HOWTOONS

The Possibilities Are Endless!

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Please note: The authors & publisher recommend adult supervision on all projects!
In a small and beautiful galaxy,
ON A WONDERFUL LITTLE PLANET...
Stirring in the quiet streets of Everyville, a small suburb surrounded by other Evilles by different names, something was about to happen...

Something important...

Mischief and Ingenuity...

Would conspire...

As they often do...

Leading two slightly unusual kids into a wild world of invention and adventure!
TUCKER!  CELINE!

CAN'T YOU KIDS MAKE SOMETHING OTHER THAN TROUBLE?
HOWTOONS

THE POSSIBILITIES ARE ENDLESS!

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HOW, adverb.
A manner or method of doing something.
"The how of research is generated by the why of the world!"

TOON, noun, informal.
A drawing depicting a situation, often accompanied by a word balloon or caption.
EVERY KID NEEDS A SPACE.

Hmm. Where do we start?

Says here we’ll need a workshop.

WHAT DO YOU THINK ABOUT THIS PLACE?

VIRGINIA WOOLF DESCRIBED IT AS “A ROOM OF ONE’S OWN.”

THE IMPORTANT THING IS THAT IT’S A PLACE FOR YOUR BOOKS, DRAWINGS, TOOLS, TREASURES AND PROJECTS.

With a little clean up... it’s perfect!
Yo!
Look at all the cool stuff we can build with a workshop!

Sir Lawrence Hargraves
designed the first box kites,
giving a lift to early aviation,
even using them to tow small boats.

NASA Engineer Lonnie
Johnson invented the world's most powerful water gun, the Super Soaker.

Mary Anning carried her workshop with her. With her geologist's tools, she discovered the first Plesiosaurus fossil.

America's first female astronomy professor, Maria Mitchell, instead of just learning from books, instructed her students to do real research.

George Washington Carver didn't invent the peanut, but did find thousands of uses for them.

Leonard's HK MacMillan invented the first pedal bicycle.
MUSEUM OF YOUR MOST FANTASTIC FAILURES AND TREMENDOUS TRIUMPHS!

ORGANIZE YOUR SPACE! MAKE YOUR MAKING EASY, SAFE, FUN AND PRODUCTIVE. ALWAYS BE PREPARED FOR THAT NEW PROJECT.

BUT...DON'T LET IT GET TOO CLEAN — YOU'LL WANT TO FEEL FREE TO MAKE A MESS. OOH, AND HOW YOU WILL WANT TO MAKE SOME TERRIBLE MESSES.
There are many, many, many projects to undertake...

...and in the cracks of those projects and beneath the filthy underbelly of your latest frustration is something special...

...your latest invention!
ANATOMY OF A TOOL BUCKET

A STURDY PLASTIC BUCKET IS LIKE A PORTABLE WORKSHOP. ONE WITH A STRONG WIRE HANDLE IS GOOD. YOU CAN WRAP THINGS AROUND THE HANDLE TO MAKE IT EASIER TO CARRY.

HAMMER, SCREWDRIVERS, RULER, PLIERS, CUTTERS, SCISSORS, WRENCHES, CLAMPS, FILES, PENCILS AND BRUSHES, ADD A DRILL AND YOU ARE READY TO REPAIR, CREATE AND INVENT!

You can bend hooks from coat hangers to hang useful items like rope and cord from the side of your bucket.

ALWAYS KEEP A ROLL OF DUCT TAPE AND A ROLL OF WIRE HANDY.

KEEP YOUR TOOLS SHARP. OIL THE JOINTS AND BEARINGS AND WIPE THEM CLEAN. DON'T DISCARD OLD TOOLS, THEY ARE OFTEN THE BEST, AND BROKEN TOOLS CAN BE USEFUL TOO. SOMETIMES YOU CAN CONVERT A BROKEN TOOL INTO A NEW TOOL FOR AN UNUSUAL JOB. IT HELPS TO WRITE YOUR NAME OR INITIALS ON YOUR TOOLS SO YOU CAN SHARE THEM WITHOUT CONFUSION.

ORGANIZE YOUR BUCKET TO EASILY LAY YOUR HANDS ON YOUR TOOLS. LIKE AN OLD WESTERN GUNSLINGER, YOU SHOULD BE READY TO PULL THE PERFECT TOOL FOR THE JOB AT THE RIGHT MOMENT AS A MERE REFLEX. OLD JARS OR THE BOTTOM HALF OF SODA BOTTLES CAN BE USED TO SORT THE TOOLS INSIDE THE BUCKET.
A TALE OF THE INVENTION OF EVERYONE’S FAVORITE DESSERT...

CHOCOLATE TRIP

ICE DREAMS

SOME SAY ICE CREAM WAS INVENTED IN ANCIENT MONGOLIA. MAKES SENSE...

BRRR... I'M FREEZING!

ME TOO!
A long time ago, in an era of emperors and kings... 

Two traders trekked homeward after a very successful trip...

I hope the king is pleased with our bananas of goods. 

How could he not be delighted?

The travelers’ mule was packed with goods from the four corners of the globe.

From the west African trading city of Timbuktu they purchased salt mined in Mali and shipped across the desert by camel – at the time salt was worth its weight in gold!
From the glaciers of Norway they cut the purest blocks of ice, a delicacy in warmer climates — they had to move quickly with their precious quarry.

They found sugar in Persia, a valuable commodity that had made its way from New Guinea via India and China.

From Spanish conquistadors they received some of the first samples of the versatile vanilla bean that was being cultivated in Mexico.

