



THE
AERONAUTS
DISCUSSION GUIDE

prime video

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HOW TO USE THIS GUIDE

This discussion guide is a learning tool for teachers, parents and students to more deeply explore a variety of topics in the film **THE AERONAUTS**. This resource can help engage students on a variety of science concepts and design and critical thinking skills.

There are five different discussion topics:

-  **DENSITY**
-  **CLOUD ELEVATION**
-  **LAYERS OF THE ATMOSPHERE**
-  **ENGINEERING DESIGN**
-  **WOMEN AERONAUTS**



Classroom lessons are available at: primevideoedu.dothegoodery.com/film-resources/the-aeronauts

See [Amazon Prime](#) to access the film for online viewing

SYNOPSIS

A balloon pilot and a scientist find themselves in a fight for survival while attempting to make discoveries in a gas balloon in the 1860s.

In 1862, pioneering meteorologist James Glaisher (Eddie Redmayne) teams up with daredevil balloon pilot Amelia Rennes (Felicity Jones) to advance human knowledge of the weather and fly higher than anyone in history. While their voyage to the very edge of existence helps the unlikely pair find their place in the world, they face physical and emotional challenges in the thin air, as the ascent becomes a fight for survival.

DENSITY

DISCUSSION QUESTIONS



OVERARCHING THEMES:

- WHAT IS AIR DENSITY?
- WHY DOES AIR DENSITY MATTER FOR HOT AIR BALLOONS?
- HOW DOES TEMPERATURE AND ATMOSPHERIC PRESSURE IMPACT
- DENSITY?

INTRODUCTION:

When we talk about the *density* of the air, we are not referring to how thick the air is. Instead, we are describing the amount of matter contained by a unit volume. To help understand density, we can use the analogy of cookies in a cookie jar. Imagine a glass jar filled with cookies. If you remove one of those cookies, the density within the cookie jar changes. This is because the amount of matter in the jar changed, but the volume of the cookie jar remained the same. *Matter* is what makes up everything around us, from the tiniest thing in existence to the largest thing you can possibly imagine.

Air particles in the atmosphere are similar to the cookies in a jar, you just can't see them. Due to gravity, there are more particles near the Earth's surface and less air particles at the top, further away from Earth. While air particles are very tiny, they do have mass, which means that gravity will pull them downward. This means that *atmospheric pressure*, or the force of air on a surface as gravity pulls it to Earth, drops as we rise in altitude.

As we move higher up into the atmosphere and away from Earth's surface the effects of gravity

lessen, which allows the air particles to spread out, making the air at higher altitudes less dense.

Temperature changes the space between the gas particles that make up the air. Gases expand when heated and contract when cooled. This happens because as the *gas particles* are heated up they move around faster. When they collide they bounce off each other more and end up further away from each other than when they collide at lower temperatures. Therefore, when air is heated up it becomes less dense because the gas particles in it are spread out more.

This is why the hot air in a hot air balloon will cause the balloon to float. The hot air inside the balloon is less dense than the surrounding cooler air. Changing the temperature of air in the balloon by turning the hot air on or venting the hot air thus reducing the heat, is what allows the balloon to ascend and descend. The hot air inside the balloon exerts the same pressure inside as the cooler air pressing on the surface of the balloon from outside and this equalizing pressure prevents the balloon from collapsing. Without the dynamic relationship between density, temperature and atmospheric pressure, hot air balloons would never leave Earth's surface.



DISCUSSION SPARKS:

I bet you didn't know...

- > You might not think so, but air has weight.
- > The atmosphere of Venus is about 90 times heavier than that on Earth.
- > When a quarter is cut in half, its density stays the same.



FILM CLIPS:

Why Does A Hot Air Balloon Float?

(0:58 seconds)

<https://www.youtube.com/watch?v=P4awUtWW94&vI=de-AT>

5 Facts About Density?

(3:43 minutes)

<https://www.youtube.com/watch?v=zlkpZZW29b0v>

Density Featurette from the film

THE AERONAUTS

(1:23 minutes)

<https://primevideoedu.dothegoodery.com/film-resources/the-aeronauts>

THE AERONAUTS five minute video clip

(21:30-26:18 minutes)

<https://primevideoedu.dothegoodery.com/film-resources/the-aeronauts>



BE THE FILMMAKER:

Discussion Question

- > If you were a filmmaker and were asked to add a scene to **THE AERONAUTS** that highlights the importance of aeronauts understanding density, what scene would you add and why?



