP

Right now, Earth's land is broken up into five or six big areas with water in between, but before that, it was pushed together. We think this breaking up and pushing together happened a few times, although it's hard to tell how many.

THE GREAT AIR CHANGE

Around this time, the air changed. A kind of life appeared that ate the Sun's light and breathed out a new kind of air. This new air probably killed almost everything else, and for the first time it made fire possible. But it's also the part of air we need to breathe, so it was good for us!

Trees and flowers do the same kind of breathing as that early life. We think the things in their leaves that let them eat the Sun's light—the things which make them green—are the children of the life that changed the air.

RED METAL LINES

There was once a kind of metal that was spread out in all the waters of the sea (the same way the white stuff we put on food is now). When the air changed, the water changed too. The metal turned red and fell to the bottom of the sea. It left beautiful red lines in the rocks. We use the metal from those layers to make things like machines and buildings.

THE GREAT ROCK FALL

Most of the big circles on the Moon seem to be from around this time, which makes us think there were a lot of rocks flying around hitting worlds around then.

The rocks might have been thrown at us by the big air worlds far from the Sun. As they settled into their circle paths—some of them may have changed places!—their pull would have changed the path of the rocks around them, and some of those might have hit us.

If the rocks hit the Moon, they probably hit the Earth (and other worlds near us) too, and might have made the land run like water and the seas turn to air.

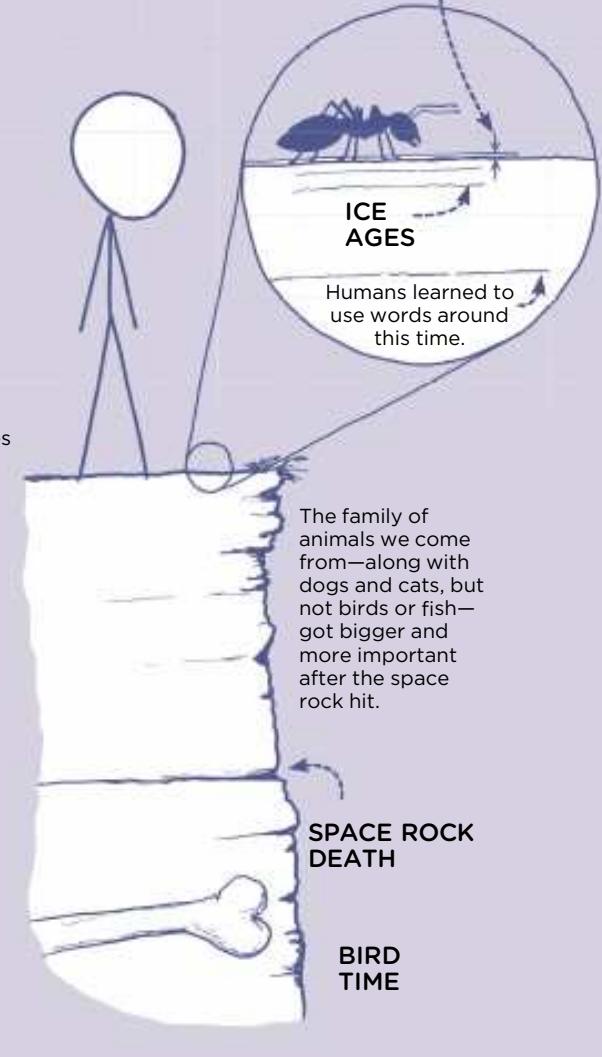
OLDER LIFE?

All life is part of one family, and the information stored in our water bags changes over time, as animals have children and those children have children. By looking at the information stored in the water bags of living things, doctors can figure out how long ago their shared parents lived.

When people have tried to work out how old life's shared parent is, they sometimes come up with a number that's a little *older* than the great rock fall. But we think the seas turned to air and the rocks to fire, and it's hard to understand how anything could have lived through that.

QUESTION TIME

This picture shows rock layers back to the start of the Earth, but in real life, there aren't any big areas of rock left over from before this time, so it's hard to say what it was like. We think there were seas, at least for part of it, but we're not sure what it was like.



TREE OF LIFE

All life (that we know of) is part of a family. We all come from one living thing that appeared in the early days of the Earth. That living thing grew, had children, and changed over time. People, trees, grass, and flowers are all children of that first life.

As living things make more living things, the information they pass to them changes, making the new things a little different from the old. Over time, these small changes can lead to very different kinds of living things growing from one. This tree shows how different kinds of life branched off from one another.

This tree doesn't show all living things, or even most of them. It just shows some of the living things you might know, along with which branch of life's family they're in.