In northern Europe they found the freshest milk and divined the secrets of making the thickest cream.
All the ingredients were stored in the clay pots and saddle bags atop their trusty mule as they made their way home over the Himalayas...

Careful! The rocks are loose.

And then... it happened...

The mountain gave way and our adventurers went a-tumbling!

The hard-won goods of their odyssey flew in all directions!
A clay urn of salt cracked into the Hessian sack's of ice.

The pots of sugar, vanilla bean, cream, milk and spices all broke into another saddle bag.

And by divine fate that saddle bag fell upon the open sack of salt and ice!

The two great explorers saw their ingredients freeze quickly in the salt and ice mix.

Hey! All of the goods mixed up and made that giant mound of ice and cream.

With a cherry on top!

Many of the world's greatest creations were brought about by the careful and enlightened observation of an accident!

Mmmmm. Creamy-ice. Smooth and delicious!

The king will be pleased.

Provided you don't eat it all.
So that’s it? That was the discovery of ice cream?

Yup, and it’s taken scientists hundreds of years to figure out how it works.

The secret is in the thermodynamics! — How quickly we freeze the ingredients.

After mixing the components thoroughly, we pour them in our first bag.

It’s important to squeeze all the air out.

Why?

Because still air is an insulator and heat doesn’t pass through it.

That’s why we use double-pane windows to keep the heat in.

To freeze our ice cream the fastest, we don’t want anything insulating our ingredients.

BAG 1

ICE CREAM

INGREDIENTS

1 CUP OF HEAVY CREAM
1/2 CUP OF WHOLE MILK
1/8 CUP OF SUGAR
3 1/4 TEASPOON OF VANILLA ESSENCE

FLAVOR WITH CHOCOLATE CHIPS, NUGS, ETC.
We need a second bag, a super freezer, to freeze the ingredients in the first bag.

The salt and ice combine to make a solution colder than the freezing point of ordinary water.

In fact, a salt-ice solution can remain a liquid to as low as -21.2°C or minus -6°F.

Now we put bag one, the ingredients bag, inside bag two, the freezer, and seal it tight!

I need gloves!
The freezer bag is sucking out my heat.

Now we just toss the bags for about 20 minutes until the ice cream ingredients are firm.

That's it! Open up the ingredients bag and serve! Enjoy!

So Tuck... what do you think?

Delicious!
Nobody knows the exact origins of what we know today as ice cream. In fact, many cultures developed similar ice-based desserts: sorbet, sherbet, kulfi, gelati, sno-cones and ice cream.

All that is really known is that it took many adventures to scour the world for the ingredients...

...and a few experimentalist chefs to convert them into dollops of delight!

Hey... uh... Celine! Do you want to take another ice cream break?
An Eye for Safety

THE BEST DEFENSE IS A GOOD IMAGINATION!
Another noxious nightmare.

Morning, Tuck.

Still having those bad dreams? You can tell?
Last night I was running with scissors!

That one never ends well.

The night before that, it was jumping an unsecured bike ramp!

The list reads like an emergency room clipboard.

You’re telling me.

Last night I cracked my thumb a mighty blow with a distracted hammer.

Later in the very same dream, I was climbing a tree, reaching for a branch...

...when my bandaged thumb lost its grip!

And gravity, as you know, is relentless.
I think Freud was right. My subconscious is trying to tell me something.

Freud? What do you mean?

Yeah, I guess our eyes and fingers are quite useful and worth protecting.

Maybe if we're more safety-conscious, our subconscious will stop giving us nightmares.

It's my brain telling me to be more prepared, to foresee and avoid the danger.

Hmm... you just reminded me that it will be vital to have safety goggles when operating my latest project.

Let's make safety goggles the first thing we do today.

I'll do anything to stop the nightmares!
We need a really tough piece of plastic.
The walls of an old soda bottle should do nicely.

Cutting a soda bottle can be tough, so start your cut by stepping on the middle of the bottle to flatten it!

WARNING!
These goggles are for basic protection, and are not to be substituted for certified safety glasses when they are recommended.

Now place the soda bottle sheet on your face and trace the outline that you will cut.
The ear pieces and nose bridge are most important.

Feel free to design it any way you want.

There, cut it out!
Use a sharp hobby knife to make two slits in each of the corners of the mask. Cut carefully! This part is tricky.

Last, you'll need straps to hold the mask on your face. Slitting an old bike inner tube into strips, or knotting rubber bands will give you what you need.

To fasten the strap, thread your rubber band through the inner slits, then through the outer.

Use a lark's head knot to connect the rubber bands.

Adjust and wear!

AHHHH!

I decorated mine with markers!

And I thought the NIGHTMARES were bad!

Grrrr.

The End!
CUT TO THE POINT

YOU NEED A HACKSAW TO CUT THE PVC FOR YOUR MARSHMALLOW SHOOTER, AND IN FACT YOU WILL NEED SAWING SKILLS THROUGHOUT YOUR LIFE.

DOVETAIL Saws
Clean, sturdy cuts, great for frames, cabinets and toys.

BACK Saws
Thick-bladed with reinforced back for precision cuts.

BOW Saws
Stake frame and blades for rough cuts of wood.

CROSSCUT Saws
Crosscut teeth are small teeth used to sever wood when cutting across the grain.

CROSS CUT TEETH
For cutting against the grain. Can be used for many purposes from logging to detailed carpentry.

RIP Saws
Rip teeth are medium-sized teeth designed to scoop out wood fibers when cutting with the grain.