BE THE AERONAUT:

Discussion Questions

- > We used cookies to help describe what density is. What other examples could you use to help a friend understand density?
- > Describe what happens to the density of air in a balloon when it is heated? How does this change when the air is cooled?
- > What role does gravity play in density? Why is the air most dense closest to the ground and less dense the further into space we go?
- > What would happen if this were reversed?
- > How are density and air pressure related? What impact does temperature have on density? As air is heated or cooled, describe what happens to its density.
- > Hot air balloons rise, but they also sink! Thunderstorms can produce both warm air (updraft that lifts the balloon) and cold air (downdraft that lowers the balloon).
- > In the film **THE AERONAUTS**, the main characters are unexpectedly caught in a thunderstorm. What effect does the change in temperature have in this dramatic scene?

Dig Deeper & Create

A hypothesis is a proposed explanation for a phenomenon. Just based on what you know about density and air particles, how do you think the density of air particles might be similar and different to water particles? What about compared to the density of solids? How might you design an experiment to explore your hypothesis?

CLOUD ELEVATION

DISCUSSION QUESTIONS



OVERARCHING THEMES:

- WHAT IS THE HYDROLOGIC CYCLE, OR WATER CYCLE, AND HOW DOES IT AFFECT WEATHER?
- WHAT ARE THE DIFFERENT CLOUD TYPES AND WHERE DO THEY OCCUR IN THE ATMOSPHERE?
- HOW CAN CLOUD FORMATION AND LOCATION HELP TO PREDICT THE WEATHER?

INTRODUCTION:

Water is constantly moving on, above and below the Earth's surface. This movement is called the hydrologic or water cycle. This cycle is important because without it, plants wouldn't grow, living creatures wouldn't have oxygen to breathe and our food source could not grow. The sun plays an important role in the **water cycle**. It is the sun that melts ice, turning it into water. The sun heats the water and eventually turns it into **water vapor**.

When the sun heats all bodies of water on earth, the water forms water vapor which rises into the sky. This process of changing water into gas is called **evaporation**.

Clouds are made when the water vapor cools as it rises higher into the sky and once again becomes water droplets. These drops come together to form a cloud. Clouds generally form within the troposphere which is the layer of the atmosphere that is closest to the Earth. The process of water vapor changing into water droplets is called **condensation**.

Inside the cloud the water droplets merge together to become even larger drops. When the drops become too heavy, they fall from the sky. This causes rain, snow or even hail. The process in which water falls from the sky is also known as **precipitation**. The water that falls is then collected by oceans and rivers. The sun heats all the bodies of water, which starts the whole process all over again.

There are many different types of clouds. **Cirrus clouds** are thin because they are made up of ice crystals rather than water droplets. They are high up in the sky and appear wispy. When there are blue skies with only a few cirrus clouds it's a good sign that it will be nice weather.

Cumulus clouds are the puffy clouds you see scattered all around the sky. These clouds can be either white, which means it is not going to rain or dark and gray, which might mean rain is on its way. If you look up and see thick clouds that are covering most of the sky, then you have spotted stratus clouds.

Stratus clouds can mean rain, if it's warm, or snow, if it is cold. If Stratus clouds move close to the ground, they will form fog.

Nimbus clouds are easy to spot because these clouds already have rain or snow falling. Nimbus clouds are also typically dark or gray and can also appear with both thunder and lightning. These clouds can combine with other clouds to form a combination cloud. An example of this would be when a nimbus cloud combines with a cumulus cloud to form a cumulonimbus which is a puffy, black cloud with rain.

Clouds help us to predict the weather through movement and appearance. You can tell in which direction weather is approaching by watching cirrus clouds and how they move. When you see cirrus clouds you can bet that the weather will be changing, usually within 24 hours.



DISCUSSION SPARKS:

I bet you didn't know...

- Clouds can travel at speeds of more than 100 mph with the jet stream.
- Cumulus clouds are puffy, cotton-like and often resemble animal shapes and/or well-known objects.
- When a meteorologist gets the weather forecast wrong it is called a "bust".



FILM CLIPS:

THE AERONAUTS: Balloon launch with white cumulus

(03:49-05:01)

THE AERONAUTS: Clouds change and storm occurs

(20:03-23:07)

<https://primevideoedu.dothegoodery.com/film-resources/the-aeronauts>

The Water Cycle - How Rain is Formed

(running time: 2:43)

<https://www.youtube.com/watch?v=sObS-SBAqJI>



BE THE FILMMAKER:

Discussion Question

- Filmmakers often use the weather in a scene to make you feel a certain way. If you were shooting a sad scene for a movie which clouds might you want in the background and why? Do you think the type of clouds in the sky could help you show that something sad is going to happen?