THE START

This is the start of all known life. Here, pieces that send information from parents to children somehow ended up together in a bag of water, and the bag started making more of itself.

We don't know exactly how that happened; that's one of the biggest questions humans are working on answering.

???

We're still figuring out exactly which things came together here and when.

TWO GROUPS

Early on, life broke into two big branches. The things in both branches were made of single bags of water and were pretty simple.

The things in these branches look a lot like each other—it took us a while to figure out that they were from such different parts of life's family tree.

FIRST GROUP

(Tiny living things)

THIRD GROUP

(Big living things, and some tiny ones, too)

SECOND GROUP

(Tiny living things)

GROWING THINGS

This group is made of growing things like trees and flowers. Most of them are green.

HOW THE THIRD GROUP STARTED

At some point, probably when the Earth was about half as old as it is now, some of those bags ate other bags, and the eaten bags started living inside them.

Those new living things, made from the two groups put together, formed a third group. After a while, the little living things in that group started sticking together to make bigger living things. All living things made from more than one bag of water—like trees, flies, and humans—come from this group.

The other two groups are still around, and in many ways they're much bigger than our group. The creatures in those groups are very small, but there are so many different kinds of them that no one has come close to counting them all. They live everywhere, from seas to the air to inside our bodies and our food. Some of them are even found far below the land's surface, where they live by eating rocks and metal. (Until we found those, we didn't know living things could do that.)

WHAT THIS TREE IS GOOD FOR

You can use the tree to tell how much one creature is like another by following their paths. An animal whose path broke off from ours earlier is different from us in more ways than one whose path broke off later, like how an aunt or uncle is different in more ways than a brother or sister.

Sometimes, these families can be a little surprising. Birds and humans are closer to one another than we are to the fish we keep in our houses, which makes sense. But those fish are closer to humans than to the big bitey fish that sometimes eat people, which is strange!

STRANGE GROWING THINGS

These look like tiny trees, but are closer to animals than trees. Some of them are good on food, but some can make you sick.

PLATE WASHERS

CLEAR SEA BAGS

LAND BUILDERS

ANIMALS

STUFF YOU WON'T FIND ON A ROLLING STONE

COOL-SHAPED LEAVES

THINGS WITH FLOWERS

BIG BRAINS WITH LOTS OF ARMS (WRITING WATER ANIMALS)

STOMACHS WITH HOUSES

FLAT STONES THAT BREATHE WATER

BITTERS WITH EIGHT LEGS
LUCKY RED ANIMALS

FAST FLYING STICKS

HOUSE FLIES

DANCING PAPER COLOR FLIES

HILL MAKERS

YELLOW-AND-BLACK FLOWER HELPERS

FLIES WITH POINTY BURNING ENDS

This is a big group of animals from several parts of the tree.

ANIMALS WITH CUTTING HANDS

WATER BEARS

LITTLE ANIMALS

This is a very big group of very small animals.

GRASS JUMPERS

HOUSE EATERS

These like to eat the wood under houses, which can make them fall down.

OLD TREES

TREES THAT KEEP THEIR POINTY LEAVES IN WINTER

ROUND FOOD

which shares its name with a round bird

LIGHT DRINK THAT WAKES YOU UP

LITTLE ROUND BLUE THINGS

DARK DRINK THAT WAKES YOU UP

SOFT RED GARDEN FOOD

BROWN ROCK FOOD

This food looks like a brown rock, but is white inside.

TREE THAT STOPS HEAD PAIN

CRYING TREE

TIRE TREE

JUMPS

(flowers used to make beer)

SWEET THINGS

This group has a lot of the sweet round colorful things we eat.

SMALL FOOD THEY SAY BIG GRAY ANIMALS LIKE FOOD OFTEN IN CANS

THE STUFF IN DARK SWEETS

TREES WITH SWEET BLOOD

Pretty Flowers

Food Fixers

Food that makes you cry when you cut it

Bent Yellow Food

Sweet Pointy Food

Beach Trees

Yellow and Yellow-Reds

If you get this food wet and then heat it (in air) while still in its leaves, it tastes really good.