RIP TEETH
For cutting with the grain, the ripping action of the saw produces a course, ragged cut which makes the saw unsatisfactory for finish work.

COMPASS Saws
Small blades used for cutting curved or sculpted holes.

KEYHOLE Saws
Indicate, close, inside work for specialized jobs.

COPING Saws
Cuts irregular shapes and intricate patterns.

THE HACKSAW
Cuts plastic, metal, wood.

CUTTING ANGLES?

30°

USE A MITER BOX!

UPKEEP A light coating of oil will make blades last longer. Be careful not to bend your saws. Hanging them up is a good method for storage.

This is the correct cutting position. Your vision should always be true to the cutting plane, and always keep a straight line of action.

If possible use a clamp or vise to hold your piece and stop vibration.

1" 4 T.P.I.

T.P.I. stands for teeth per inch! Rule of thumb: the more T.P.I. the harder the material the saw can cut!
THE INFAMOUS MARSHMALLOWSHOOTER

I'm gonna NAIL that BOOB TUBE HEAD!

You can't TOUCH this!

IF YOU'RE A KID BROTHER OR SISTER, THERE'S A YARN YOU KNOW ALL TOO WELL...

BECAUSE THIS ONE'S AN OL' FASHIONED SHOWDOWN!
You know, Tucker, staring at the TV will make your head square.

WHAT!? Leave me alone... I'm playing video games.

Huh?

Go ahead... put your safety goggles on.

Okay... I'll play your little game.

They're on. Now what?

NOOOO!
Say hello to my little friend, Tucker!
The infamous Marshmallow Shooter! I thought it was only possible in theory!

Your only mistake was letting me see it!

Using my photographic memory, I'll make an exact replica!

You may have won the battle, but not the war!

Hmmmm...
LATER...

I had no idea Celine was this clever.

MATERIALS
- 25 inches of 1/2" internal diameter PVC pipe
- 4 elbow joints
- 2 end caps
- 2 T-joints

3" PVC pipe 1/2" dia.
Load one mini-marshmallow at a time into the mouthpiece.

Seal your lips against the mouthpiece to avoid air leaks... and loss of power!

 Blow as much air as possible in a short, sharp blast. The harder you blow, the farther it'll go!

Always use fresh mini-marshmallows.

When the marshmallows are soft, they create a better seal against air leaks.
Tucker...

Ooohhh...

Knock knock knock... Tucker...

Come out and play...

You know the possibilities are endless!

I've modified my shooter a little!
GET A GRIP

Grip, snip, bend, cut, twist, clamp and vise. Pliers are versatile... get to know the usual suspects...

YO, FOOL! USE THE RIGHT TOOL!

Many pliers have shears for cutting wire....

...place the edge of the jaws of the pliers where you want the bend and use your other hand to make the angle. Needle-nose pliers can be used to make tight corners.

Tempting as it may be... pliers should not be used to tighten or loosen nuts unless it is an absolute emergency. Both nuts and the pliers will be damaged!

Wrong!

Right!
The Happy Hippo

The lion may be king of the jungle, but surely the hippo is lord of the lower levels.

Its natural environment is a luxurious, aromatic swamp.

Amidst trees, foliage, fellow animals and denizens of the deep, the hippo lurks, stalking grass in prodigious quantities.

They're beautiful.

Indeed, the hippo is never happier than when it shares its inner essence with the world.

Occasionally, a bit of excitement bubbles up.

I will capture the inner essence of the hippo if it's the last thing I do!
I don't know, Tucker. Maybe it's just not physically possible!

Nonsense, Celina!

We're so close... I can smell it!

I know these are the keys to capturing the acoustic aura of the mighty hippo!

HANGER

WASHERS

WIRE CUTFING PLIERS

2 RUBBER BANDS
The wire coat hanger, for example, is one of the most versatile raw materials in existence.

And a simple pair of pliers is all I will need to bend it to my will.

First I'll cut the length!

That should do.

By gripping the wire with the pliers, I can precisely place my angles.

To finish my frame, I just need to bend over the ends. Perfect!
Of course we'll need an energy source, too.

That's where the rubber bands come in. It's like a rechargeable battery of wound-up energy.

The hippo is, after all, a very powerful creature.

And by careful selection of the washer string between them... I should be able to tune my instrument.

Now just to put it all together by placing the rubber bands over the hooks...

At last! My masterpiece!
Let's give it a test drive.
Wind up the washer very tightly!

Sit on the wound-up rig.

Then shift your mass to release the harmony!

Don't you just love the sounds of nature!
See, Celine, I told you that garbage Santa existed... look at all this awesome stuff he has left us!

The important thing is to see the world for what it could be, not for what it is. Coat hangers, soda bottles, inner tubes, rubber bands, cardboard, wood and plastic... and this cool jar! We've got everything we need!

You know, Celine, it might be even better if we collect these things before they hit the trash heap. That'll save us from diving around in this stinking Dumpster.
TErrarius
Celine, are you nuts!? You've been staring at that jar all night!

Not nuts, Tuck... Just dreaming and thinking.

About how to become the first...

Astro-

Paleo-

Xeno-

ologist...

Cool!

That's someone who studies the history of alien civilizations by researching the fossil records of other planets!
I’m going to need a spacecraft that can support human life for long periods of time without resupply ships...

And scientists haven’t yet figured out how to create such a complex ecosystem. It’s hard, like trying to make a miniature world...

