The Wild Blue Yonder

"You can never tell where the winds will blow you, what fantastic good fortune they can lead you to. Long Live Balloons!"

Do you ever dream of flying -- making lazy circles in the sky like a seagull or a hawk? If you do, you're not alone. World travel has always, inevitably, held both allure (attraction) and certain danger. It was undertaken only by the few explorers who were brave enough to risk treacherous (dangerous) passages over uncharted terrain (unexplored landscapes). There are two types of journeys: one that aims to reach a place within the shortest time, and another that begins without regard to speed and without a destination in mind. Balloon travel is said to be ideal for the second kind.

As the oldest successful method of human flight, hot air balloons were indeed a perilous choice for travel in their early years. But as classic author Jules Verne reminds us: "Anything one man can imagine, other men can make real," and hot air balloons have been flying high in human imagination for ages and the indomitable tenacity (determined stubbornness) of the human imagination has only continued to prove Verne right.

.

Image Credit: Balloon Sketch done by the very talented Suhita. Find her and her art at http://sketchaway.wordpress.com/2013/05/19/hot-air-balloons-and-vintage-cars/.

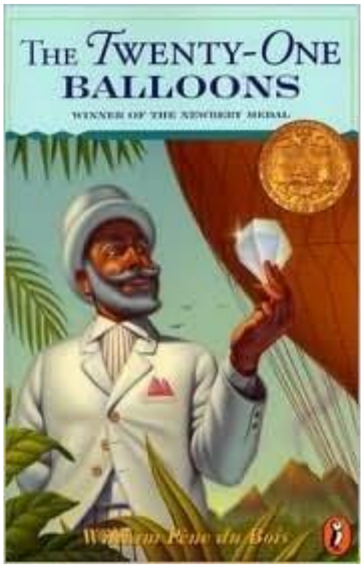
Have students experience the magic of a Hot Air Balloon Ride: with this beautiful video from Katie Damien http://vimeo.com/18922930

See a BBC camera operator go up to get a lovely aerial view of a tree (and crash into it!), http://www.bbc.co.uk/learningzone/clips/life-on-earth-filming-an-airiel-sequence/8243.html Or shout "follow that plane!" and take a ride across America

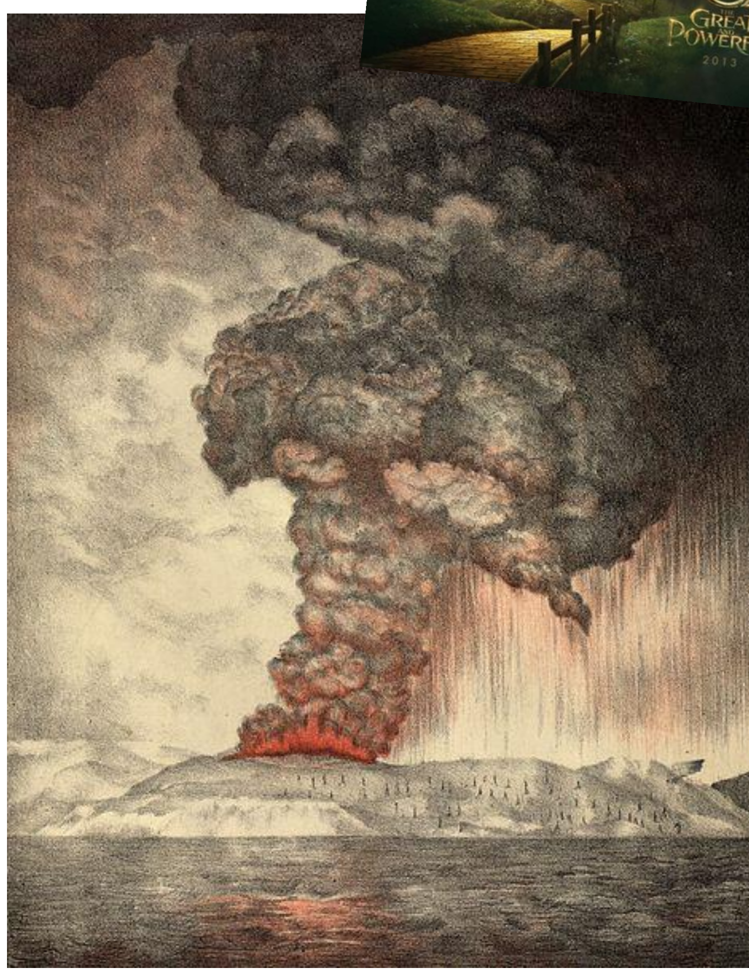
http://pinterest.com/pin/159385274284941265/

Authors, they're Full of Hot Air

Ever since Homer (famous Greek author) set Odysseus (famous Greek hero of a story) off on his epic journey, the road trip has been a classic setup for storytelling and hot air balloons have swept characters away in classic stories ranging from Frank L. B classic *Wizard of Oz* to Mark Twain's *Tom Sawyer Abroad* and beyond to Jules Verne's *Five Weeks in a Balloon* (though a balloon was mentioned in his Around the World in 80 days, the intrepid adventurers dismissed it as being " highly risky and, in any case, impossible.") and *The Man in the Moon and the Hot Air Balloon* by David Delamare. It's not limited to classic tales either, current authors like Monk Ashland still dream up places like *Sky Village*, an intricate web of interconnected hot-air balloons, floating above the troubled landscape.



In, arguably, one of the most memorable, fifty-one years before an around the world balloon flight became a reality; William Pène du Bois (an author most noted for his eccentric and comic characters) was dreaming it up in his Newberry Medal winning story *21 Balloons*. If there was one thing Professor William Waterman Sherman was tired of, it was teaching mathematics to little children. For years and years he'd done it and finally, once retired, he was given a chance to fulfill a lifelong dream. Sherman would engineer himself a fabulous balloon. It would be the second largest ever commissioned and would carry a small wicker house, in which Sherman would be able to sail in perfect peace and comfort. Containing a great deal of food, the hope on his part was to be able to sail around the world for at least a year without having to come into contact with another human being. On August 15, 1883 he sets out



above the Pacific in a single balloon to live in the sky. On September 8, 1883 he is picked up by a passing American freighter in the Atlantic while, "clinging to the debris of twenty deflated balloons". **How is this possible? Where did the balloons come from? How did he travel around the world so quickly? And what stories has he to tell?** "The Twenty-One Balloons" is Sherman's wild, impossible, and truly original tale of his time spent on the island of Krakatoa, mere days before it exploded sky high. (The island actually did erupt in 1883 in real life, see the text box and map for more information. ***Have students map out the points mentioned and create circles of "ripple effect" or influence from the eruption. Also use Google earth to find the locations if available.***)

And what he found there will astound. Published in 1947, the novel was awarded the Newbery Medal for excellence in American children's literature in 1948. The events and ideas are based both on scientific fact and imagination.

Before you begin reading, show students the cover and ask students to tell you everything they can about the picture. **What do they think the story is about?** Illustrators choose images, colors, and use techniques to convey messages about the stories they are illustrating. **What did the illustrator try to show you or tell you with the cover? What might be some key elements of the story?**

(Note: You might choose to read the Introduction from the book to the class and use the questions below to set the stage for the story.) Tell students that this story is set in the framework of a lecture Professor Sherman is invited to

Did you know?

There were enduring and world-changing effects of the catastrophic eruption off the coast of Java of the earth's most dangerous volcano – Krakatoa—considered the greatest natural disaster to occur on this planet since mankind began recording history some 30,000 years ago.

It was exactly 10:02 a.m. on Monday, August 27, 1883 when the small volcanic island of Krakatoa-- the name has since become a byword for a cataclysmic disaster – in the Sunda Strait between Java and Sumatra blew itself out of existence.

The small volcanic island had given plenty of warning. There had been a serious eruption the previous May and the warning signs of the big bang of late August were obvious. Yet, as so often happens in both natural and manmade catastrophes, no one put the pieces of the puzzle together in time. The eruption actually began on Sunday the 26th, but no one was prepared for the incredible disaster of the next morning.

Awesome powers churned beneath the surface of the island, before it gave way to 4 eruptions, the 4th so powerful that the island self-destructed, which was followed by an immense tsunami that destroyed 165 villages, killed 36,417 people, though some put estimates closer to 120,000, and left uncountable thousands more injured. This moving mountain of seawater wiped out whole towns; devastated the social and economic life of a region measured in thousands of miles; and was recorded on tide gauges as far away as France.

Ships were thrown miles inshore, endless rains of hot ash engulfed those towns not drowned by 100 foot waves, day turned to night, and vast rafts of pumice (lava rock) clogged the sea. There are numerous documented reports of groups of human skeletons floating across the Indian Ocean on rafts of volcanic pumice and washing up on the east coast of Africa up to a year after the eruption. The explosion was heard thousands of miles away, and the eruption's shock wave traveled around the world seven times. The sound of the island's destruction was heard in Australia and India and on islands thousands of miles away. That eruption is believed to be the loudest sound ever heard by human ears.

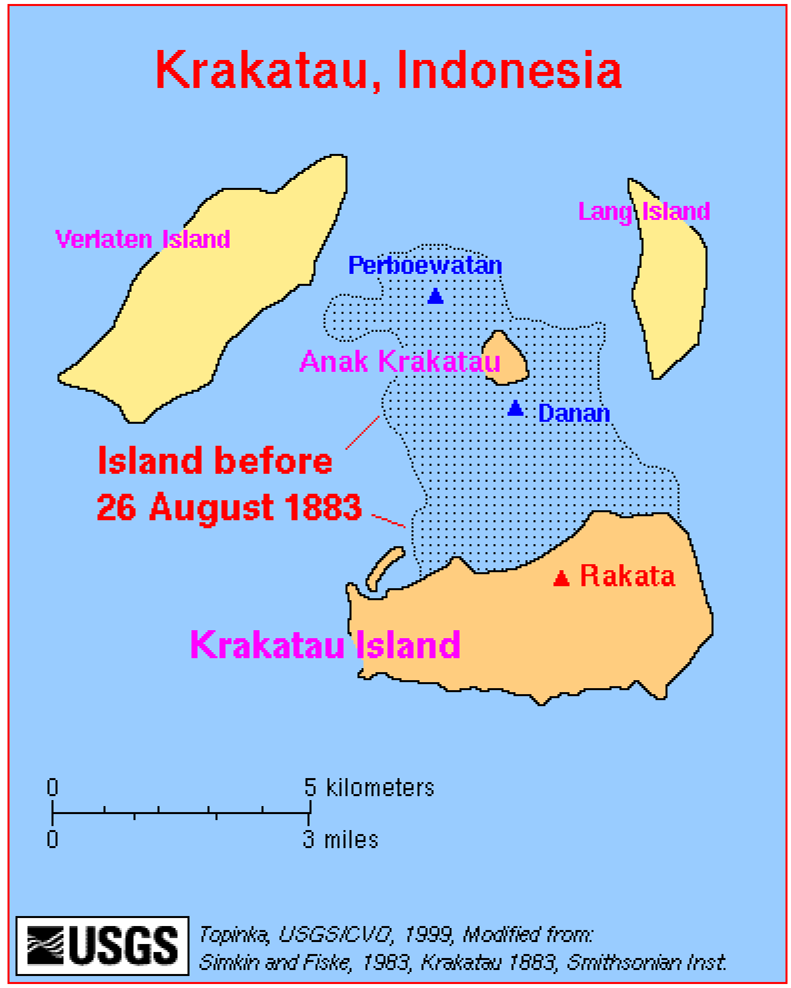
Beyond the purely physical horrors of an event that has only very recently been properly understood, the eruption changed the world in more ways than could possibly be imagined. Dust swirled round the planet for years, causing temperatures to plummet and sunsets to turn vivid with lurid and unsettling displays of light. The effects of the immense waves were felt as far away as France. Barometers in Bogota and Washington, D.C., went haywire. Bodies were washed up in Zanzibar.