Yellow Food Wrapped in Leaves

Sweet Stick Grass

White Food

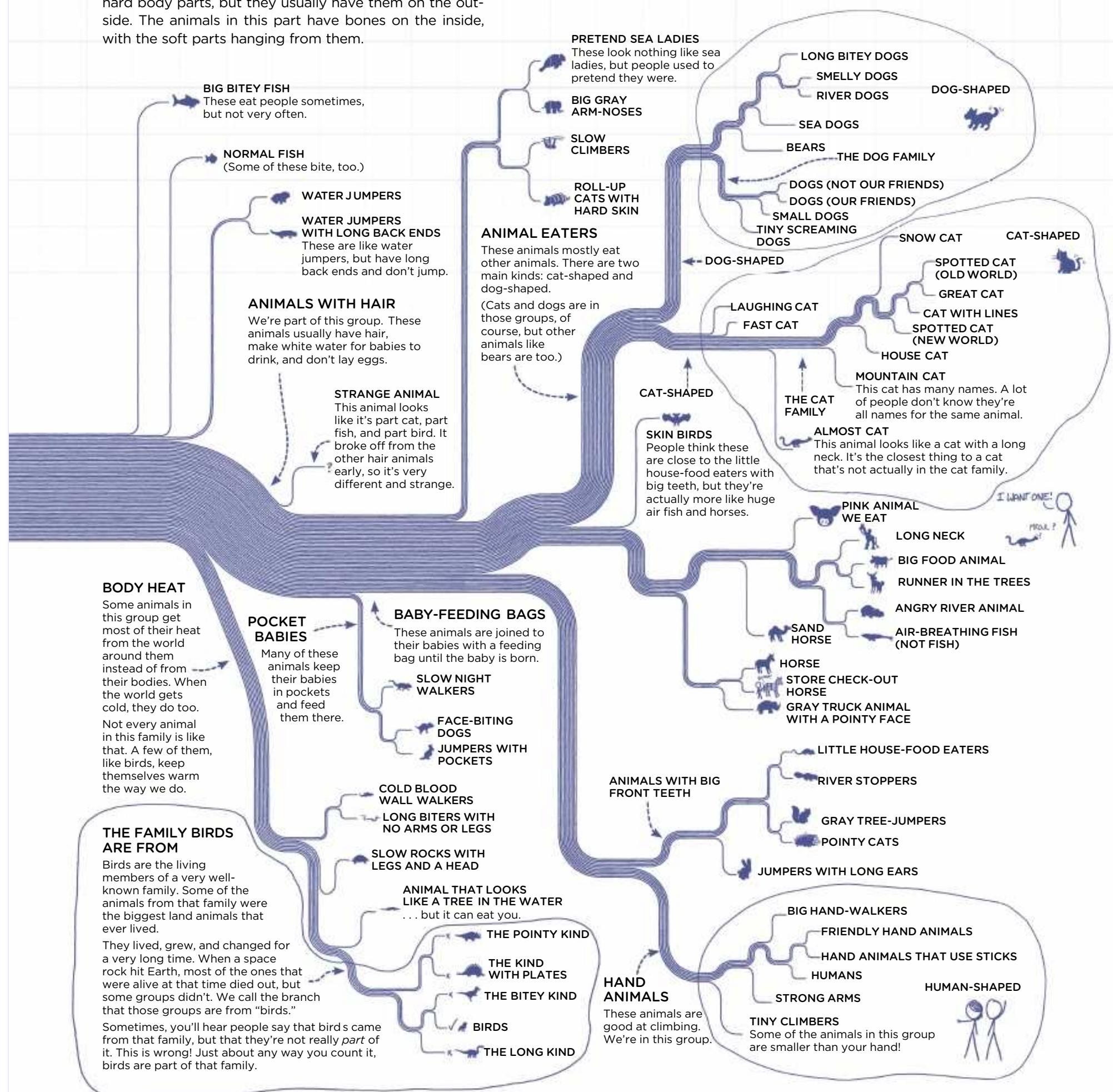
Gold Food Grass

Fast-Growing Stick Grass

Yard Grass

ANIMALS WITH BONES

The animals in this part of the tree have bones inside them. Some of the animals in other parts of the tree have hard body parts, but they usually have them on the outside. The animals in this part have bones on the inside, with the soft parts hanging from them.



This is just a tiny part of the tree of life. The whole tree is too big to fit in any single picture, and there are too many kinds of life for anyone to give names to all of them—no matter what kind of words they use.

And really, a true tree of life wouldn't just have a line for every *kind* of life. It would have a line for each living thing that ever was, every one of them crossing and joining and winding across the page, slowly changing from one kind of life to another, in a path

that reaches all the way back, without a single break, to that very first life.

No one really knows how many living things there are in the world, but we can make some guesses, and they're big. Not only can we never find enough words to talk about all those lives, we have a hard time talking about the number itself.