And we humans haven’t exactly figured out how not to pollute Earth, either...

So I’m practicing here in my...

TERRARIUM!
A terrarium, Tucker.

Hmm... a terror-arium!

No, Tuck, a terrarium. It's one of many different types of vivarium. It's a container, usually glass, and sometimes sealed, for observing flora and fauna.

A paludarium is a miniature rainforest, a riparium is a mini river. Terrariums are generally simulating dry climate areas...

Fomicariums are ant farms, and insectariums are for insects.
A nice big pickle jar with a lid will work nicely. You could use a fish tank, or even a large soda bottle with the top cut off.

Place a few inches of dirt in the jar, with pebbles on the bottom to give it better drainage.

Small shade and water-loving plants are best, like clover or small ferns. Mosses and lichen work very well, too!

But beware! creatures need to eat! If your terrarium can't supply enough nutrients, you will have to feed them.

Fill the terrarium with everyday things you find in nature: rocks, sticks, worms and insects. If you build a really large one, you can try small lizards.

Place the jar where it will receive partial sunlight. Water once in the beginning, but not too much, or the plants will rot. The water vapor will stay in the jar and be continually recycled.

You can leave the terrarium open at the top by putting small holes in the lid. This way it can get nutrients from the outside world and survive a long time. If you seal it completely, you are running an experiment in closed ecosystems. The nutrients from the soil feed the plants, and the nutrients from the plants feed the insects, and the carbon dioxide needed by all living things will have to be balanced perfectly by the whole system.
Wow! It's so beautiful. It really is like a whole world in there.

It makes you think, huh?

Like maybe something's watching over us. Just like we're watching over the terrarium.

Maybe. Tuck...

Maybe.
IT'S TIME TO...

PUMP IT UP!

No steroids. No protein powders. None of those tedious hours at the gym. Follow our step-by-step guide to instant muscles.

Yo! Tuck! Can you give me a hand?

Hey! Doesn't anyone knock anymore?

Congress may even subpoena us for this one!
Can't a man just flex his muscles in private?

If you help me, I promise to give you instant results.

Instant muscles, huh? Bigger than these pythons?

That's right, Tuck! And the only things we need are:

- scissors
- duct tape

and last... we'll need an old person.

That fossil will do!
First, put the old T-shirt on the old person.

Ha... old!

Next, taking strips of the duct tape, fully cover the T-shirt. Two layers will do.

Using the scissors, carefully cut up the back of the shirt and duct tape.

Easy, sis.

Now just wriggle the old person out!

Then we tape up the seam in the back where we cut.

Well, Tuck... Try it on! Wow!! This is really gonna bulk me up!
Thanks for the... **MUSCLES!**
Thanks for the help, Tuck!

To make my sewing dummy, I just stuff the inside of a form made from a T-shirt my size with newspaper.

In order to keep the newspaper in, I seal off all holes at the arms, neck, and bottom.

This is also a good stage to shape it to your physique! Just use scissors to cut up the sides where changes need to be made.

Now just prop it up on a base. I used an old coat rack!

And voilà! Sewing dummies are great for making your own clothes. Now I can finish my spacesuit!
"Excuiiiuse me, Ladeeeez..."

Have you seen...

my beach ball?

It'z about...

And I left it... over dare.

diss big!
BIT BY BIT

OUR ABSURD ADVENTURERS GO TOTALLY DIGITAL
What's this crazy sign language you're flipping, Tuck?

Shh, I'm not signing, I'm counting my comics. I've got to keep concentrating.

You still use your fingers to count? I thought you were past that, Tuck.

I'm so past that. I'm into counting in binary now. It's awesome. I have the capacity to count like a computer.

With a single hand I can count to 31; with two I can reach 1023! Enough even for my monster comic collection.
You belong in those funny pages, Tuck!

No! It's actually really simple. It's used in all electronics equipment! Cell phones, wristwatches, CD players and computers...

All counting super fast... like me... using nothing but ones and zeros.

Imagine each finger represents a number, and each double the digit before it: 1 for the thumb, 2 for the index finger, to 16 for the pinky.

Each finger can be extended, a one, or closed up, a zero. Adding the values of the extended fingers is the total number!

I'm getting the hang loose of it!

So counting from 0 to 31 is easy, look:

<table>
<thead>
<tr>
<th>Hand Position</th>
<th>Binary Code</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>00000=0</td>
</tr>
<tr>
<td>1</td>
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<td>11110=30</td>
</tr>
<tr>
<td>31</td>
<td>11111=31</td>
</tr>
</tbody>
</table>
Then to get to 1023, I simply add my next 5 fingers... 32, 64, 128, 256, 512.

I can even go over a million when I use my toes. 1,048,575 to be precise...

That stinks, Tuck.

No not at all, this binary counting system is what makes everything work.

Robots...

...computers...

...and telecommunications through wires or fiber optics.

In electronics, the zeros and ones are represented by high and low voltages, or flashes of lights, not by my fingers... A zero or a one is called a bit.

It's all a bit hard to believe, Tuck! Get it? Bit hard...!

Only if you byte off more than you can chew!
Legend of the Monkey Fist Clan

Always employ an experienced adult in the choice of a tree and installation of a tree swing.
It's perfect!

But how?

Okay, sis! Boost me up.

Urrghh!

I don't think so.

Let's try the old human ladder.

Steady...

Easy...

Uhnh...

Sigh..
We'll never do it! My swinging days are doomed.

You know, Tuck, there is a way.

But you need to swear to keep it a secret!