BE THE AERONAUT:

Discussion Questions

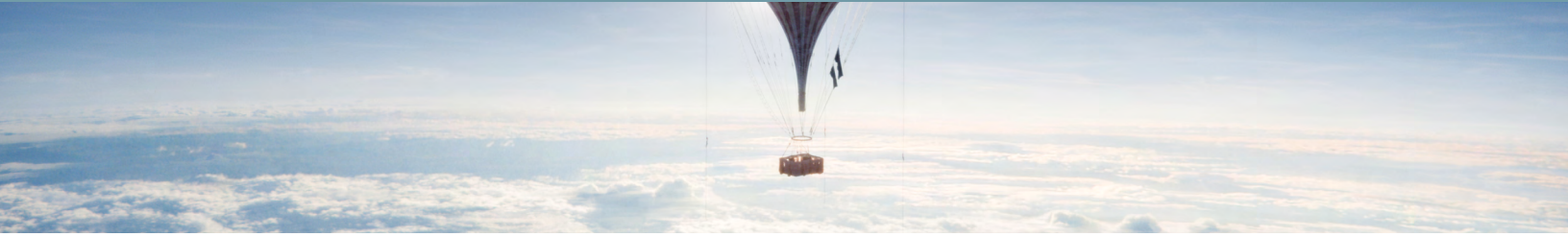
- The water on Earth moves in a continuous cycle. This cycle, the hydrologic cycle, or water cycle helps us live. Why is the water cycle important?
- Describe the different stages of the water cycle. What occurs in each of these cycles?
- What are clouds and how are they formed?
- What are the different cloud types? What are their unique characteristics and what type of weather usually occurs with each cloud type?
- In the movie/clips/featurettes, The Aeronauts, we see many different cloud types and weather. What types of clouds and weather did you see? What characteristics did you use to identify the cloud types?
- How can clouds help us to understand what type of weather might occur?
- What is rain and how does rain happen? What is snow and how does snow happen? What is hail and how does hail happen?
- What is transpiration? What role do plants play in the water cycle?

Dig Deeper & Create

Does the Earth have more or less water now than it did 1,000 years ago? What about billions of years ago? Research, explain your answer and create a visual representation of what you learned.

LAYERS OF THE ATMOSPHERE

DISCUSSION QUESTIONS



OVERARCHING THEMES:

- WHAT ARE THE 5 LAYERS OF THE ATMOSPHERE AND WHAT ARE THEIR DISTINCT CHARACTERISTICS?
- WHAT WOULD HAPPEN TO THE EARTH IF THE ATMOSPHERE NO LONGER EXISTED?
- HOW DOES THE ATMOSPHERE HELP US PREDICT THE WEATHER?

INTRODUCTION:

Earth's atmosphere is made up of layers, each with its own distinct characteristics. Starting at the Earth's surface or ground, each layer moves upward from the troposphere layer, which is where humans live, all the way to the exosphere layer, which gradually fades into unexplored space.

The **troposphere layer** is the layer of the atmosphere closest to Earth's surface. It starts at ground level and extends up 6.2 miles or 33,000 feet. This is where human plants and animals live, where weather occurs and where hot air balloons fly. The higher you go up in the troposphere, the colder it gets.

Above the troposphere layer, lies the **stratosphere layer**. It extends up 31 miles or 163,680 feet above the ground. The ozone layer, which protects us from the sun's rays can be found here. Commercial jet planes fly in this layer. Unlike the troposphere layer, this layer is warmer the higher you go.

The next layer is the **mesosphere**. It extends above the stratosphere up to a height of 53 miles. This layer is a protective layer because it is where most meteors burn up before they can reach Earth's surface. Yet the coldest temperatures are found in this layer and can reach as low as -130°F .

Above the mesosphere layer you will find the **thermosphere**. This layer extends to over 600 miles above the ground. This layer is extremely hot, with temperatures reaching 5000°F ! This is the layer where satellites orbit the Earth.

The top layer of the atmosphere is the **exosphere**. It extends until it fades into outer space. The estimated range varies between 62,000 miles and 120,000 miles. This layer is freezing cold at night and very hot during the day. Atoms, molecules and air slowly but consistently leak from this layer of the atmosphere.