Here's one way to think about how many things have lived on Earth: The world is covered in seas that are ringed with beaches

of sand. One day, when you're walking on a beach, pick up some sand and look at it. Imagine that every tiny piece of sand under your feet is a whole world of its own, each one with its own seas and beaches, just like Earth.

The full tree of life has as many living things as there are bits of sand on all those beaches on all those tiny sand worlds put together.

Next to the world we're talking about, all our words are small.

THE TEN HUNDRED WORDS PEOPLE USE THE MOST

This is my set of the ten hundred words people use the most.

There are lots of different ways of counting how much people use a word. You can look at what words people use in TV shows, in books, in news stories, in the letters they write, or when sending computer messages. You can also look at words that are most used right now, or at words that have been used for the past ten years, or the past hundred. You can look at all books, or books of made-up stories, books of history, or well-known old books. These different ways of

counting all come up with different sets of words people use the most.

I wanted to write this book using words that sounded familiar and simple. To choose the set of ten hundred words I would use, I looked at many sets of words put together in different ways (I even made one by counting the words in computer messages people had sent me). I especially looked at sets of words made from books that told made-up stories, since I found that counting how much a word was used in those books fit well with how “simple” it sounded.

If the different sets agreed that a word was used a lot, I added it to my ten hundred. If they didn’t agree on a word, I used my sense of how simple the word was to decide whether it should be in the ten hundred.

Here are the words I chose. If you want to try explaining something using only these ten hundred words, you can use xkcd.com/simplewriter to check your words as you write!

a	anywhere	below	burn	climb
able	apartment	bend	bus	close
about	appear	beneath	business	clothes
above	approach	beside	busy	cloud
accept	area	best	but	coat
across	arm	better	buy	coffee
act	around	between	by	cold
actually	arrive	beyond	call	college
add	art	big	calm	color
admit	as	bird	camera	come
afraid	ask	bit	can	company
after	asleep	bite	car	completely
afternoon	at	black	card	computer
again	attack	block	care	confuse
against	attention	blood	careful	consider
age	aunt	blow	carefully	continue
ago	avoid	blue	carry	control
agree	away	board	case	conversation
ahead	baby	boat	cat	cool
air	back	body	catch	cop
alive	bad	bone	cause	corner
all	bag	book	ceiling	count
allow	ball	boot	center	counter
almost	bank	bore	certain	country
alone	bar	both	certainly	couple
along	barely	bother	chair	course
already	bathroom	bottle	chance	cover
also	be	bottom	change	crazy
although	beach	box	check	create
always	bear	boy	cheek	creature
among	beat	brain	chest	cross
and	beautiful	branch	child	crowd
angry	because	break	choice	cry
animal	become	breast	choose	cup
another	bed	breath	church	cut
answer	bedroom	breathe	cigarette	dad
any	beer	bridge	circle	dance
anybody	before	bright	city	dark
anymore	begin	bring	class	darkness
anyone	behind	brother	clean	daughter
anything	believe	brown	clear	day
anyway	belong	building	clearly	dead

death	except	funny	history	law
decide	excite	future	hit	lay
deep	expect	game	hold	lead
desk	explain	garden	hole	leaf
despite	expression	gate	home	lean
die	extra	gather	hope	learn
different	eye	gently	horse	leave
dinner	face	get	hospital	leg
direction	fact	gift	hot	less
dirt	fade	girl	hotel	let
disappear	fail	give	hour	letter
discover	fall	glance	house	lie
distance	familiar	glass	how	life
do	family	go	however	lift
doctor	far	god	huge	light
dog	fast	gold	human	like
door	father	good	hundred	line
doorway	fear	grab	hurry	lip
down	feed	grandfather	hurt	listen
dozen	feel	grandmother	husband	little
drag	few	grass	I	local
draw	field	gray	ice	lock
dream	fight	great	idea	long
dress	figure	green	if	look
drink	fill	ground	ignore	lose
drive	final	group	image	lot
driver	finally	grow	imagine	loud
drop	find	guard	immediately	love
dry	fine	guess	important	low
during	finger	gun	in	lucky
dust	finish	guy	information	lunch
each	fire	hair	inside	machine
ear	first	half	instead	main
early	fish	hall	interest	make
earth	fit	hallway	into	man
easily	five	hand	it	manage
east	fix	hang	itself	many
easy	flash	happen	jacket	map
eat	flat	happy	job	mark
edge	flight	hard	join	marriage
effort	floor	hardly	joke	marry
egg	flower	hate	jump	matter
eight	fly	have	just	may
either	follow	he	keep	maybe
else	food	head	key	me
empty	foot	hear	kick	mean
end	for	heart	kid	meet
engine	force	heat	kill	member
enjoy	forehead	heavy	kind	memory
enough	forest	hell	kiss	mention
enter	forever	hello	kitchen	message
entire	forget	help	knee	metal
especially	form	her	knife	middle
even	forward	here	knock	might
event	four	herself	know	mind
ever	free	hey	lady	mine
every	fresh	hi	land	minute
everybody	friend	hide	language	mirror
everyone	from	high	large	miss
everything	front	hill	last	moment
everywhere	full	him	later	money
exactly	fun	himself	laugh	month