You're talkin' to the Tuckster, keeper of major secrets, sis.

Okay then, listen up! But don't tell a soul.

Behold! The Legend of the Monkey Fist Clan!
A shipwrecked family of seafaring arborists, the Monkey Fist Clan had to survive on a deserted island with nothing but their knot-tying tricks and rope skills to aid them.
In order to survive they learned to use rope for everything; their braids, knots, splices and weaves transformed the desolate environment into a treehouse paradise.

To throw their ropes, the clan developed a heaving knot, the Monkey's Fist. Mastery of this decorative, yet functional, knot was the first sign of adulthood.
To scale the highest trees and taste the most succulent fruit the clan needed a number of special knots...

Knots they could throw...

grip... and connect!
Start with a light line, 1/4 - 1/2" in diameter.

Holding one end between the forefinger and the thumb, wrap the first three coils around your hand, then slip those loops off.

Now is a good time to put a stone or golf ball in the center to bulk up your knot.

You are ready to coil in the opposite direction.

Like so... be careful to keep the first three loops open.

Now you are ready to put the final three loops back through the first three.

You're almost done!

You'll need to tidy the knot by carefully working backward, pulling the slack and pulling it tight as you go.

This knot takes some patience and learning...

...but has many decorative uses as well as utility in throwing.

Voilà! Our heaving line is ready for action!
Pick a branch with a fork. This is what keeps your line from sliding down the branch.

When choosing your branch, make sure it is sturdy and has live foliage at the tips. If it is still alive it will be strong; not rotten!

Heave the monkey fist over that branch, Tuck!

Sweet toss!

The next important knot is the sheet bend. It's the oldest known knot, dating back 9,000 years.
The sheet band will join the lightweight throwing line...
...which is the tail end of your monkey's fist...
...to the sturdy piece of rope we'll use for swinging from the tree.
Use at least a 5/8" line for tying around the branch.
With the thick rope, you'll make a bight, which is a pinched loop. Thread the loose end of your throwing line through the bight.

Then loop it around behind the bight, bringing it up in front of the bight and under the throwing line. Pull tight.

If it looks like this, we're ready for hauling our swing line into place.

Pull, tuck! Pull!
We tossed the rope through the fork so we can tie the swing at the base of the tree with a killick hitch. This means we'll be able to remove the rope easily when we are done and reuse it for future trees. We no longer need the heaving line, so we can untie the sheet bend.

Watch closely.
How are we going to tie up our loose ends, sis?

We need something to sit on...

And this branch should do nicely.

The final knot we need is...
The clove hitch, a simple knot for fixing line to poles, or in this case, our seat-stick.

Be sure to tie a big knot at the end of your line to prevent the clove hitch from slipping.

How do you like it, Tuck?

Totally swingin', Caline!
There once was a young sailor man...

Who grew up with the Monkey Fist Clan.

A half hitch on the bight...

And knot tying foresight...

Let him swing through the sky as he’d planned!

There was a strange boy named Tucker...
For limericks he was such a sucker...
Hey Tuck! What are you doing?

Nothing really. Just some simple oceanography.
The only things you need to make an underwater scope are a pair of scissors... ...and a 2-liter soda bottle.

An easy way to start your cut in the bottle is to squeeze it in the middle and make a small cut.

Cut the shape out below for your viewing pleasure.

Now just submerge the scope halfway into the water and start exploring.

I wonder if this is how goggles were invented?
FOR THOSE ABOUT TO ROCK,
WE SALUTE YOU!
What is that noise?!

It's coming from the kitchen.

Huh?
Pots, pans, and trashcans! Sweet drums!
Swinging, huh?!
I'm thinking of starting a band!

Can I join the band?
Can I join the band?
Can I join the band?

Pleasease...

Look, sis... I think it's cool you want to be in the band. I really do.

But you've got to bring something to the table.

You dig?
Ar-gh!

I'll show him!

Deep in the archives of invention...

I know I've got a musical instrument in here somewhere!

BINGO!

Hmm... Where is it?
The turkey-baster flute!
To make a flute, fill the turkey-baster up half way.

Having a good technique is vital to getting a good sound on your flute.

It is important to hold the baster top at the correct angle against the lower lip.

Flautists call this the embouchure, and it can take years to perfect.

By blowing a smooth jet of air across the top, a tone is produced.

By squeezing the bulb and changing the water level, you can change the notes.

Tune your flute by placing rubber bands at whole note intervals.
Cool, Celine!
That's a wallin' tune...

Your flute will be a welcome addition to the band.

Thanks, Tuck...
I thought we could use another wind instrument...

Other than your hot air!
In 1834, blacksmith and inventor Thomas Davenport built the first direct current electric motor. He went on to build the first model electric railroad. In his humble workshop in Vermont, Thomas used the threads of his wife Emily's silk wedding dress for the insulation around the wires of his motor. After years of struggle and persistence, Davenport's motor came to revolutionize science and industry.

Couldn't you have waited until I changed clothes?!
Building your own super-simple electric motor is easy, given a little patience and some simple objects.

The key to making the electric motors that drive everything from forklifts to toothbrushes is the coil of insulated wire. As a current passes around the coil it turns the loop into an electromagnet. The permanent magnet and electromagnet then push and pull on each other to create motion.

The ends of the coil act as an axle.

A permanent magnet provides the driving force by repelling the magnetic field induced in the coil.

You’ll need some insulated wire.

22 gauge magnet wire is ideal because it comes with an enamel (insulating) coating.