The captain of a passing British ship, awestruck, wrote in his log: "A fearful explosion...I am writing this blind in pitch darkness...The eardrums of over half my crew have been shattered. My last thoughts are with my dear wife. I am convinced that the day of judgment has come."

The island of Krakatoa --- six miles long and two miles wide --- was largely destroyed. Only tiny fragments of remain today, along with an island, locally known as Anak Krakatoa which rose from the seabed where the volcano's crater once stood. June 29, 1927, the sea was bubbling and exploding from below. This activity went on for 3 years until in 1930, the new volcano; Anak Krakatoa became a volcanic island. "The Child of Krakatoa" was what this new name meant, and it was quite fitting indeed. This island currently has a radius of roughly 2 kilometres (1.2 mi) and a high point of around 324 metres (1,063 ft) above sea level,[6] growing 5 metres (16 ft) each year.

give to the Western American Exploratory Club in San Francisco upon his return from his balloon adventure.

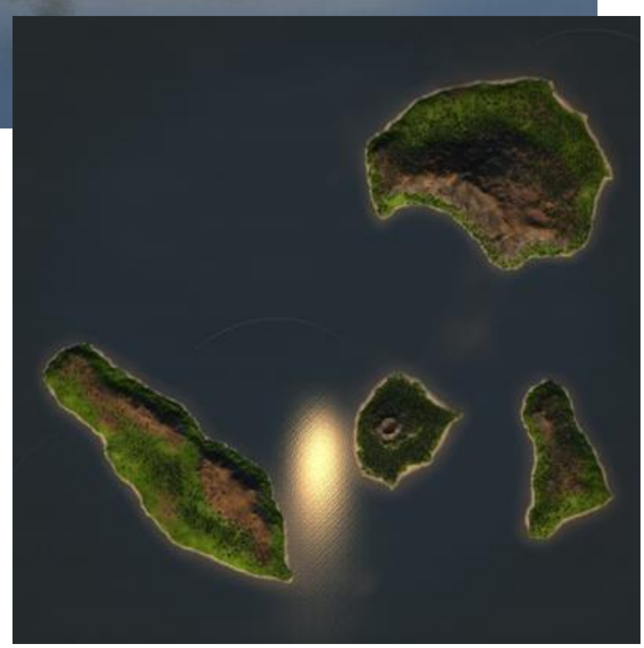
The setting of the story is real, the plot is pure fantasy told in his words to the audience. The setting shifts from San Francisco, where he amazes his audience with the details of his past adventure, to Krakatoa, where he experienced the amazing adventure. **Point out this island on a map or have students find it and invite students to tell what they know about volcanic eruptions and the possible dangers of living near an active volcano.**



Sample Discussion Guide for the Introduction of *The 21 Balloons* (pages 3-7)

Vocabulary you may need to explain: conveyance (3), atomically (4), descent (3), inundating (4)

1. What two kinds of travel does the author describe? If you were ballooning home from school, where might your balloon take you?
2. What is your first impression of Professor Sherman? Is he a person you would like to know? Why or why not?
3. How does the author expect travel to change in the future? What example does he give to illustrate this? What does he mean when he say that "miles per hour" will become "most old-fashioned." Has his prediction come true? Explain.



4. During what part of the nineteenth century were balloons particularly popular? What do you think might have caused this interest? Why have people through the ages been interested in flight? Tell about other examples you have read about.
5. What facts does the author give you concerning the eruption of the volcano on Krakatoa?
6. Have you ever been to a hot-air balloon show or seen one flying? Tell about it.
7. What might be the difference between a hot-air balloon and a gas balloon?
8. What ideas in this Introduction do you think will play a big part in the story?

The author and illustrator, William Pène du Bois, has cleverly mingled truth (real engineering, geography, and other facts and concepts) and fiction throughout the story. After you read a chapter or section each day, discuss with students what they think is real and what is "absurd and fantastic" and note how the author's illustrations contribute to their understanding of the "absurd and fantastic".

5 Key Story Elements

The most basic elements of a story are setting, characters, plot, conflict and theme. Recognizing what each of these elements adds to the story and how they work together helps the reader understand the structure and meaning of a story.

http://pinterest.com/pin/266767977897895057/ Fun video and rap about the elements of a story. Explains plot, character, conflict, setting and theme.

Note: If there are time constraints, you may wish to read the introduction and summarize what happens in preparation on his way to San Francisco to tell his story. Then, read the story in sections throughout the unit as he begins to tell his tale.

Strategy Tips:

Model Thinking Aloud

Think-alouds are "eavesdropping on someone's thinking." With this strategy, you will verbalize aloud while reading a selection orally. This includes describing things you're doing as you read to monitor your comprehension. The purpose of the think-aloud strategy is to model for students how skilled readers construct meaning from a text.

1. Begin by modeling this strategy. Model your thinking as you read. Do this at points in the text that may be confusing for students (new vocabulary, unusual sentence construction).

2. Develop the set of questions to support thinking aloud (see examples below).
    - Do I understand what I just read?
    - Do I have a clear picture in my head about this information?
    - What more can I do to understand this?
    - What were the most important points in this reading?
    - What new information did I learn?
    - How does it fit in with what I already know?

3. Read the selected passage aloud as the students read the same text silently. At certain points stop and "think aloud" the answers to some of the pre-selected questions.

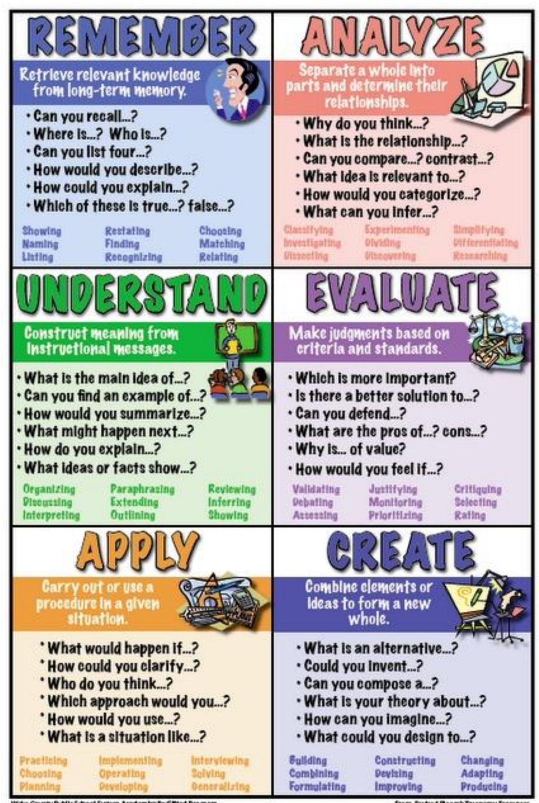
4. Demonstrate how good readers monitor their understanding by sometimes rereading a sentence, reading ahead to clarify, and/or looking for context clues. Students then learn to offer answers to the questions as the teacher leads the Think Aloud.

5. Tip: Use a tap-it light to show think a-louds during your read a-louds. Tap the light "on" when you stop reading and discuss what the text makes you think. This technique helps students to "see" the difference between your reading and your thinking.

I’m Thinking that Discussion is Critical

During discussions encourage students to use “Accountable Talk” and practice critical thinking skills by listing the following sentence starters on the board and encouraging students to use them during discussions and by using them yourself to model the technique for students.

- I agree with ____________ because…
- I must disagree with _____________ because…
- Why do you think that?
- Where can I find that in the book?
- Would it be better if…?
- So, what you’re saying is…
- Couldn’t it also be that…?
- Can you explain what you mean?
- Can you tell me more?
- Can you give me an example of that?
- What can you conclude…?
- What might result if…?
- How would you solve…?



Getting There:

Students will create a “Lit Trip” as they journey through the story. They’ll create their flight plan and calculate how far they will be traveling. They will then calculate what day is best to depart and how long this trip will take by finding the wind patterns of the globe.

If possible, go to Google Earth and find San Francisco, California. Find the “Beach Chalet Soccer Fields” on the northwest coast of San Francisco. This is the field where we will begin oour fantastic journey.

The field is located near (37°46’2” N, 122°30’31” W) Put a place marker here. If internet is not available, find San Francisco on a map, and put a place marker there.

Using either method they now need to find Krakatoa, Indonesia at about (6°9’9”S, 105°26’9”E) and put another place marker here.

Using a ruler, or the ruler tool on Google Earth, draw a path from SF to Krakatoa and calculate the total mileage of your trip which you will need.

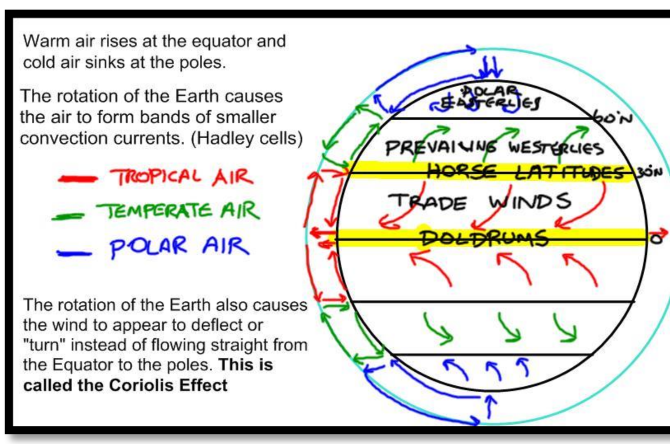
If possible, go to http://www.windfinder.com, where students will find the most up to date information on wind direction and speed. Using the information provided on this website, calculate the best day for departure and how long the flight to Krakatoa will take.

Hint: Go into the “Forecasts & reports” tab, input “San Francisco Airport” in the search box. Click on either “Report” or “Forecast” and it will lead you to a new page. On this page you will find a tab called “Wind Statistics”. This tab will be most helpful for students in planning their departure date. Remember they will want an easterly or southeasterly wind direction. They can then click on the “weather maps” tab where they can find the wind patterns and speed for the globe, information which will help them calculate the length of their trip.

Have students enter their departure date and length of trip calculations with explanations as to why they chose the date and how they calculated the time in their daily journal. They will also need to draw a simple map showing their flight path, with wind directions and wind speeds.

Warm Goes Up & Cool Comes Down

The Earth's atmosphere is a gaseous layer that wraps around the Earth, separating the planet from the rest of the universe. It sits above the planet, held in place by gravity. Air is in constant motion. It is affected by changes in pressure and temperature. Heating of earth’s surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds. When one area heats up more than another area that it is next to, the difference in pressure creates wind. It is a rotation cycle of cool air and warm air moving around each other.



Air that grows warmer rises upward. This is called an updraft. Cooler air flows to the surface to fill up the space vacated by the rising air. This cooler air also heats up and rises. The air above cools down, but it can't get back to the surface because of the warm air rising from beneath it. This flow of air pushes off to the side as wind, to head back to where the cooler air came from. These changing levels of temperatures of warm and cool air are what push hot air balloons around!

The Birth of Balloon Flight

Not so very long ago, space was not the final frontier.
Indeed, before Buzz Lightyear (or anyone else) could lead us to "infinity and beyond" we first needed to conquer the realm of the sky.

Although many early attempts at flight involved gliders or wings that mimicked birds, one of the first successful methods of early aviation was much simpler. Rather than creating lift using wings and a source of propulsion, clever aviators discovered that heated air trapped inside of a thin, lightweight container would rise.

Try It! Let's grab a thin lightweight container called a Solar Bag.

Materials:

- Solar Bag
- String
- Cool sunny day

Use caution when handling the bag since the plastic will tear easily. A handy explanatory video for the following instructions is available at http://www.stevespanglerscience.com/solar-bag.html

A Solar Bag is a long plastic bag made from a very thin plastic and colored black to absorb solar energy. The heated air inside the bag provides buoyancy and causes the bag to float in the cooler surrounding air.