What would happen if Earth suddenly lost all of its atmosphere at once? Life as we know it would cease to exist. There would be no sound since sound needs the atmosphere to transmit waves. The sky would turn black instead of appearing blue and birds and planes would no longer be able to fly. The most serious side effect would probably be that all life on the Earth would die.

The atmosphere not only provides us a compatible environment in which to live, it also helps us to predict the weather. Through observation of the atmosphere and the use of various weather instruments including weather balloons, Doppler radars and satellites, forecasters can more accurately determine temperature, humidity, precipitation, air pressure, wind speed and wind direction.



DISCUSSION SPARKS:

I bet you didn't know...

- > The average amount of water in the Earth's atmosphere at any given time is almost 40 trillion gallons.
- > The reason the sky appears blue is because colors like blue and purple have shorter wavelengths and are therefore scattered by the atmosphere in a more overpowering way than orange or red.
- > Earth's atmosphere protects us from all sorts of space-related threats including meteors and radiation.



FILM CLIPS:

What if the Earth suddenly lost its atmosphere?

(3:50 minutes)

<https://www.youtube.com/watch?v=Ehzzm4rjJj8>

How high can a hot air balloon go?

(4:43 minutes)

<https://www.youtube.com/watch?v=CUoWscq3ZM>



Layers of the atmosphere

(3:58 minutes)

https://www.youtube.com/watch?v=Y0AOg_fPkog

BE THE FILMMAKER:

Discussion Question

- > Audiences love the thrill of weather-related disaster films. If you were a filmmaker, which weather-related phenomena would you focus on and what would your solution to that problem be?



BE THE AERONAUT:

Discussion Questions

- > The Earth's atmosphere provides us with a stable and unique place to live. What would happen to the Earth and its inhabitants if we suddenly lost our atmosphere? How does the atmosphere make life possible? How does life (humans, animals and plants) alter the atmosphere?
- > What are the five layers of the Earth's atmosphere and what unique properties do each of these layers have including physical, temperature and composition characteristics?
- > The atmosphere provides us layers of protection. What are some of the ways in which the atmosphere protects us?
- > How does the atmosphere help us to predict the weather? What kind of observations and tools are used?

Dig Deeper & Create

- > In the film **THE AERONAUTS**, the main characters break a record by ascending to over 37,000 ft. The current world record holder, Vijaypat Singhania beat that altitude by ascending to 68,986 ft. Which layer of the atmosphere did he reach and what did he probably encounter?
- > Describe the phenomenon of auroras (e.g. northern lights). In which layer of the atmosphere does this occur? Examine pictures of auroras paying attention to the brilliant colors and the patterns they make as they dance across the sky. Using a black piece of construction paper and crayons or colored pastels recreate your favorite picture of the northern lights.

ENGINEERING DESIGN CHALLENGE

DISCUSSION QUESTIONS



OVERARCHING THEMES:

- HOW HAS HISTORY INFLUENCED THE DESIGN OF HOT AIR BALLOONS?
- HOW CAN DESIGN THINKING HELP DESIGNERS AND ENGINEERS ASSESS THEIR IDEAS?

INTRODUCTION:

Did you know that before the hot air balloon carried people up into the sky, the sky lantern was used in China during the 3rd Century BC as a military signaling tool? These miniature hot air balloons were too small to carry people. They were about twelve inches high, made of very thin paper and had an opening where a small fire was suspended inside. When the flame was lit, the air inside of the lantern increased in heat, which simultaneously lowered the density and the lantern would begin to rise. Many other countries around the world also came to use similar military signaling devices.

In the 18th Century a Portuguese Jesuit Priest name Bartolomeu de Gusmão innovatively imagined that what started as military signaling devices could be transformed into manned air vessels. He successfully demonstrated a prototype for the Queen Maria Anna of Austria. This unmanned flight would later inspire the first manned flight in history.

French brothers, Joseph-Michel and Jacques-Étienne Montgolfier developed a hot air balloon in 1783. They tested the balloon first, unmanned. The flight lasted 10 minutes. The brothers continued to experiment with unmanned flights and over time advanced to flights that carried animals into the air, and ultimately carried humans. As a safety and

ultimately carried humans. As a safety precaution, these flights were conducted with ropes tied to the hot air balloon, which anchored the balloon to earth. The ropes also prevented the hot air balloon from floating higher than the length of the ropes. This safety measure helped the early aeronauts study the design of the hot air balloon and make changes to improve their aircraft.