The safety pins conduct electricity up from the battery into the coil.

The safety pins act as the simplest possible "commutator"; that’s what makes everything work. As the axle rotates in the safety pin, it turns the current from the battery on and off each rotation, which turns the electromagnet on and off.

A rubber band will hold your safety pins to the battery, and the magnet will stick to the battery naturally.

Neodymium rare earth magnets are the strongest and will really make this motor fly.
Start with your magnet wire.

Wrap it 10-12 times around a C- or D-cell battery.

Wrap the loose ends 3-4 times around the coil you have created and cut a 2-3 inch axle on both sides.

To make your motor really spin you will need to balance its coil. It needs to be symmetrical about the axle.

A knife or one blade of a pair of scissors will do this perfectly.

Carefully scratch the insulation off one side of the axle.

The induced magnetic field is north poled on one side of the coil and south poled on the other.

This field is repelled by the permanent magnet and kicks the coil over.

When the insulated side touches the safety pin, the field turns off and the coil can spin right around to do it all over again.

As it spins, the motor gets a little magnetic kick on every revolution, keeping it spinning.

The current in the loop induces a magnetic field. The rubber band holds everything in place.
THE RIGHTEOUS STUFF

GO WHERE NO KID HAS GONE BEFORE
It should be self-evident that rockets have rectangular doors.

No way; round is the obvious choice.

If astronauts were spherical, the doors might need to be round... but we are not round, so rectangular is far more economical.

But Celine, in zero gravity you don’t walk through doors...

You float through head first. Therefore, round doors are perfect!
Sometimes the ship will land on a planet with gravity. Then how are you going to float through your round doors?

We've agreed on safety protocol, soda bottle fuselage, and the air fuel source... but as you obviously cannot see the advantages of my round doors...

I've got no choice other than privatizing my space program.

Fine! Let the space race begin.

Hmmmphhh! That stubborn $%*?!
At the launch site.

I'll launch first.

Fine! Let's set 'em up.

Ready, Tuck?

My systems are go.

Me too!
Ready to see my baby fly?

You won't be seeing for long if you don't put your goggles on.

Check.

Pump me up some air pressure.

More...

Faster...

Higher...

Huh? Stop!

The hangers aren't holding!

She's gonna blow!

Sigh... if only...

Sorry, Tuck.

Looks like you're going into orbit first, Celine. I'm ruined.
Safety systems enabled.

And the energy source is ready.

Start pumpin', Tuck!

Ready in 3...2...1...

Blasé....

We were too gung ho. A space program isn't built in a day. Let's put differences aside and work together...

My design was also flawed, Tuck. Looks like neither of us will go to space at this pace.

How about we sign an inter-neighborhood space treaty?

I'd be honored to work with you, Tuck!
Trying to launch a soda bottle really is rocket science.

We'll need to draw from everything we've ever built to pull this thing off!

Celine! That's it.

The modified marshmallow shooter.

What are you thinking?

It might not have worked for marshmallows...

...but it's got serious rocket-launching potential.

Check this out... it might just work.

You're right, Tuck. I can see it!

That rocks... I'll gather the materials.
MATERIALS LIST:

1 - 10 FEET OF PVC PIPE OF 1/2" INTERNAL DIAMETER
2 - 1/2" PVC T-JOINTS
1 - 3/4" O-RING
3 - 1/2" PVC PIPE END CAPS
1 - 1" PVC PIPE CONNECTOR
1 - 2L SODA BOTTLES
1 - BICYCLE INNER TUBE
1 - COAT HANGER
1 - 5/16" DRILL BIT AND DRILL
1 - BAR OF SOAP
1 - SCISSORS
1 - STRONG STRING
1 - PVC GLUE
1 - ROLL OF DUCT TAPE
1 - FILE
1 - RUBBER GLOVES
1 - SAFETY GLASSES
Together they work...

And with heated debate,

Moments of clarity

And persistence of vision,

They took the data,

Corrected the plans

And refined over and over...

Until...
The design was complete...

We’ve outdone ourselves this time.

She certainly looks like she’s gonna fly.

8" PVC PIPE

2 LITER SODA BOTTLE

T-BAR GIVES LAUNCHER STABILITY

12" PVC PIPE

10" PVC PIPE

1/2" PVC END CAP

STRING FOR PULLING RELEASE PIN AT SAFE DISTANCE
DUCT TAPE FOR NOSE CONE AND STABILIZER FINS

COAT HANGER RELEASE PIN

MAKE THIS PIECE OF PVC AS LONG AS POSSIBLE FOR SAFETY! 4-6 FEET IS GOOD.

BIKE VALVE CONNECTION TO LAUNCHER

BIKE PUMP ENERGY SOURCE. NEVER INFLATE TO MORE THAN 60 POUNDS PER SQUARE INCH.
The air valve is one of the most important features. We need a great seal.

Cut the valve out of an old bicycle inner tube. Carefully cut around the base of the valve.

Now we need to drill a hole in the 1/2" PVC end cap. You'll want a 5/16" drill bit straight through the center.

Push the valve through the hole — now is a good time to trim the rubber at the base of the valve to match the inside diameter of the end cap.

Finish it off by pulling the valve all the way through. It will be very tight — for a good seal — so you may need to grasp it with pliers.
Now, for the most critical job of all — the O-ring rocket booster seal.

Mark the pipe at 1.25 inches.

Carefully file a groove all the way around the pipe. You may need to try this more than once.

The groove needs to be just a little shallower than the O-ring.