1. Notice that the bag is made out of a light weight plastic material. Use caution when handling the bag since the plastic will tear easily.

2. Carefully remove the plastic bag from the packaging and locate one of the open ends of the bag. Tie a knot in this end of the bag.

3. The best time for a launch is in the morning when the temperature of the air outside is cool. We have not had much success with a launch attempt in the middle of a hot day.

4. Select an appropriate location for the launch. Find a park or an open field clear of any buildings, trees, and power lines to conduct the launch. Select a day to do the experiment when it's sunny and free of any wind.

5. Unroll the Solar Bag onto a soft surface like grass. Avoid pavement or gravel since the plastic material can easily tear. Have one person hold the bag open as you begin to run around and scoop up air. Believe it or not, you can inflate the bag in just a couple of minutes.

6. Fill the bag with air until approximately 2 feet of deflated plastic remains in your hand. Slide your hand along the plastic to make sure that the air in the inflated portion of the bag is stretching the plastic tight. Tie a knot in the end of the bag, and tether it to the ground with Solar Bag String. **Do NOT let go of the string, the solar bag will fly away and rise higher and faster than you will believe..**

How does it work?

The remainder of the work is done by the sun. Gather around the giant bag but try not to touch it - sharp fingernails will easily puncture the very thin plastic. Be careful, the outside of the bag also gets very hot to the touch. What is happening to the gas molecules inside the bag? Of course, as the sun warms the air molecules in the bag, their movement begin to speed up. Since the heated air inside the bag is less dense than the cooler air on the outside of the bag, the Solar Bag will float. It's important to remember that it may take as long as ten minutes for the air inside to heat up enough to cause the bag to float.

Have students feel the top of the bags: what does it feel like?

Have students feel the bottom of the bag: what does it feel like? Are there any temperature differences? What is the warmer air doing? What is the cooler air doing?

Have students hypothesize whether or not a long black trash bag filled with air would work as well as the Solar Bag. Test it. Is the black color necessary for absorption of solar energy? Will a long white bag work as well? Or another color? Test their theories.

Additional Info: Storage and Repair

We store the deflated bag in an old pillow case, which helps prevent accidental punctures or tears when it's not being used. If a small tear is spotted, clear packing tape can be used to repair the damage.

The First Documented Hot Air Balloons

The Chinese are recorded as being the first to make use of lighter than air technology with small unmanned hot air ba lloons which are know as Kongming Lanterns or sky lanterns. These were developed around the 3rd century by originally used as military signaling devices but later became a tradition at Chinese festivals. Kongming Lanterns were made from oiled rice paper on a bamboo frame, the heat source used was a small candle made from a waxy, flammable material.

Hot Air Balloon History Hotly Disputed

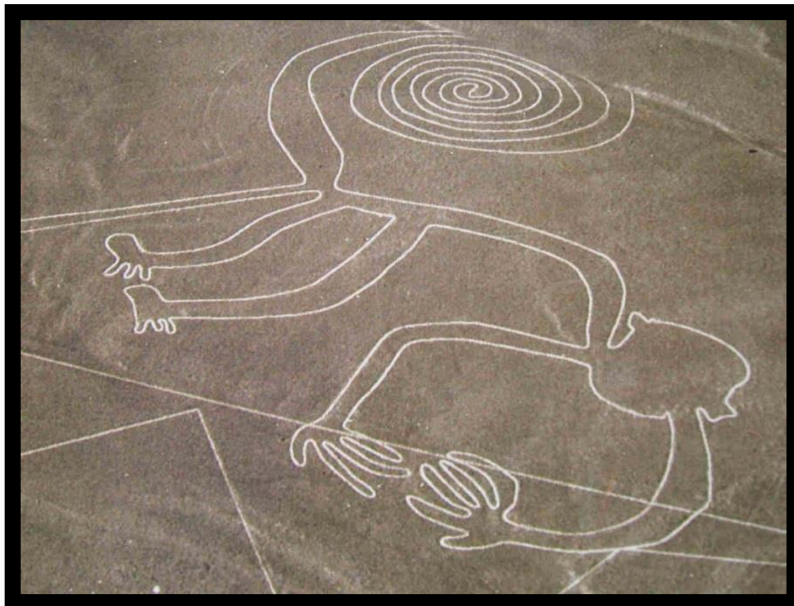
The claim for the first use of hot air balloons is hotly disputed, no pun intended. The Nazca Indians of Peru are thought to have used hot air balloons as an aid to creating the famous Nazca Line Drawings which were created in the period 700 B.C. to 200 A.D.

Giant drawings in the desert sand: Nazca Lines

The Nasca Lines are one of the world's great enigmas. Who etched the more than 1,000 animal, human, and geometric figures that cover 400 square miles of barren pampa in southern Peru? How did the makers create lifelike images of monkeys, birds, and spiders without an aerial vantage point from which to view these giant figures that stretch across thousands of square yards? Most puzzling of all, *why* did the ancient Nasca lay out these lines and images in the desert?

Scattered over 500 km² of an arid plateau between the Nazca River and Ingenio River, they are huge representations of geometric patterns, animals, human figures and thousands of perfectly straight lines that go on for kilometers. By simply removing a layer of dark stones cluttering the ground, exposing the lighter sand beneath, the Nasca created markings that have endured for centuries in the dry climate. Archaeologists believe both the construction and maintenance of the lines were communal activities—like building a cathedral.

Have students watch fascinating animations of how scientists believe the linear and spiral lines were constructed at http://ngm.nationalgeographic.com/2010/03/nasca/nasca-animation. Also, have students explore an interactive digital map of the geoglyphs at http://ngm.nationalgeographic.com/2010/03/nasca/nasca-interactive



They're unquestionably ancient (dating back 1400-2200 years), and remarkably precise (with straight lines and clean curves). *Although the Nasca were certainly the most prolific makers of geoglyphs, they were not the first.* The images are so huge that some believe they are only appreciable from the air, a fact which has led to speculation that the ancient Nazca people either had access to hot air balloons or alien helpers. Most academics attribute the lines' precision to low-tech surveying techniques, but nobody actually knows who made them or why. New findings make an important point about the Nasca lines: They were not made at one time, in one place, for one purpose. Many have been superimposed on older ones, with erasures and over-writings complicating their interpretation; archaeologist Helaine Silverman once likened them to the scribbling on a blackboard at the end of a busy day at school. The popular notion that they can be seen only from the air is a modern myth. At one time or another, they have been explained as Inca roads, irrigation plans, images to be appreciated from primitive hot-air balloons, and, most laughably, landing strips for alien spacecraft.

It is now believed that they are ritual paths that were sacred to the Nasca people and used for worshiping mountain deities in the Andes and mountains such as Cerro Blanco, a sacred mountain, in times of plenty and in times of desperate want. They would pray for rain to fall in the Andes to their east and to flow down to their valleys. Water—or more precisely, its absence—was of paramount importance to the desert people. Ultimately, all those offerings and prayers went unanswered and the Nasca people died out.

Nazca town is full of hotels and tour agents peddling flights over the lines in Cessnas, few, if any, will offer a decent price. A seat in a four-seater plane (two pilots, two passengers)should start from US$50 in the low season, don't pay more than US$90. Haggling is necessary. An airport tax of 25 soles is usually not included in the price. Longer flights which include the nearby Palpa lines (even older lines) are also available.

The pilots love banking (turning) their small planes hard (for good views of the ground) and motion sickness can occur. "Orca!" shouts our pilot over the roar of the engine. He pointed down at the form of a killer whale. "¡Mono!" he said moments later, when the famous Nasca monkey came into view. "¡Colibrí!" The hummingbird. We may need to take a motion sickness pill.

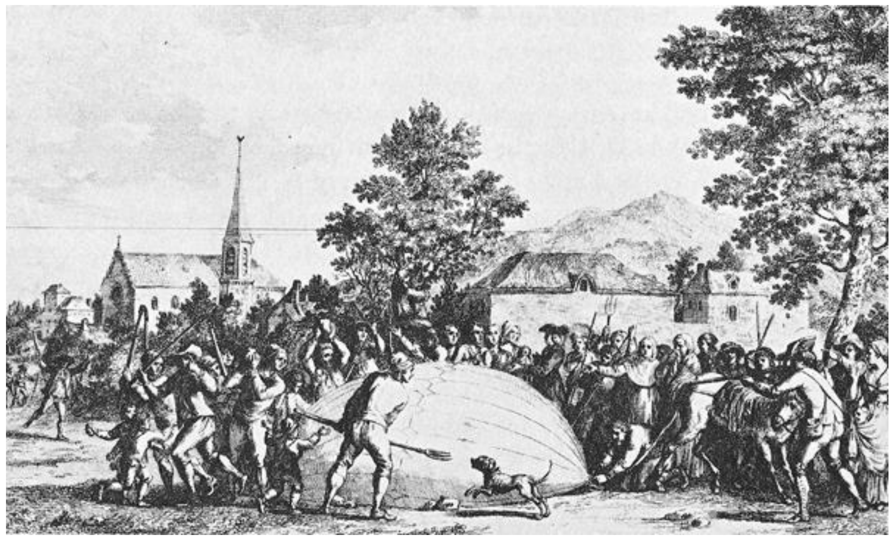
Legendary Balloons

An 18th century issue of the newspaper 'La Gaceta de Mexico' noted that in 1667, a citizen of Las Mendarios del Perro, Veracrus broke his leg in a fall following ascent in a strange device with fire.

The Portuguese claim that a priest, Batholomeu Laurenco de Gasmao demonstrated a small working balloon model on the 3rd August 1709. He was subsequently awarded a Professor of Mathematics by King

John V of Portugal for his efforts.

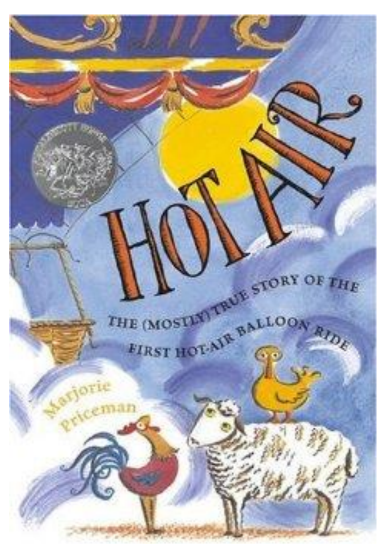
There are also reports of pre-Montgolfier balloons from Russia in 1731. A young military officer Kria Kutnoi is reported to have launched a primitive balloon from Ryazan, about 120 miles south of Moscow. It reputedly flew over a grove of birch trees crashing into the tower of a church in the neighboring town. The balloon is said to have been made from hides and filled with evil smelling smoke.