The first free flight (not tethered), that included a human pilot took place on November 21, 1783. Jean-François Pilâtre de Rozier and the Marquis d'Arlandes made a 25-minute flight and achieved an altitude of 3,000 feet.

Rozier also reimagined the design and engineering of the hot air balloon. Earlier hot air balloons included building materials like wallpaper and sheep skin. These pioneering models of the Montgolfier hot air balloon also used wood, straw, potatoes, charcoal and brady in a stove to try to heat the air enough to make the balloon rise. Rozier modified the Montgolfier design to use a combination of hydrogen and heated air. This innovation increased the ability of the hot air balloon to fly for a longer time, at a higher altitude. As a result of this innovation, the modern hybrid gas and hot air balloon is named after Rozier.



DISCUSSION SPARKS:

I bet you didn't know...

- > A rooster, a duck and a sheep were the first animals to go up in a hot air balloon.
- > Condemned criminals were first on the list to pilot the first flight until Rozière and d'Arlandes volunteered.
- > Hot air balloons were used for reconnaissance during the Civil War.



FILM CLIPS:

THE AERONAUTS movie trailer

(running time: 2:21)

<https://www.youtube.com/watch?v=Rm4VnwCtQO8>

Who Invented the Hot Air Balloon

(running time: 11:03)

<https://www.youtube.com/watch?v=GgnDWx1CP6k>

THE AERONAUTS two-minute video clip

(16:02-18:29)

<https://primevideoedu.dothegoodery.com/film-resources/the-aeronauts>



BE THE FILMMAKER:

Discussion Question

- > If you were asked to produce a film that highlights an invention that has significantly changed over time, what invention would you choose and why would you choose it?



BE THE AERONAUT:

Discussion Questions

- > What role did the early pioneers of the hot air balloon play in the development of the modern-day hot air balloon?
- > Innovative thinking was critical in reimagining a floating lantern as an aircraft that could be piloted and carry humans. What process did these innovators use to test their ideas? Why was creating a prototype important?
- > Sometimes, innovative thinking is criticized by those who do not understand the vision. James Glaisher believed the weather could be predicted, but his ideas met criticism at the Royal Society. How did Glaisher respond to the criticism? Why did he continue to pursue this idea after it was criticized? What does his persistence tell you about the character of innovators?

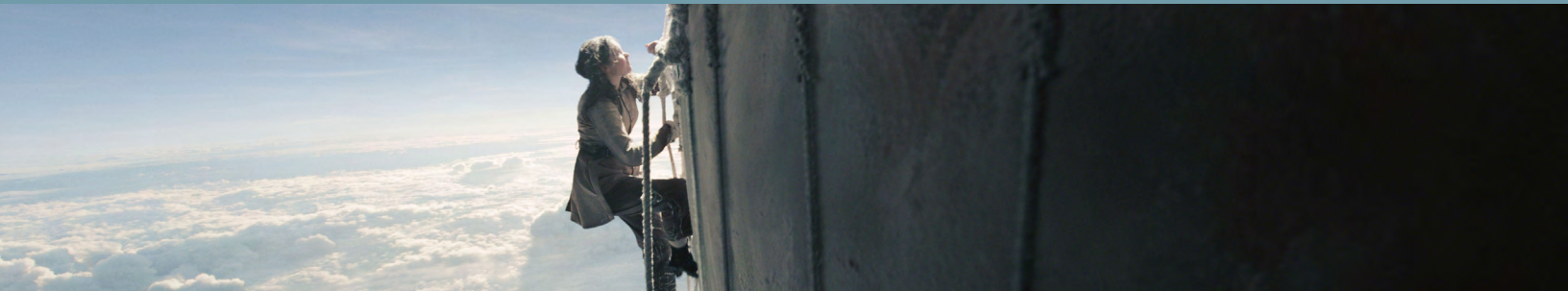
Dig Deeper & Create

Designers ask important questions and gather information to help solve creative problems. Open-ended questions can help designers reflect on their ideas and explore possibilities. Using these design questions, can you create the next hot air balloon?