moon	our	quickly	send	smile
more	out	quiet	sense	smoke
morning	outside	quietly	serious	snap
most	over	quite	seriously	snow
mostly	own	radio	serve	so
mother	page	rain	service	soft
mountain	pain	raise	set	softly
mouth	paint	rather	settle	soldier
move	pair	reach	seven	somebody
movie	pale	read	several	somehow
much	palm	ready	sex	someone
music	pants	real	shadow	something
must	paper	realize	shake	sometimes
my	parent	really	shape	somewhere
myself	part	reason	share	son
name	party	receive	sharp	song
narrow	pass	recognize	she	soon
near	past	red	sheet	sorry
nearly	path	refuse	ship	sort
neck	pause	remain	shirt	soul
need	pay	remember	shoe	sound
neighbor	people	remind	shoot	south
never	perfect	remove	shop	space
new	perhaps	repeat	short	speak
news	personal	reply	should	special
next	phone	rest	shoulder	spend
nice	photo	return	shout	spin
night	pick	reveal	shove	spirit
no	picture	rich	show	spot
nobody	piece	ride	shower	spread
nod	pile	right	shrug	spring
noise	pink	ring	shut	stage
none	place	rise	sick	stair
nor	plan	river	side	stand
normal	plastic	road	sigh	star
north	plate	rock	sight	stare
nose	play	roll	sign	start
not	please	roof	silence	state
note	pocket	room	silent	station
nothing	point	round	silver	stay
notice	police	row	simple	steal
now	pool	rub	simply	step
number	poor	run	since	stick
nurse	pop	rush	sing	still
of	porch	sad	single	stomach
off	position	safe	sir	stone
offer	possible	same	sister	stop
office	pour	sand	sit	store
officer	power	save	situation	storm
often	prepare	say	six	story
oh	press	scared	size	straight
okay	pretend	scene	skin	strange
old	pretty	school	sky	street
on	probably	scream	slam	stretch
once	problem	screen	sleep	strike
one	promise	sea	slide	strong
only	prove	search	slightly	student
onto	pull	seat	slip	study
open	push	second	slow	stuff
or	put	see	slowly	stupid
order	question	seem	small	such
other	quick	sell	smell	suddenly

suggest	thick	tree	wash	window
suit	thin	trip	watch	wine
summer	thing	trouble	water	wing
sun	think	truck	wave	winter
suppose	third	true	way	wipe
sure	thirty	trust	we	wish
surface	this	truth	wear	with
surprise	those	try	wedding	within
sweet	though	turn	week	without
swing	three	twenty	weight	woman
system	throat	twice	well	wonder
table	through	two	west	wood
take	throw	uncle	wet	wooden
talk	tie	under	what	word
tall	time	understand	whatever	work
tea	tiny	unless	wheel	world
teach	tire	until	when	worry
teacher	to	up	where	would
team	today	upon	whether	wrap
tear	together	use	which	write
television	tomorrow	usual	while	wrong
tell	tone	usually	whisper	yard
ten	tongue	very	white	yeah
terrible	tonight	view	who	year
than	too	village	whole	yell
thank	tooth	visit	whom	yellow
that	top	voice	whose	yes
the	toss	wait	why	yet
their	touch	wake	wide	you
them	toward	walk	wife	young
themselves	town	wall	wild	your
then	track	want	will	yourself
there	train	war	win	
these	travel	warm	wind	

Notes

In this set, I count different word forms—like “talk,” “talking,” and “talked”—as one word. I also allowed most “thing” forms of “doing” words, like “talker”—especially if, like “goer,” it wasn’t a real word but it sounded funny. In some places, I didn’t use words even when they were allowed. I could have said “ship,” but I stuck to “boat” because “space boat” makes me laugh. Also, there’s a pair of four-letter words that are very common, but which I left off this page since some people don’t like to see them. (I didn’t want to use those words anyway.)

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A lot of people helped me with this book. Their names aren't words that people use a lot, but I'm going to write them anyway because they're important.

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