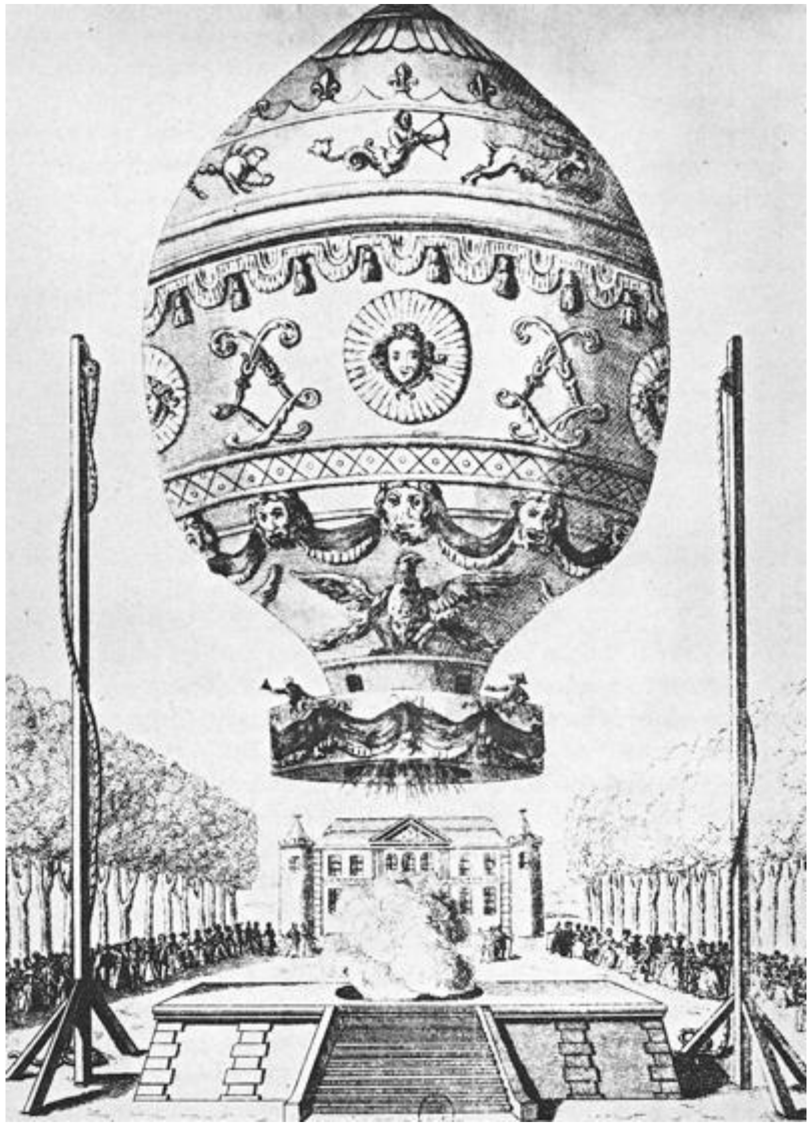
French brothers, Jacques and Joseph Montgolfier were the local paper manufacturers in the town of Alchemy in Southern France. The brothers noticed that when they burnt paper the ashes floated up in to the air. They thought that the heat and smoke from the flame had a special lifting power and they set their minds to inventing a craft that could capture the heat and smoke and lift them off the ground. It is recorded that on the 4^{th} June 1973 the first large scale balloon flight was launched by the Montgolfier Brothers from Annonay, France.It was reported in a Paris newspaper on the 10^{th} of July as having been witnessed by many people.The report says that the balloon was 'about 36 feet long and 16 feet high and about as high', on landing about 7 - 8 minutes after takeoff the 'globe' was destroyed by peasant workers who believed it was the moon was falling from the sky.

A Sheep, a Duck and a Rooster Hopped into a Balloon

It sounds like the beginning of a silly joke, but on the 19th Sept, 1783 the Montgolfier brothers successfully launched their first load carrying hot air balloon made of paper and cloth. To inflate the craft they burned a combination of straw, chopped wool and dried horse manure underneath the balloon. As the straw burned it released heat that helped the balloon float. The wool and manure made lots of smoke and helped keep the burning flame low, which lessened the risk of setting the balloon alight. The brothers were too nervous to try out their invention themselves so they sent a sheep, a duck and a rooster to see what would happen. The balloon floated up into the sky and landed safely eight minutes later.



Once the Montgolfier brothers realized what they had achieved they approached the King of France to see if he would view their invention, with two people on board instead of farm yard animals. King Louis XVI agreed.



Read with kids the book *Hot Air: The (Mostly) True Story of the First Hot-Air Balloon Ride* – written by Caldecott Honor-winning author Marjorie Priceman. The first "manned" hot-air balloon is about to take off! But what are those noises coming from the basket? Based on the (POSSIBLY) true report of a day in 1783, this is the story of (PERHAPS) the bravest collection of flyers the world has ever seen, as (SORT OF) told to Marjorie Priceman. A time line on the endpapers fills in some of the historical data, but this "(mostly) true" version (which the author "heard…from a duck, who heard it from a sheep, who heard it from a rooster a long, long time ago") is just the way it should have happened.

The First Manned Flight

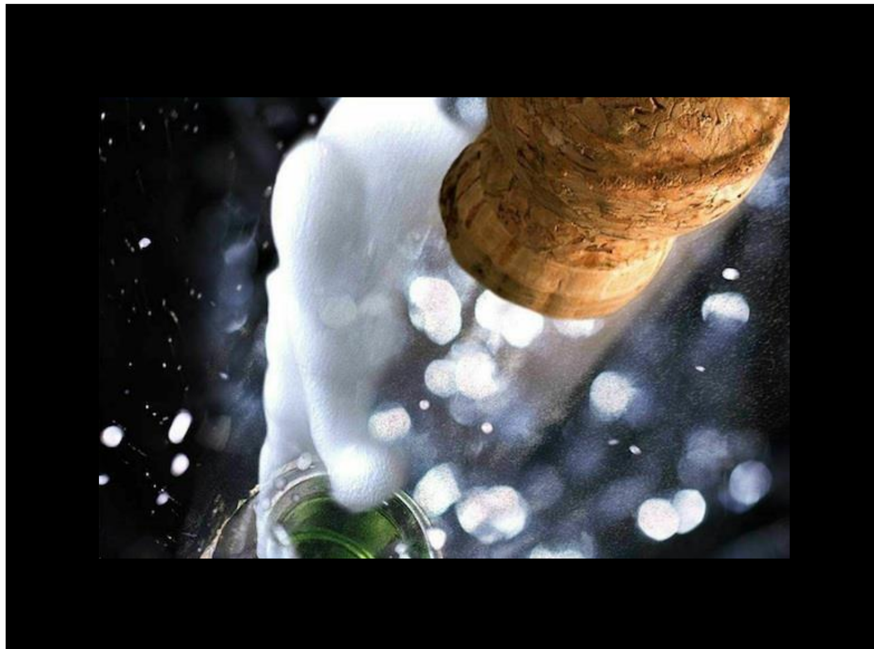
On the 21st November 1783, a hot air balloon was launched in Paris for all to see. On board were two close friends of the Montgolfier brothers, Pilatre de Rozier and Francious Laurent. The balloon was successfully launched and rose about 500 feet / 150 meters (measure it with students) above the rooftops of Paris, after a flight lasting about 25 minutes the flight eventually landing a few miles away in some vineyards.

Benjamin Franklin is noted to have been present at the launch and met with the Montgolfier Brothers later in the day to sign a witness report that was submitted to the Academy of Science.

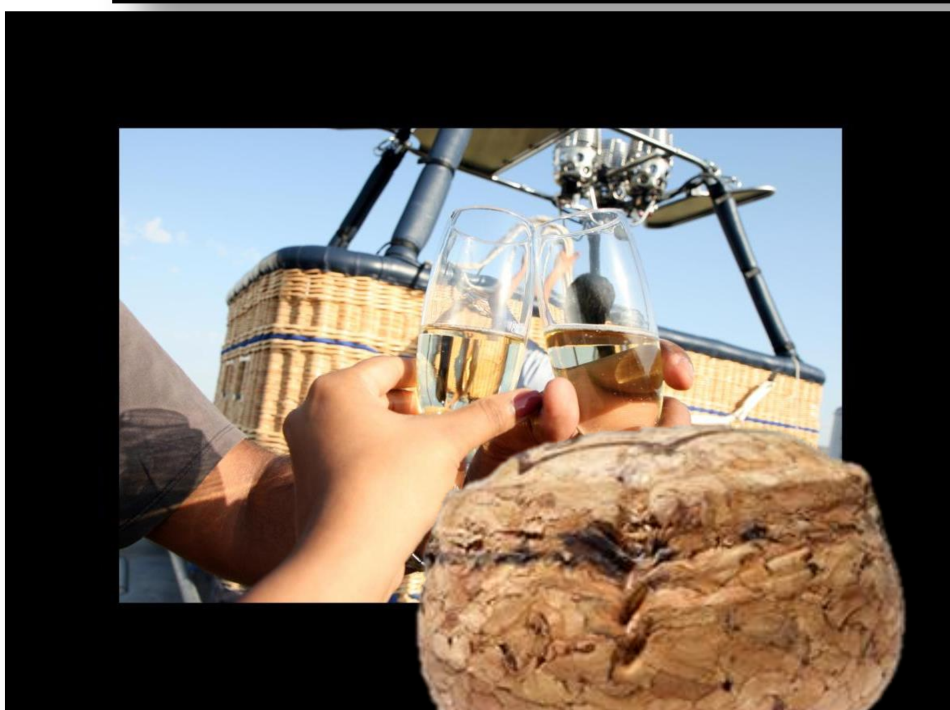
A recent HBO miniseries about John Adams (the second president of the United States) includes a scene in which John Adams, Abigail Adams, and Thomas Jefferson observing the Montgolfier brothers famous 1783 balloon launch in Paris. You can view the clip at the bottom of the page at the following link:

http://www.middleschoolchemistry.com/atomsworld/2012/09/not-just-hot-air/

The Birth of a Tradition



One of the facets of ballooning that adds a certain romanticism to it that has largely been lost to other forms of flying is that it holds to certain small traditions, some of which go back to ballooning's origins in France.



One of these traditions is for the pilot/aeronaut to present the landowner on whose property you make your final landing with a ceremonial bottle of champagne. This tradition is reputed to have started with the first balloonists in France. The first hot air balloons were filled with not just hot air but smoke, due to a slight mistake by scientists of that era who believed the lift was due to the smoke rather than the heat. Thus, early balloons landing in peasants' farm fields were likely attacked to be attacked with stones an d clubs and pitchforks, since they were obviously fire-breathing monsters. French peasants came with a certain level of sophistication, however. Early French aeronauts found that the peasants could be easily distracted if the monster's human occupants offered them a glass of champagne. It is very unlikely that any landowner today thinks the balloons are monsters, but some remain irate until offered the champagne! (Today we offer the whole bottle!)

Another champagne tradition is the "First Flight Ceremony" which provides a memorable finish for someone taking their first free flight in a balloon. The ceremony can range from gentle and dignified to bizarre (strange) and sadistic (cruel/unkind). The gentle and dignified version, preferred by balloonists in the Eastern United States, has the pilot telling the story of the French origins of the champagne ceremony. With champagne-filled glasses raised, the pilot pronounces "Mother Nature has taken you into the skies and returned you gently to Earth. Welcome to the ranks of the Aeronauts!" Glasses are touched, a cheer sounded, and the champagne given a just reward. In Albuquerque and other locales of the Western balloonist, a slightly nastier version may be inflicted on the newly initiated. The new aeronauts are made to kneel on the ground while the story is told. With the final pronouncement, champagne is poured on the victim's head and dirt (to commemorate the return to earth) sprinkled onto their wet hair for good measure. The Germans are apparently the most sadistic of all. Word has it that they add to the Western U.S. version, and burn the ends of the hair of the probably horrified new aeronauts to commemorate the fire that took them aloft! Aren't you glad we don't have to do that! But perhaps we can celebrate our own eventual launching with a little sparkling juice!

The Origin of a Word

The word 'pilot' is derived from 'Pilatre', the name of the first person to command an aerial vehicle.

Moving Up in Time

Just 2 years after the first manned flight in 1785 a French balloonist, Jean Pierre Blanchard, and his American co pilot, John Jefferies, became the first to fly across the English Channel. In these early days of ballooning, the English Channel was considered the first step to long distance ballooning so this was a large benchmark ballooning history. *The distance of the English Channel is 23.69 land miles across from the White Cliffs of Dover at Shakespeare Beach in England to Cap Gris-Nez in France. If flying, you will most likely wind up traveling between 30 and 40 miles because the winds will push you from side to side a little. Your path will probably look like the letter 'S'.*

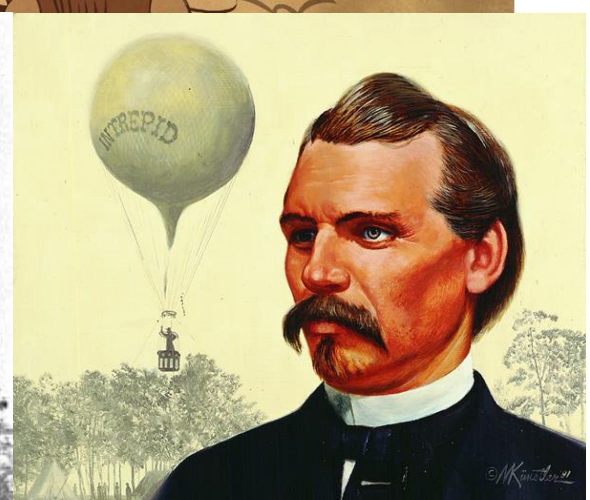
Unfortunately, this same year Pilatre de Rozier (the world's first balloonist) was killed in his attempt at crossing the channel. His balloon exploded half an hour after takeoff due to the experimental design of using a hydrogen balloon and hot air balloon tied together.