Slide the O-ring onto the pipe...

...and into the groove.

Test the bottle mouth — it should be a neat fit.

If not, file off the high points or start again.

Tip: a little soap on the O-ring will help glide the rocket into position.
Now that the subcomponents are ready, it is time for assembly.

You will need PVC glue, which is toxic! So be sure to apply the glue in a place with good ventilation so you don’t breathe the fumes.

Wear rubber gloves, and get the assistance of an adult in handling it.

Paint the glue around the pipe at each joint — do them one at a time.

Place the valve assembly on firmly.

Glue the remaining T-joints and end caps.
The launch mechanism requires some monkey clan skills and some of the usual suspects...

With the same 5/16" drill bit, drill two holes in one end of the 1" connector...

...and four holes in the other end.

Cut an 8" length of coat hanger and bend it halfway around a piece of 1/2" pipe.

The coat hanger will sit through the four holes like this and grip the top lip of the bottle.

Finally, we need to attach this release mechanism to the main body of the launcher — Start by tying one end of a piece of string through one of the bottom holes.

Tie your release string to the coat hanger here...

Slide it onto the launch tube.

Wrap the string under and tie it through the hole on the other side.
And of course the last thing you'll need is a rocket!

You can leave a message in your bottle for the aliens who will find it once it reaches orbit—or you can figure out a way to pack a parachute in there.

For the fins, cut some fin shapes from cardboard...

...and tape them firmly to the outside of the bottle.

The stabilizing fins should be symmetrical and aligned with the flight direction!

For the aerodynamic nose cone, cut the top off a second bottle...

And tape it around the bottom of the main bottle.

And after all that work, we can finally fill the rocket with the power source—plain tap water will do.
Turn the launch mechanism upside down and push it into the bottle.

Try a half-full bottle for the first launch then try different water-air mixes to get to the highest altitude.

Flip everything back over and place the coat hanger release through the release holes.

The coat hanger wire needs to sit just above the lip of the bottle and the O-ring seal should fit firmly in the bottle’s mouth.

There’s one last thing we need to decide on. The door.

I’m prepared to compromise and do square doors… With round corners!

Awesome. Let’s get back to the launch site!
All systems locked and loaded... Time to pump.

Ready to initiate launch procedure.

Stand a safe distance back, at least 10 feet. Never, ever, put your body over the bottle once you've started pumping, and remember—what goes up must come down.

60 PSI! I can't pump any more...

Note the coat hanger stakes pinning the launcher down.

Proceed to countdown. Ready to launch in...
BLAST OFF!
GLOSSARY

AERODYNAMICS: This is the study of the way objects move through gases such as air. An object can be considered highly aerodynamic if it meets with little resistance or "drag," as it moves through the air.

ARBORIST: Also known as a tree surgeon. They are lucky people who get to climb trees all day and care for them. Kind of like vets for plants.

ARMATURE: The rotating coil in electric motors and generators. In our motor, it's the 10 loops of copper wound around the battery.

BASSO: A deep, low singing voice.

BEND: A knot tying two lines (ropes) together.

BIGHT: When you bend a piece of rope to make a knot, it is called a bight. This U-shaped section of rope is useful in forming many knots. Threading the end of the rope around or through the bight is what creates the knot.

BIT: This is the fundamental unit of computation as we know it. It is the name for the 1 or the 0 in binary digits.

BOOB TUBE: This is an antiquated, derogatory term that the artist's mother used to describe a television to those who watched it too much.

BRAID: Three or more things can be interwoven into a braid. Ropes and hair are often braided, but rarely together!

BYTE: 8 bits in a row are called a byte. 00100001 is a byte that represents 131.

CENTIMETER: 1/100th of a meter. It is a commonly used unit in metric measurement. There are 2.54 centimeters in one inch.

COMMUTATOR: The device that switches the direction of current in the armature of an electric motor so that it always goes one way.

CONDUCT: This term is used in science to describe movement through things. Heat conduction describes the movement of heat through a material. Electrical conduction is the movement of charge (or current) through a material.

CURRENT: In the same way that current describes the flow of water in a river, it describes the flow of charge in an electric circuit.

DRAINAGE: The process of draining the liquid from something. Allowing the water to flow to the bottom of your terrarium is drainage for the soil or top.

ECOSYSTEM: In ecology, an ecosystem describes all the living and non-living things in an area. The bacteria and dust in your navel (or belly button) might be described as its own ecosystem.
EMBOUCHURE: The shaping of the lips and movement of face muscles required to make wind instruments work.

FOOT: 12 inches long, or 12 \times 2.54 = 30.48 \text{ cm}. Very few people have feet that are a foot long.

FOSSIL RECORD: In the layers of earth beneath us lie the amoeba plants and dinosaurs that used to live on Earth. The order of the layers tells us much about our origins. The fossil record resembles a layered cake of history, with the oldest layer on the bottom.

FREEZING POINT: This is the temperature at which a liquid, such as water, turns into a solid, such as ice.

FUSELAGE: The body section of an airplane.

GAUGE: A tool for making measurements, like a pressure gauge, or a strain gauge, or a fuel or gas gauge.

GRAVITY: The force between two masses. The earth has a huge mass, which means it has a very strong force that pulls your small mass toward it. This has an unfortunate tendency to make you fall toward the ground.

HESSIAN SACK: Also known as burlap, hessian is a heavy woven fabric made principally from jute and other vegetable fibers.

HITCH: A hitch is any form of knot that ties off to a post or ring.

