Hulls

In this packet, we will be learning about how ship's hulls are made and what they can be used for, as well as the basic physics of buoyancy: what makes ships float! We are then going to build our own hulls with an easy and fun activity that can be done in the classroom or at home.

Contact the Albacore Museum for Field Trip and School Visit Opportunities!

*This packet is intended for middle schools, to be used in groups of three or fewer and/or individually.

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How Does a Hull Work?

The hull is the watertight body of a ship. Hulls can be made of many different kinds of material, and come in several shapes and sizes. It all depends on what the needs of the vessel and the people using it are.

Why Does a Ship's Hull Float?

The scientific principle that causes an object to float is called **buoyancy**. All objects will either float or sink based on their **density**. Density is the measure of how much matter is inside an object. For example, a baseball and a tennis ball might be about the same size, but the baseball is denser, making it heavier and more solid. The basic rule is that objects will sink if they weigh more than exactly the same volume of water. It's also important to remember that not all water has the same density: fresh water is less dense than salt water, for example.

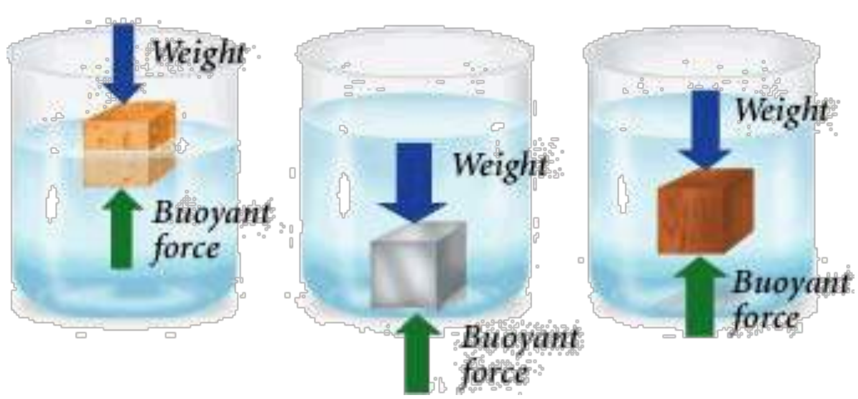
> **Did you know?**
> The *USS Enterprise* has a displacement of about 75,000 tons unloaded or 95,000 tons with a full load.

Ships and boats do not actually truly float: part of the hull is always fully submerged under the water. The heavier a ship is, the lower it will sit in the water. If you put too much weight on even the best designed ship, it will sink to the bottom! It's therefore very important for engineers and designers to calculate how much weight a ship can safely hold. This can be done using Archimedes' Principle.

Archimedes was a Greek mathematician who realized that when an object is resting in the water, it feels a buoyant force equal to the weight of the water it **displaces**, or pushes aside. If an object is fully submerged in water, the buoyant force pushing the object upwards makes it seem like it weighs less than it does on dry land. You might have noticed this when playing in a swimming pool or at the beach.

For a big ship like an aircraft carrier or destroyer to stay afloat, it needs to weigh less than the maximum volume of water it could displace. If its weight and the upward force match perfectly, the ship will sink!

Buoyancy



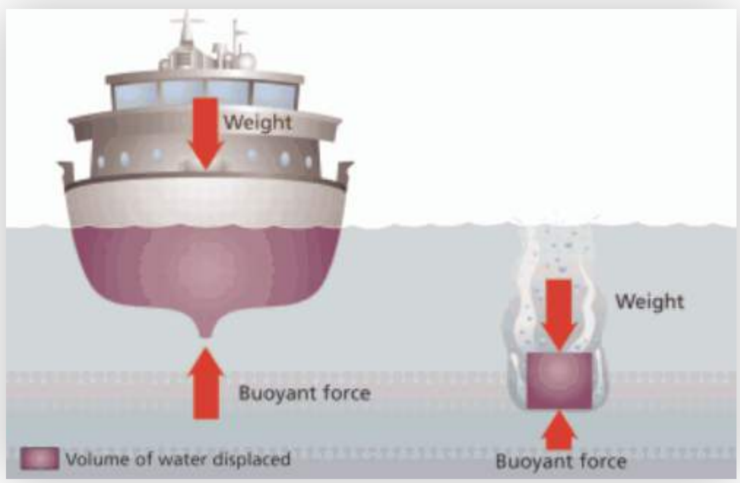
How is a Hull Designed?