The enthusiasm for the original hot air balloons soon waned, however, dimmed by the smoky fuels of the day which included straw, rags, and a variety of other less-than-wonderful materials. The scientists of the day believed that smoke and not hot air created the lift. And they may have been right for the wrong reasons. The porous (lots of tiny holes) fabrics used in the early balloons may have needed the carbon and soot from the dirty smoke to seal the fabric pores to hold in the heated air that really created the lift.

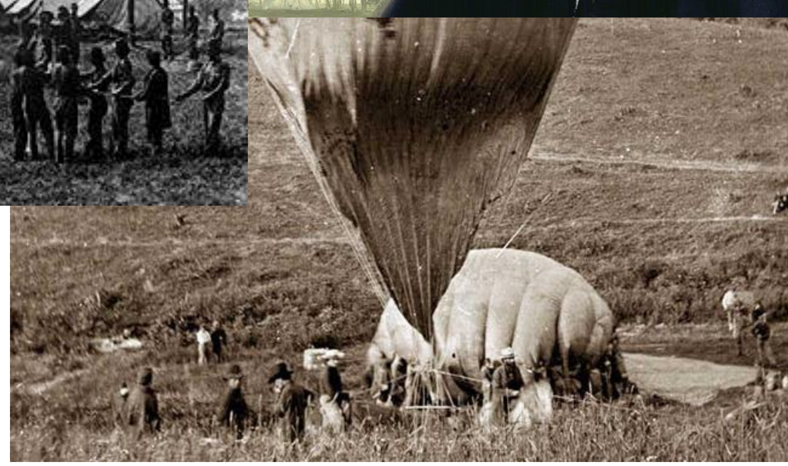
The next major pivotal point in balloon history was on January 7th 1793. Jean Pierre Blanchard became the first to fly a hot air balloon in North America. George Washington was present to see the balloon launch.

Lincoln's Flying Spies

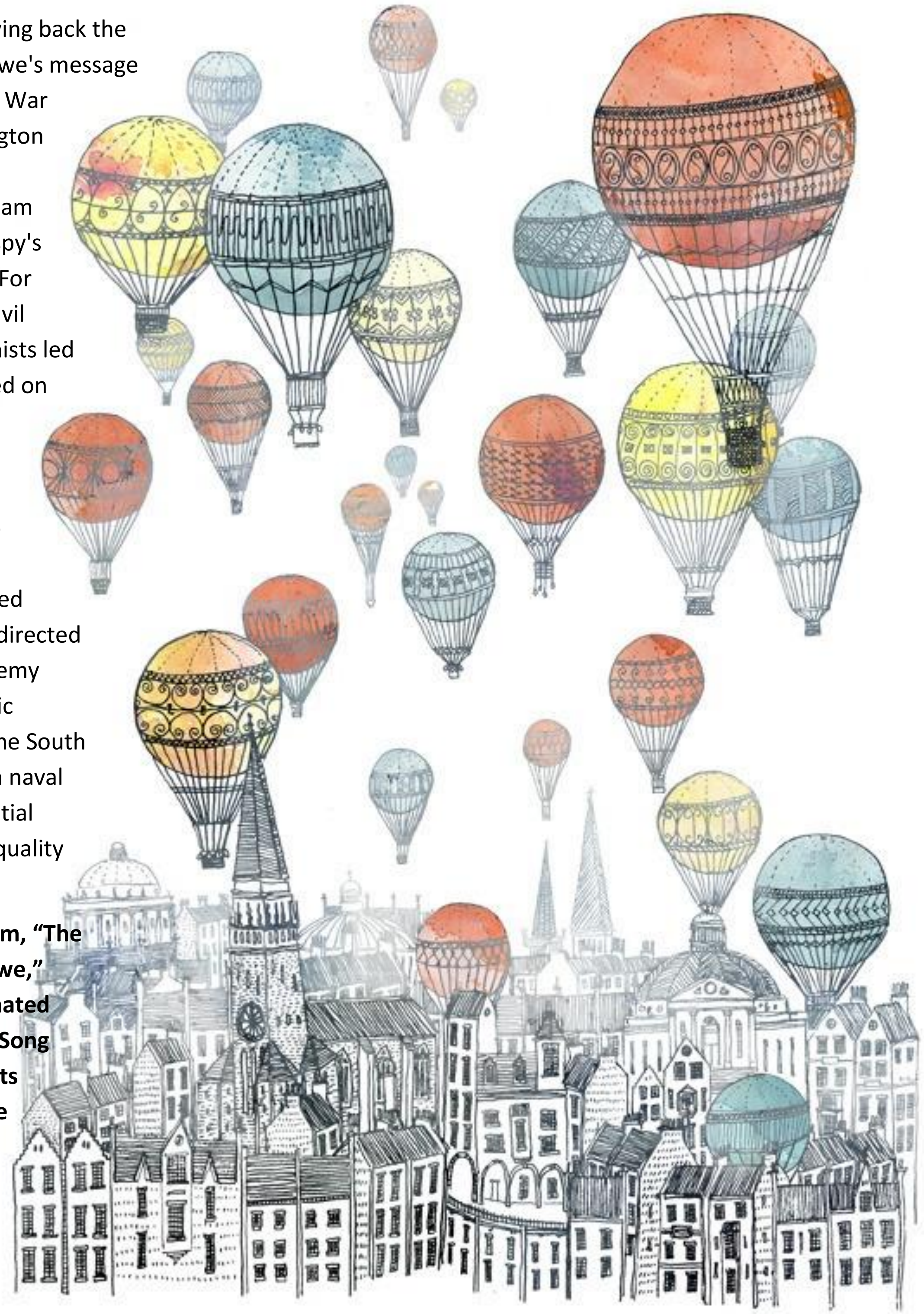
Another president put hot air balloons up in the sky in order to spy! Forgotten bits of history often make the most interesting stories, as is the case with this account of the Union Army's Aeronautics Corps during the Civil War. Who knew you could spy from a hot air balloon! Did you know there was a Union Army Balloon Corp during the Civil War? The Union and the Confederate armies both used Hot Air Balloons for spying during the Civil War.



On June 1, 1862, Thaddeus Lowe (a handsome, charming, and endlessly self-promoting scientist and entrepreneur who forged a new military branch and laid the foundation for aeronautics strategies in future wars) floated a thousand feet above a fierce Civil War battle raging just outside the Confederate capital of Richmond, Virginia. From the wicker basket dangling under his silk hydrogen balloon, the aeronaut telegraphed a message to Northern generals on the ground: Union



troops were finally driving back the Confederate forces. Lowe's message was transmitted to the War Department in Washington a hundred miles away, where President Abraham Lincoln read his flying spy's good news with relief. For two years during the Civil War, a corps of balloonists led by Thaddeus Lowe spied on the Confederate army. The aeronauts from both sides at times successfully and not-so successfully counted enemy soldiers, detected troop movement, and directed artillery fire against enemy positions. The economic hardships suffered in the South as a result of the Union naval blockade limited potential resources for building quality balloons.



The following short film, "The Ballad of Thaddeus Lowe," Written Directed Animated Narrated and Original Song by Kelly Jones highlights the life of the one-time aeronaut and pioneer, Thaddeus Lowe. The catchy tune and colorful characters in this ballad will ensure that Thaddeus Lowe will never be forgotten! Song, Dance, Guns, and War! What more could you ask for? http://vimeo.com/63138379

(Quite) A Few years later

Now a large jump in time, of over 100 years: In August of 1932 Swiss scientist Auguste Piccard was the first to achieve a manned flight to the Stratosphere. He reached a height of 52,498 feet, setting the new altitude record. Over the next couple of years, altitude records continued to be set and broken every couple of months - the race was on to see who would reach the highest point.

In 1935 a new altitude record was set and it remained at this level for the next 20 years. The balloon Explorer 2, a gas helium model reached an altitude of 72,395 feet (13.7 miles)! For the first time in history, it was proven that humans could survive in a pressurized chamber at extremely high altitudes. *To give you perspective, the thickness of the atmosphere is only about 60 miles according to NASA. And the world's tallest mountain is only 29,035 feet high.* This flight set a milestone for aviation and helped pave the way for future space travel.

The Altitude record was set again in 1960 when Captain Joe Kittinger parachute jumped from a balloon that was at a height of 102,000 feet (19.3 miles!). The balloon broke the altitude record and Captain Kittinger, the high altitude parachute jump record. He broke the sound barrier with his body!

THE ATLANTIC CHALLENGE: Conquered!

In 1978, the Double Eagle II became the first balloon to cross the Atlantic, another major benchmark in the History of Ballooning. After many many unsuccessful attempts this mighty Ocean had finally been cracked. It was a helium filled model, carrying 3 passengers, Ben Abruzzo, Maxie Anderson and Larry Newman. They set a new flight duration time at 137 hours.

In 1987 Richard Branson and Per Lindstrand were the first to cross the Atlantic in a hot air balloon, rather than a helium/gas filled balloon. They flew a distance of 2,900 miles in a record breaking time of 33 hours. At the time, the envelope they used was the largest ever flown, at 2.3 million cubic feet of capacity. A year later, Per Lindstrand set yet another record, this time for highest solo flight ever recorded in a hot air balloon - 65,000 feet (12.3 miles up in the atmosphere)!

THE PACIFIC CHALLENGE: Conquered!

The first Pacific crossing was achieved 3 years later in 1981. The Double Eagle V launched from Japan on November 10th and landed 84 hours later in Mendocino National Forest, California. The 4 pilots set a new distance record at 5,678 miles. 3 years after this, Captain Joe Kittinger flew 3,535 miles on the first solo transatlantic balloon flight, setting yet another record.

The great team of Richard Branson and Per Lindstrand paired up again in 1991 and became the first to cross the Pacific in a hot air balloon. They travelled 6,700 miles in 47 hours, from Japan to Canada breaking the world distance record, travelling at speeds of up to 245 mph. 4 years later, Steve Fossett became the first to complete the Transpacific balloon route by himself, travelling from Korea and landing in Canada 4 days later.

All the Way around the World?

Finally, in 1999 the first around the world flight was completed by Bertrand Piccard and Brian Jones. Leaving from Switzerland and landing in Africa, they smashed all previous distance records, flying for 19 days, 21 hours and 55 minutes. *Based on the diameter of the Earth (look it up!), how long would it take to circumnavigate the globe using different types of transportation? Research the average speeds (and possible speeds) of various methods of travel: plane, train, automobile, motorboat, sailboat, etcetera.*

It's interesting to see how the development of the hot air balloon has gone full circle on itself. At the very start, the first balloonists burnt materials onboard the balloon to generate heat to propel the envelope into the air. This theory then became obsolete as gas and helium designs were introduced as it was considered safer and more reliable than flying with an open flame. It is only within the last 50 or so years that hot air balloons have come back into interest.

Although they aren't our primary means of air travel today, we still see hot air balloons in use. You've probably seen pictures of hot air balloons floating gently over some picturesque scenery, or if you're very lucky, perhaps you've flown in one yourself.