INCH: 1/12th of a foot.

INSULATOR: Thermal insulation slows the flow of heat, while electrical insulation slows the flow of electricity.

LIMERICK: A short and generally humorous poem with a strict format. It’s typically five lines long, with an A-A-B-B-A rhyming pattern (this means that the first, second and last lines rhyme with each other, and that the third and fourth lines rhyme with each other).

MAGNET: Originally found in Magnesia in Ancient Greece, the word magnet came to describe materials where a magnetic polarity could be stored. The magnetic poles act upon each other to exert force, either attracting or repelling each other.

MASS: The mass of an object is kind of like the weight, except that it doesn’t change if you move to planets with less gravity, whereas your weight does.

METER: The international standard unit of length. There are 100 centimeters in a meter.
**MILLIMETER:** 1/1000th of a meter. There are 25.4 mm in an inch. 10mm in 1cm.

**NUTRIENTS:** A nutrient is food for an organism. The marshmallow in your navel is a nutrient for the bacteria there.

**NUTS:** Nuts screw onto screws, or bolts. They are often hexagonally shaped donuts with a screw thread in the middle. Like donuts, the right one can be hard to find when you need it.

**OCEANOGRAPHY:** This is the study of the oceans and the seas of the world. It is becoming increasingly important in terms of understanding global warming and the heating of the oceans. More than 70% of the earth is covered in water; most of it is in the oceans.

**PICCOLO:** This is a fancy Italian word for a small flute, but can refer to any tiny musical instrument.

**PLANE:** Mathematically a plane is a two-dimensional surface, like a sheet of paper. A plain sheet of planar paper can be folded into a paper plane. A three-dimensional paper plane can fly.

**POLLUTE:** A foreign or toxic item in an ecosystem is a pollutant. Pollution should be avoided. Things like soda bottles should be recycled or reused rather than tossed into the environment where they pollute.

**PVC:** Polyvinylchloride is the plastic material more commonly known as PVC. It is used a lot in construction, and sometimes in the construction of toys.

**ROBOT:** A robot is a machine that is programmed to do things. They eat, sleep, and dream in binary.

**SAFETY PROTOCOL:** A set of guidelines to help you do things safely.

**SCOPE:** This is the suffix for many technical instruments used to look at or observe something, such as microscopes and telescopes.

**SHEARS:** The general term for big scissor-type things. Because of their large handles with lots of leverage, they can cut thick things.

**SIGN LANGUAGE:** Combines hand shapes and positions into an entire language that is often used by deaf people.

**SPICE:** If you braid the end of a piece of rope to the end of a piece of hair, it would be called splicing. Splicing joins two ropes end to end.

**SYMMETRICAL:** An object is symmetrical or has symmetry, when it is a reflection through a plane or a rotation around an axis. Your face is mostly symmetrical around the plane of your nose. A soda bottle is symmetrical about the axis that runs from the center of the base to the center of the cap.

**THERMODYNAMICS:** This is the branch of physics that studies the movement of energy, often in the form of heat, in a system.
**Voltage:** The measure of the electrical potential of something. The more volts, the more jobts.

**Weaving:** Two sets of threads are woven together to create fabric; the process is called weaving. The warp is the direction the weave comes out of the weaving loom, and the weft is the thread that passes along the length of the loom. You can remember that the weft goes west (if the warp goes north to south!).

**Wood Grain:** The patterns in a piece of wood caused by the alignment or growth direction of the wood fibers.

**Yard:** 3 feet or 36 inches long. A yard can also be a great place to play in, and should be many yards long.
SAUL GRIFFITH grew up in Australia, and his earliest memories of inventing things were of making grappling hooks for climbing trees and buildings. His childhood adventures included making his own rocket-powered toy cars, kites, and enormous puppets. He kept a diary of drawings of his inventions as a kid that included fantastic monorails and airplanes shaped like manta rays. Saul ended up studying materials science—the structure of the materials we use every day—before going on to MIT to do a PhD in building self-replicating machines and a theory for folding 3-dimensional objects. He now works at Squid Labs in California inventing cool new things for making the world a better place. He still builds kites; they are just much, much bigger now.

NICK DRAGOTTA first knew the power of comic art when he drew injuries on the blackboard at school that were so graphic that his fellow classmates had to leave the room to throw up. Since then he has tirelessly practiced the art of comics and researched the great artists of the field. Nick has drawn for Marvel and DC and is currently passionate about making more comic books for kids. Nick lives in a small apartment with walls lined by the shortened stubs of ruined pencils. He sleeps in a pile of eraser filings, drinks black ink, and exists on a diet of pureed superhero comic books.

JOOST BONSEN immigrated as a young boy to the United States from the Netherlands with his parents and his personal suitcase full of LEGOs. He grew up in Silicon Valley, California, immersed in that creative and entrepreneurial culture. While Joost was growing up, the vacant lot across the street from home served variously as play space, special-effects set, racetrack, rocket launch pad, and more as he and his friends made home movies, practiced being space explorers and plotted space projects. Joost went to MIT for undergraduate studies in bioengineering and recently finished his graduate degree at the MIT Sloan School of Management, studying how labs are run, how research themes emerge, and how new technologies are commercialized.
Lurking in the corners of your garage, on the dusty shelves of hardware stores, and in your own trash can are the tools and ingredients for creating your own adventures!

Follow Celine and Tucker as they learn the secrets of making their own entertainment. Challenged to make something “other than trouble,” this brother-and-sister pair use everyday objects to invent toys that you can build.

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