- > **CREATIVE:** What might happen if...?
- > **CLARIFYING:** What is another way you might...?
- > **ANALYTICAL:** What are the most important ideas related to...?
- > **PROBING:** What do you think would happen if...?
- > **REFLECTIVE:** Why is _____ important?
- > **AFFECTIVE:** How do you feel about...?
- > **EXPLORATIVE:** How would _____ impact _____?
- > **BALANCE:** What are the strengths and weaknesses of...?
- > **VIEWPOINTS:** How would people from a different culture or gender view this?

WOMEN AS AERONAUTS

DISCUSSION QUESTIONS



OVERARCHING THEMES:

- WHAT BARRIERS DID WOMEN FACE IN THE FIELD OF AERONAUTICS IN THE 19TH CENTURY?
- WHAT DROVE THESE FEMALE AERONAUTS TO TAKE DANGEROUS RISKS IN THEIR PURSUIT OF FLIGHT?
- HOW DID THE ACCOMPLISHMENTS OF WOMEN IN AERONAUTICS ULTIMATELY BENEFIT SCIENTIFIC DISCOVERY?

INTRODUCTION:

Aeronauts were pioneers in the pursuit of human flight. Ever since 1783, when French brothers Joseph-Michael and Jacques-Étienne Montgolfier invented the hot air balloon, individuals have sought to navigate, advance and deepen the understanding of aeronautical design and flight.

As depicted in the film **THE AERONAUTS**, balloonists were treated as celebrities, with their launches drawing huge crowds and prominent guests including royalty, famous scientists and popular writers. Their adventures fueled people's imaginations as the impossible now seemed possible. The public's fascination with ballooning dominated Europe and England from the late 1700's until the mid-1800's. Women played key roles in the field of aeronautics during this time.

Women balloonist had to face many barriers that their male counterparts did not. Women and men did not have equal status in the 19th century and women were viewed as the weaker gender. A key example of this occurred in 1798 when the famous balloonist and self-promoter Andre'-Jacques Garnerin announced that he would be taking a young woman, Citoyenne Henri, with him on his next ascent. As a result of this bold announcement, Garnerin was forced to appear before officials to justify his intentions. The flight was considered controversial for many reasons including

the moral implications of a man and women being alone in such a state and the popular belief at the time that a woman's body would be "too delicate" to withstand the effects of the elevated air pressure.

To the contrary, the first professional female balloonist, Sophia Blanchard, proved women were as durable as men when she braved the risks of ballooning and endured loss of consciousness, freezing temperatures and near drowning when her balloon crashed into a marsh. Married to Jean-Pierre Blanchard, the world's first professional balloonist, Sophia specialized in night flights, firework displays and often conducted experiments with parachutes. Credited with making over 60 ascents, Blanchard used creative aeronautic design and paved the way for other women aeronauts to push beyond the limitations of the expected roles for women during this time period.

Another female aeronaut of note was Margaret Graham, who claimed to be the only English female aeronaut and wrote thrilling accounts of her many adventures. Brought into aeronautics by her husband George, an accomplished English aeronaut, Margaret had a passion for ballooning and eventually was known for her extraordinary aeronautical skill. Both Sophia Blanchard and Margaret Graham were the inspiration for Amelia Wren, the fictional female pilot in **THE AERONAUTS**.



DISCUSSION SPARKS:

I bet you didn't know...

- > To become a hot air balloon pilot, you must be at least 14 years of age, have 10 hours total flying time with one solo flight, pass a written test and pass a supervised ride with a certified examiner.
- > Montgolfier got the idea for the hot air balloon when he and his wife were drying her dress in front of a fire and the hot air made the dress billow and float.



FILM CLIPS:

THE AERONAUTS movie trailer

(running time: 2:21)

<https://www.youtube.com/watch?v=Rm4VnwCtQO8>

Understanding the cultural and historical context:

THE AERONAUTS six-minute video clip
(00:45 - 06:42)

THE AERONAUTS five-minute video clip
(01:21:40 - 01:26:50)

<https://primevideoedu.dothegoodery.com/film-resources/the-aeronauts>



BE THE FILMMAKER:

Discussion Question

- > If you were producing a film that showcased a female aeronaut during the 19th century what important characteristics, barriers, feats and/or innovations would you choose to focus on and why would you choose them?



BE THE AERONAUT:

Discussion Questions

- > What role did the early pioneers of the hot air balloon play in the development of the modern-day hot air balloon?
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Dig Deeper & Create

Research pioneering and notable women in the history and science of aviation. Find one that stands out to you. What contribution did she make to aviation and why did you choose her? Create a presentation, work of art or essay to share what you learned.



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