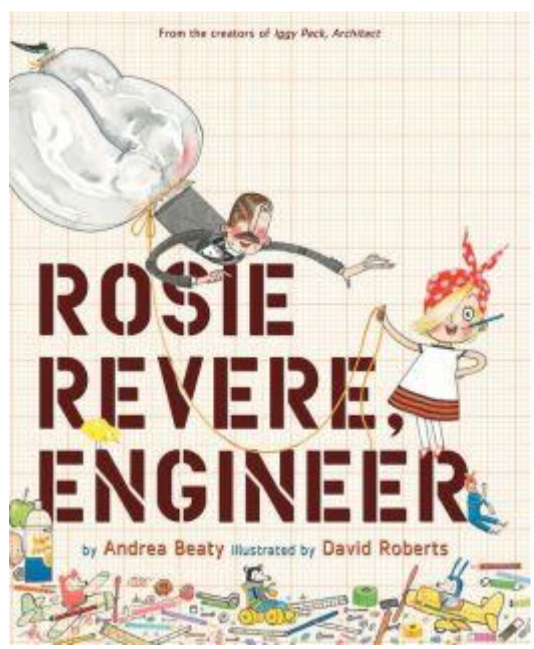
But why, exactly, do hot air balloons fly? Why? Oh why, do they fly?

(That was a haiku).

How Do Hot Air Balloons Work?

Note: Students are going to design their balloon and decide what supplies they will need for their journey. In order to design their balloon, they will need to know/estimate how much their supplies, passengers and equipment will weigh. This information will enable them to determine how large their balloon will need to be.

Discuss the following basics of hot air balloons and their construction. There are three different types of hot air balloons, the Montgolfier, the Hybrid and the Solar balloon. Students will need to decide what type of balloon is best for their trip.



A fun way to introduce this section and spark student's enthusiasm and interest in engineering is to read *Rosie Revere, Engineer* by Andrea Beaty . Rosie may seem quiet during the day, but at night she's a brilliant inventor of gizmos and gadgets who dreams of becoming a great engineer. When her great-great-aunt Rose (Rosie the Riveter) comes for a visit and mentions her one unfinished goal--to fly--Rosie sets to work building a contraption to make her aunt's dream come true. But when her contraption doesn't fly but rather hovers for a moment and then crashes, Rosie deems the invention a failure. On the contrary, Aunt Rose insists that Rosie's contraption was a raging success.

You can only truly fail, she explains, if you quit. **Practice your think-aloud techniques.**

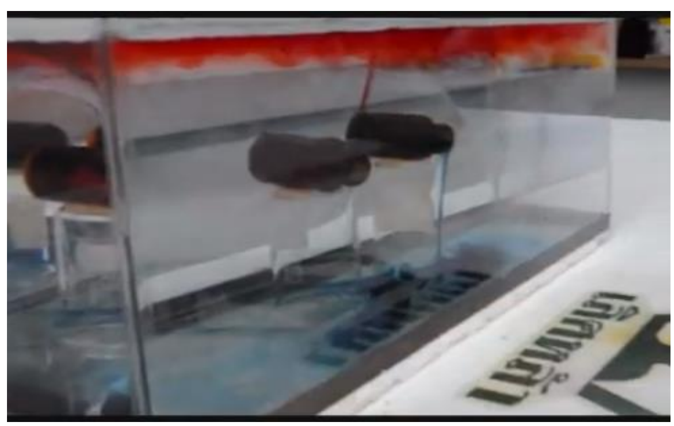
If you actually need to get somewhere specific, a hot air balloon is a fairly impractical vehicle. You can't really steer it, -and it only travels as fast as the wind blows (which is sometimes too fast). But if you simply want to enjoy the experience of flying, there's nothing quite like it. Many people describe flying in a hot air ballo-on as one of the most serene, enjoyable activities they've ever experienced.

Hot air balloons are also an ingenious application of basic scientific principles. Through our own exploration, following in Professor William Waterman Sherman's footsteps we'll see what will make our balloons rise up in the air, and we'll also find out how the balloon's design lets us, the pilots, control altitude and vertical speed. You'll be amazed by the beautiful simplicity of these early flying machines.

At first glance, anything "floating" in the air seems a bit ridiculous. How can that possibly happen? How can a big heavy balloon with a basket full of people float in the air?

Explore convection and unlock the secrets of why hot air balloons rise and fall and why the winds blow! *See a sample of this experiment at https://www.youtube.com/watch?v=G9QJ1vv2WyM*

- a clear tank, large glass bowl, or large clear pitcher
- 2 small glass bottles with narrow mouths (such as dropper bottles with the droppers removed)
- string and scissors
- tap water,
- hot water,
- ice water,
- ice
- red and blue food coloring
- Option: small clear cups

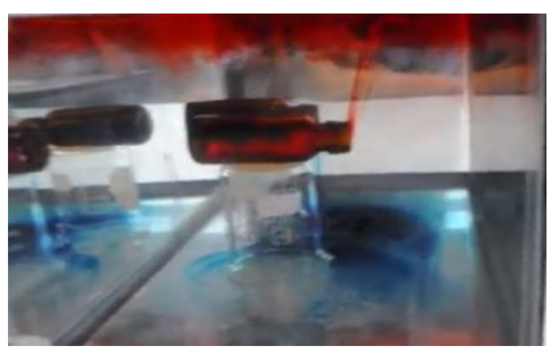


Guide your kids as they:

1) Fill the tank or pitcher with tap water.

2) Obtain two small glass bottles with narrow mouths. Tie a long string around the neck of each small glass bottle.

3) Fill one of the small glass bottles with hot water. Color this hot water with red food coloring.



4) Fill the second small glass bottle with ice water (strain to remove ice). Color this cold water with blue food coloring.

5) Use the strings to carefully lower the bottles of red and blue water into the tank. Keep the bottles upright as

you lower them and let them come to rest on the bottom. You can let go of the strings at this point. *Note: Some demonstrations have them rest on top of small clear cups if using a tank to enable students to see what happens even more clearly.*

6) Watch what is going on inside the tank. What do they notice? How does each color of water behave?

7) After 5 minutes or so, when it seems like nothing new is happening, carefully add some ice to the water in the tank, trying not to mix or disturb the water.

8) Make some more observations. What is happening now?

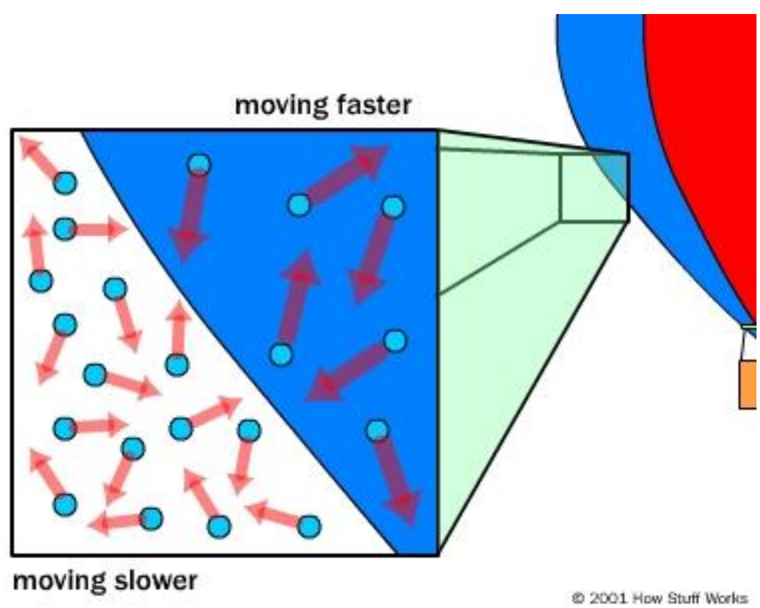
Explain to the class that air and water are both considered fluids and thus behave similarly. Because we cannot see the particles that make up the air around us, it can be tempting to regard air as a sort of nothingness, but be careful: although we can't see it, air is matter. And, as such, it has a mass and takes up space. Hot air balloons are based on a very basic scientific principle: warmer air rises in cooler air.

Help students see the connection between this activity and hot air balloons. The red water represents warm air, and the blue water represents cold air. The two colors of water have slightly different densities. Gravity sorts out the two densities, with the more dense cold water sinking below the less dense red water.

A hot air balloon works by applying these simple principles to air. First, a fan is used to blow air into the balloon, but not enough to fill it up completely. Then, a burner is used to heat up the air inside of the balloon. When this happens, the air molecules in the balloon speed up and move farther apart. This causes the heated air to occupy a larger volume than it did before it was heated.

Because the heated air now occupies a greater volume, but still has the same mass, we know that its density has decreased. How do we know this? Remember that density is a measurement that compares the mass of a substance to the amount of volume that it occupies.

The more thermal energy an object (like air) has, the faster its molecules move. These moving molecules bump into each other more often as the thermal energy increases. Imagine children standing in a sandbox. If they begin bumping into each other, they will spread out and require more space. This is what happens when molecules get more energy and start moving around – they spread out, thus decreasing the density of the substance.



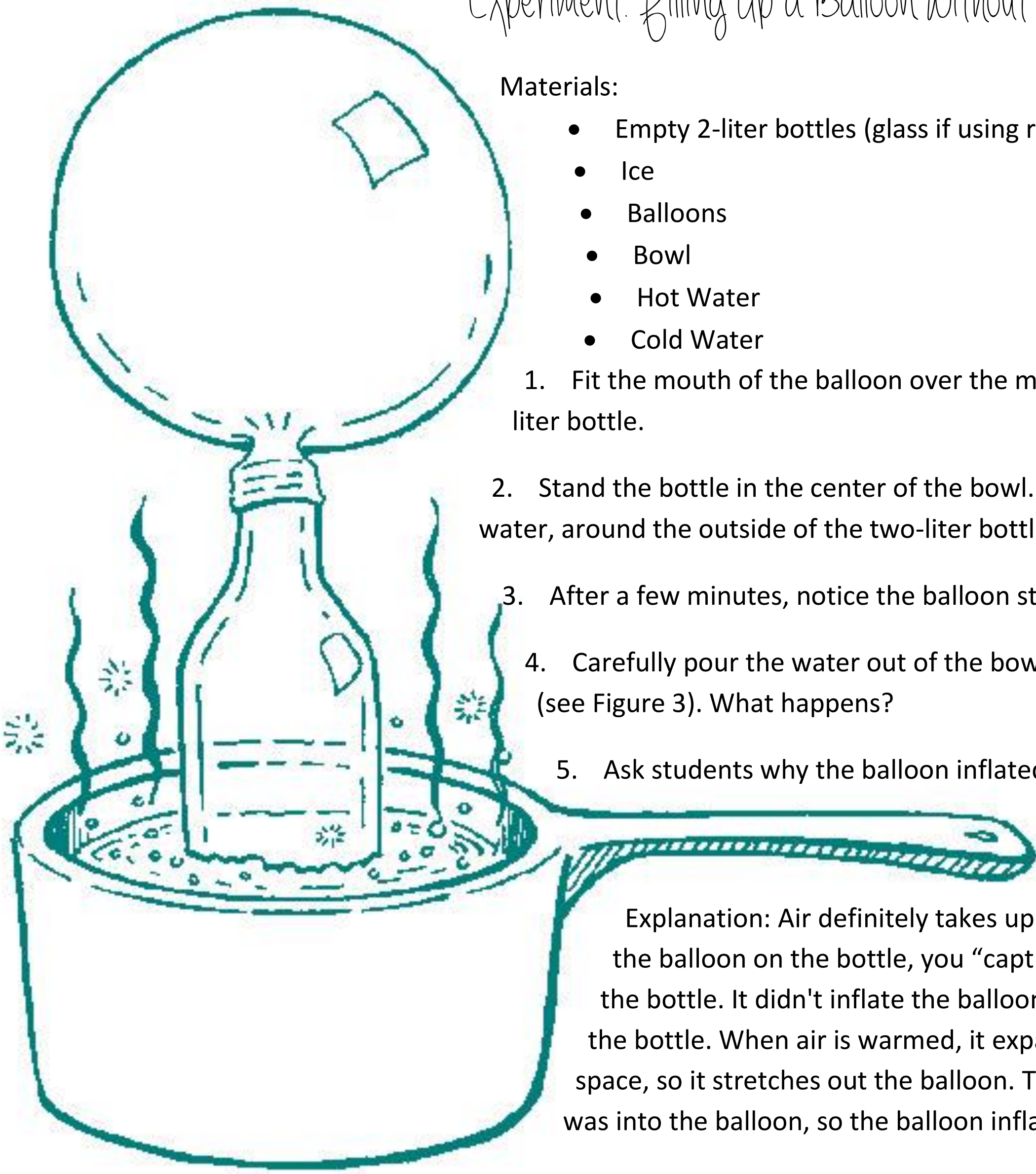
We can express density mathematically using the following equation:

$D=m/v$

This equation tells us that the density of a substance is equal to its mass divided by its volume.

So when you heat air, the volume gets bigger and the equation tells us that when you divide by a bigger V, the density gets smaller. Why, then, do hot air balloons “float” or rise in the air? Hot air balloons float because the volume of the balloon is so large that the entire balloon, including the basket and the people is less dense than the surrounding air. The more dense air falls beneath the hot air, forcing it upward. Due to their lower density, heated fluids (such as water or air) rise and cooled fluids fall. Like in our water experiment, with balloons, the cold air outside the balloon sinks below the warm air inside the balloon, pushing the balloon up into the air.

Experiment: Filling Up a Balloon Without Blowing



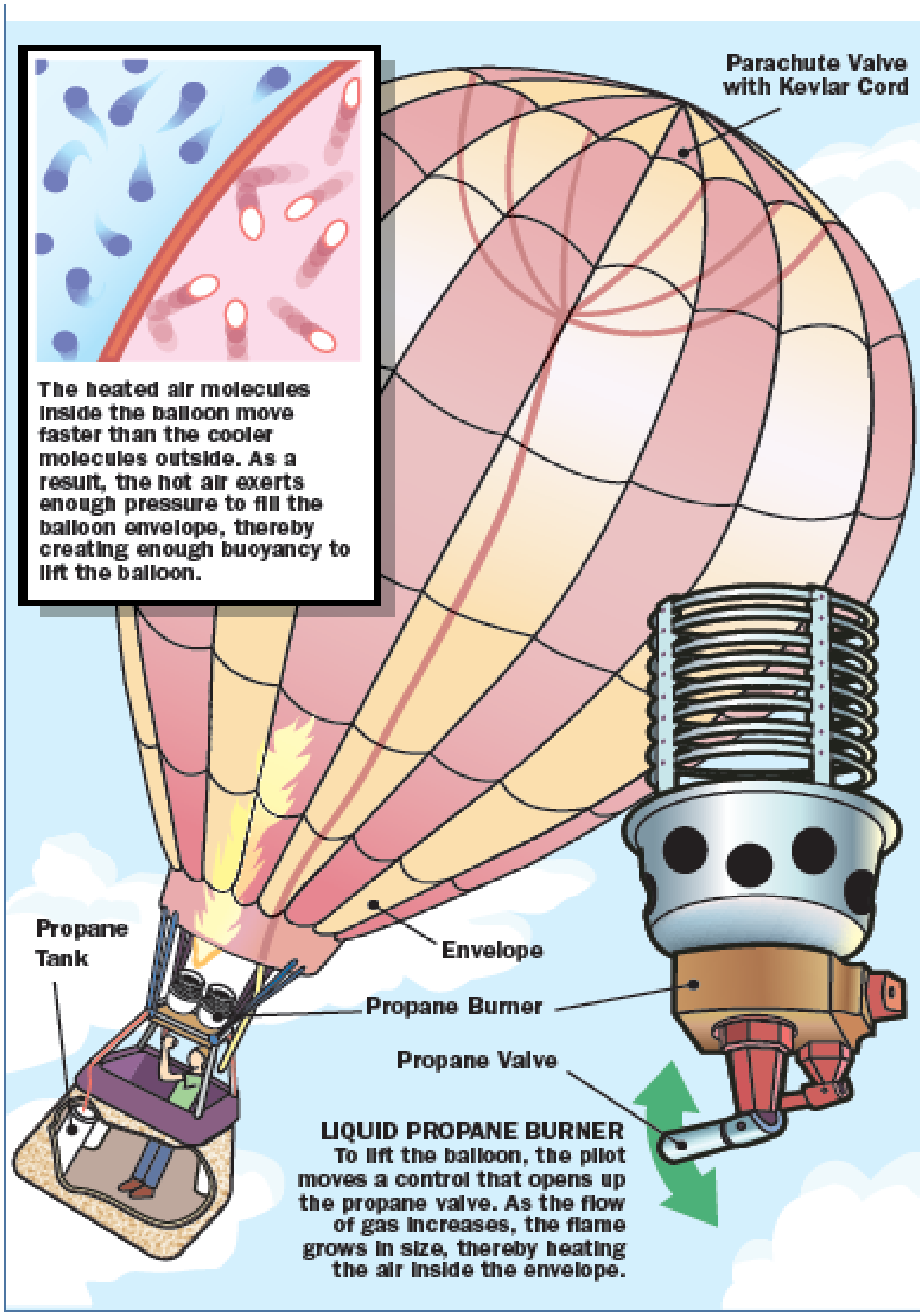
Materials:

- Empty 2-liter bottles (glass if using really hot water)
- Ice
- Balloons
- Bowl
- Hot Water
- Cold Water

1. Fit the mouth of the balloon over the mouth of the empty, two-liter bottle.
2. Stand the bottle in the center of the bowl. Fill the bowl with hot water, around the outside of the two-liter bottle.
3. After a few minutes, notice the balloon start to inflate.
4. Carefully pour the water out of the bowl and fill the bowl with ice (see Figure 3). What happens?
5. Ask students why the balloon inflated and deflated in response to the hot and cold water.

Explanation: Air definitely takes up space! When you first put the balloon on the bottle, you “captured” the air that was in the bottle. It didn't inflate the balloon because it fit nicely into the bottle. When air is warmed, it expands and needs more space, so it stretches out the balloon. The only place it could go was into the balloon, so the balloon inflated When air is cooled, it contracts and needs less space, so the balloon deflates. In this closed system, the mass of air in the bottle remains constant, so this shows that the warm air requires more space (and thus is less dense, based on the fact that density = mass/volume) than the cool air. Warm air rises because it is less dense than cold air.

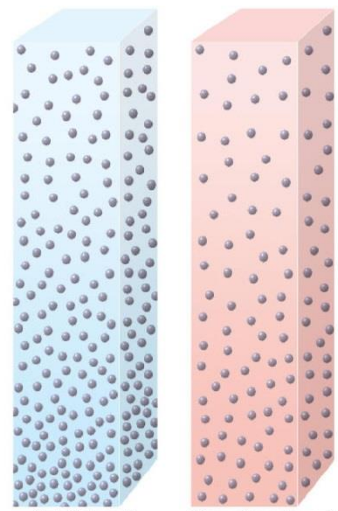
To make the air inside the balloon hotter in a real hot air balloon, a balloon pilot can turn on the propane burner. When the pilot wants the air inside the balloon to be cooler they can simply allow it cool naturally (everything hot cools down if the heat is removed) or if they want to speed up the cooling process they can let some hot air out of the balloon using a vent panel in the top of the balloon.



http://static.howstuffworks.com/pdf/ups-hot-air-balloon.pdf

How long could a hot-air Balloon stay in the air?

Flight duration is determined predominantly by three variables. The proportional load in the basket (number of people relative to fully-loaded capacity), air temperature, and the amount of fuel carried. Balloons that fly in the summer with fully loaded baskets can typically fly about one and a half hours. (The entire ballooning experience, including pre-flight preparation, flight and post-flight celebration, may take two to three hours.)



Conversely, a lightly loaded balloon flying in the winter may be able to fly six to eight hours on the same fuel volume. The reason winter flying is more efficient is that cold air is more dense, and a given temperature differential between the air in the balloon and the outside air produces more lift.

The reason passenger loading impacts efficiency is that the more people you have in the basket, the hotter you have to heat the air in the balloon in order to fly. Maintaining this temperature differential requires more fuel.

Calculating Lift

The following technical data content credited to Mr Steve Griffin.
https://www.brisbanehotairballooning.com.au/faqs/school/105-how-hot-air-balloons-fly.html

Lift = (Air density outside of the balloon - Air density inside balloon) * Volume of the balloon

The lift of a balloon can be calculated by knowing the temperature of the air inside and outside of the balloon and the volume of the balloon. The lift or buoyant force equals the difference in weight of the heated air inside the balloon and the weight of the same volume of air at the surrounding ambient temperature. The table gives the density of air at sea level for various temperatures.

Air Density Table

Temperature °C	Air Density kg/m³
-20	1.395
-10	1.342
0	1.293
10	1.247
20	1.204
30	1.165
40	1.128
50	1.093
60	1.060
70	1.029
80	1.000
90	0.972
100	0.946

Now let us look at two examples of a typical 4 person balloon which has a volume of 2,200 m^3.

If the ambient temperature was 10°C and the air inside the balloon was heated to 100°C the balloon would have a lift of:

Remember to use order of operations: PEDMAS (Parentheses, Exponents, Division, Multiplication, Addition, Subtraction) So,

2,200 * (1.247 - 0.946) kg =

First what's in the parentheses?

1.247 - 0.946 = 0.301 kg

Now what do we do? Parentheses check! No exponents, no division, and so now we multiply…

2,200 * 0.301 kg = **662.2 kg**.

If the same balloon was heated to 90oC the balloon would have a lift of:

2,200 * (1.247 - 0.972)kg = 2,200 * 0.275 kg = **605 kg**

You can see that the hotter the air is inside the balloon the more lift the balloon will generate. In this example by increasing the temperature of the air inside the balloon by 10°C from 90°C to 100°C the balloon can lift an additional 57.2kg.

Buoyancy

Recall once again that air is matter, so it has mass and takes up space. And just like a ship floating in the ocean, a hot air balloon displaces air, in the same way that the ship displaces water.

The hot air balloon floats because it weighs less than an equal volume of the air it is displacing. Or, stated more simply, the balloon is less dense than the air around it. And just like a piece of wood placed in water, this less dense matter floats in matter that is more dense than itself.

When we talk about buoyancy in a balloon we usually refer to the balloon as being either positively, neutrally or negatively buoyant. These terms refer to whether the balloon has more lift than weight (positively buoyant), the same lift as weight (neutrally buoyant), or less lift than weight (negatively buoyant).

A balloon that is positively buoyant will climb, a balloon that is negatively buoyant will descend and a neutrally buoyant balloon will remain at the same level. If our example 2,200 m^3 sport balloon was loaded so that it weighed 634kg it would maintain level flight if the envelope temperature was 95°C, it would climb if the envelope temperature was hotter than that, say 100°C and it would descend if the envelope temperature was less than 95°C.

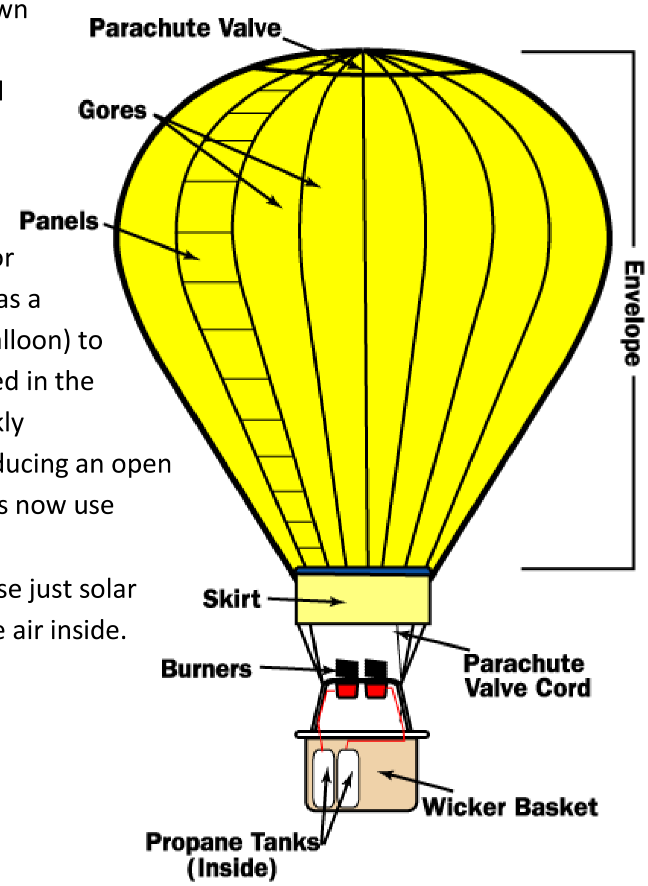
The temperature of neural buoyancy is dependent up on two things: The weight of the load, and the density of the air that the balloon is flying in. The heavier the load the hotter the balloon has to be to be neutrally buoyant. **Why?**

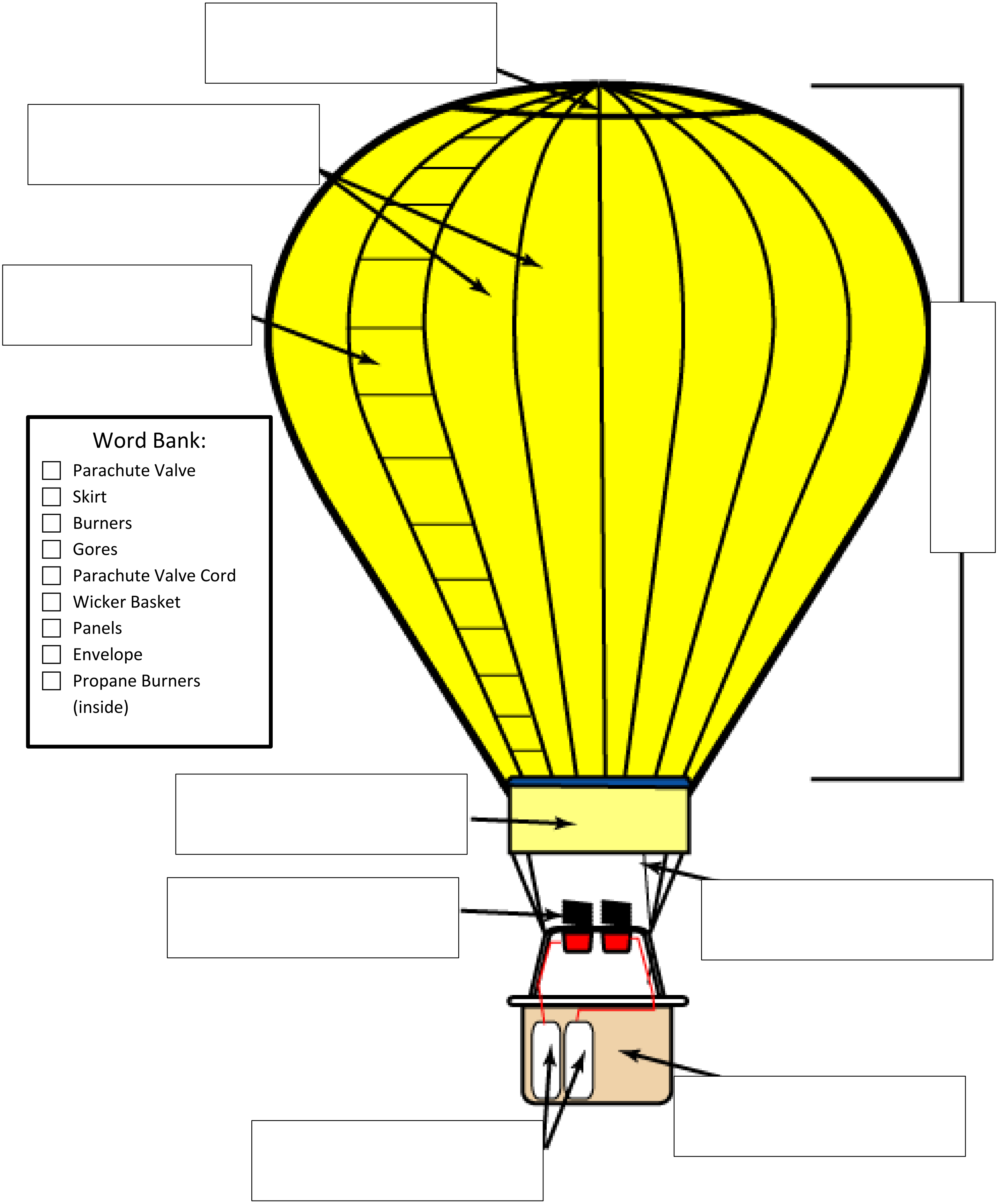
There are several factors that determine the air density: temperature, altitude, and humidity all play a role in determining air density. Given a fixed weight balloon, the less dense the air is the hotter the balloon needs to be to be neutrally buoyant. For example: The hotter the air around the balloon the hotter the balloon must be, the higher the balloon the hotter the balloon must be, the moister the air the hotter the balloon must be to be neutrally buoyant.

Rising Balloons

To keep the balloon rising, you need a way to reheat the air. There are three types of modern hot air balloons.

- Montgolfier: Standard hot air balloons are known as Montgolfier balloons and rely solely on the buoyancy of hot air provided by the burner and contained by the envelope.
- Hybrid: The 1785 Rozière balloon, a type of hybrid balloon, named after its creator, Jean-François Pilâtre de Rozier, has a separate cell for a lighter than air gas (typically helium,) as well as a cone below for hot air (as is used in a hot air balloon) to heat the helium at night. Hydrogen gas was used in the very early stages of development but was quickly abandoned due to the obvious danger of introducing an open flame near the gas. All modern Roziere balloons now use helium as a lifting gas.
- Solar: Solar balloons are hot air balloons that use just solar energy captured by a dark envelope to heat the air inside.





Word Bank:

- ☐ Parachute Valve
- ☐ Skirt
- ☐ Burners
- ☐ Gores
- ☐ Parachute Valve Cord
- ☐ Wicker Basket
- ☐ Panels
- ☐ Envelope
- ☐ Propane Burners (inside)

Raising the Standard

Standard hot air balloons have a burner positioned under an open balloon envelope. As the air in the balloon cools, the pilot can reheat it by firing the burner.

How much heat do burners produce?
Each burner canister in a State of the Art Balloon System is capable of producing in excess of 18 million BTU of heat per hour. This is the equivalent of **600**, yes six hundred, average gas grills and many balloons have two burners, meaning it's equal to 1,200 gas grils. You can literally feel the punch of hot air as it hits the top of the envelope particularly if the basket is not fully loaded.

Modern hot air balloons heat the air by burning propane, the same substance commonly used in outdoor cooking grills. The propane is stored in compressed liquid form, in lightweight cylinders positioned in the balloon basket. The intake hose runs down to the bottom of the cylinder, so it can draw the liquid out. Sport hot air balloons carry 20 to 45 gallons of propane in stainless steel fuel tanks.

Why Propane?
Propane is generally readily available. It is liquid in its stored state (which results in dense energy storage) and it does not require a fuel pump or pressurization under most circumstances and it allows storage in reasonably lightweight tanks.

- ♦ Gasoline would require onboard pressurization or a huge fuel pump (too complicated)
- ♦ Acetylene has two high a vapor pressure and would require heavy cylinders to contain the fuel (tanks too heavy)
- ♦ Butane has too low a vapor pressure and would have to be pressurized. Butane, though not ideal fuel, is used in ballooning in some countries where propane is not commercially available.
- ♦ Compressed natural gas would need very large and heavy tanks it can't practically be stored in its liquid state for transportation in a balloon.

Because the propane is highly compressed in the cylinders, it flows quickly through the hoses to the heating coil. The heating coil is simply a length of steel tubing arranged in a coil around the burner. When the balloonist starts up the burner, the propane flows out in liquid form and is ignited by a pilot light. As the flame burns, it heats up the metal in the surrounding tubing. When the tubing becomes hot, it heats the propane flowing through it. This changes the propane from a liquid to a gas, before it is ignited. This gas makes for a more powerful flame and more efficient fuel consumption.

In most modern hot air balloons, the envelope is constructed from long nylon gores, reinforced with sewn-in webbing. The gores, which extend from the base of the envelope to the crown, are made up of a number of smaller panels. Nylon works very well in balloons because it is lightweight, but it is also fairly sturdy and has a high melting temperature. The skirt, the nylon at the base of the envelope, is coated with special fire-resistant material, to keep the flame from igniting the balloon.

The basket holds the passengers, propane tanks and navigation equipment.

The hot air won't escape from the hole at the bottom of the envelope because buoyancy keeps it moving up. If the pilot continually fires the fuel jets, the balloon will continue to rise. There is an upper altitude limit, however, since eventually the air becomes so thin that the buoyant force is too weak to lift the balloon. The buoyant force is equal to the weight of air displaced by the balloon, so a larger balloon envelope will generally have a higher upper altitude limit than a smaller balloon.

The basket is where the passengers and pilot stand during flight. It also contains the tanks of propane which are connected to the burners overhead. The basket may also contain instruments such as an altimeter and a radio to aid the pilot in their flight.

Most hot air balloons use a wicker basket for the passenger compartment. Wicker works very well because it is sturdy, flexible and relatively lightweight. The flexibility helps with balloon landings: In a basket made of more rigid material, passengers would feel the brunt of the impact force. Wicker material flexes a little, absorbing some of the energy. Balloon baskets are generally still made from traditional woven willow branches as no modern material gives the same combination of lightness, strength and flexibility. Flexibility is especially important to absorb the impact on landing and save the knees of the passengers. Very strong steel cords pass through and underneath the basket and are attached to the load tapes of the envelope.

Technology Link: Putting it all together

Now that we know all about it, let's watch as Masha and Patsy of Dragonfly TV from PBS learn all about hot air balloons, including the temperature gauge, which showed the temperature inside the

balloon, and the variometer, which shows how quickly the balloon ascends or descends during flight. Fly along with them and a hot air balloon pilot at http://pbskids.org/dragonflytv/show/balloon.html.
Then have students take part in the great balloon race! Their challenge is to beat the other balloonists times by reaching the finish line without crashing! Find the game at http://pbskids.org/dragonflytv/games/game_balloon.html

Sources and Resources

http://www.eballoon.org/history/history-of-ballooning.html

http://www.apexballoons.com/balloons/

http://en.wikipedia.org/wiki/The_Twenty-One_Balloons

http://www.middleschoolchemistry.com/atomsworld/2012/09/not-just-hot-air/

http://scienceforkids.kidipede.com/physics/weather/hotairrises.htm

http://tenkidsandadog.blogspot.com/2009/04/unplugged-project-science-warm-air.html

http://www.eballoon.org/flights/first-around-the-world-solo.html

http://pbskids.org/dragonflytv/web_assets/pdf/dftv_gpsedguide_balloonfiesta.pdf#page=2

http://www.netplaces.com/kids-science-experiments/the-planet-earth/try-this-space-of-air.htm

https://www.classzone.com/books/earth_science/terc/content/investigations/es1908/es1908page04.cfm

http://glencoe.mcgraw-hill.com/sites/0078664233/student_view0/unit4/webquest_projects_3.html

http://pbskids.org/dragonflytv/games/game_balloon.html