There are many factors ship designers and builders need to think about when they construct a new vessel. If the ship is going to need to break through ice, the shape, style and materials needed will be different than if the ship is only going to be used in warmer climates. Ships that need to move quickly through the water have different hulls than ships that can move more slowly and steadily.

There are three main categories of hulls:

Displacement

Ships with this hull move through the water by **displacing** water, meaning it pushes the water aside. They are designed to move with very little propulsion or force. This is the oldest design for ships and boats. The amount of water displaced is equal to the weight of the ship itself. These vessels cut through the water very smoothly even in rough water, but move relatively slowly. Although this category of hull has become less common, many modern ships like tugboats and cruise ships still rely on displacement hulls.



Planing

This type of hull doesn't push water aside – it balances on top of it! Ships with this type of hull can move very quickly through the water. Because they are skimming along on top of the water rather than resting it, in choppy water the ship can slam into the water, creating a very bumpy ride for passengers and cargo. This hull type is common in smaller vessels, but is relatively uncommon in the Navy.

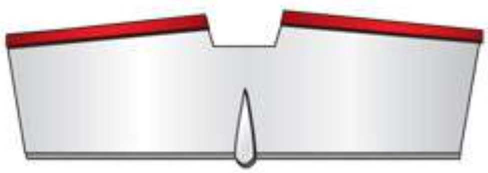
Semi Displacement or Semi Planing

Semi Displacement hulls combine attributes from displacement and planing style hulls. This allows the vessels to be faster, but sturdy and stable, too. Many U.S. Navy ships use this hull shape to help combine the benefits of a displacement and a planing hull.

Utilize this information on the next page for an activity!

Hull Shape Activity

There are four main categories of hull shapes:



Flat Bottom Hull

Deep Vee Hull

Multi-hull

Round Bottom Hull

Using the information about hull categories, what category of hull are these shapes? What ships or boats might use these hulls? Connect the Hull Shape with the corresponding category.

Shape	Category
Multi-hull	**Semi Displacement or Semi Planing**
Deep Vee Hull	**Planing**
Round Bottom Hull	**Displacement**
Flat Bottom Hull	

Guiding Question:
Why is it important to have many different kinds of hull designs? Are some better than others? Why or why not?

How are Hulls made?

Diagram of a tree collected for hull planks

U.S. Navy ships were originally made of wood. Craftsmen would carefully consider the properties of different kinds of wood, selecting ones that were sturdy and resistant to rot. Oak was a particular favorite. When the new U.S. fleet was first being constructed after the Revolutionary War, there were no lumber yards. The U.S. Navy sent teams to forests in New England, Georgia and Mid-Atlantic states to harvest trees that were the exact right size and shape to create the planks they needed. Because there are very few straight lines on a vessel, the planks would need to be carefully bent into shape to form the ship.

These early U.S. Navy ships were unique because they used white oak *and* live oak for the hulls. By putting live oak planks in between the white oak, the ships were more sturdy and durable when in combat. Cannonballs would literally bounce off of the ship!

The first ship to be made of iron instead of wood was a French steamship first launched in 1821. American designers began to investigate building ships out of iron instead of wood soon afterward. Iron was rolled into sheets, cut, and drilled into place to make hulls and other structures for ships. In 1862 at the Battle of Hampton Roads, the *USS Monitor* fought the *CSS Virginia* in what was the first battle between ironclad ships in world history.

Soon afterward, shipbuilders began to use steel as well as iron to construct ships. Although iron and steel make sturdier ships than wood, they aren't invulnerable: iron and steel rusts when exposed to wet conditions. To help prevent this, shipbuilders paint the hull and other exposed parts of the ships to protect the metal from the elements. Metal hulls are also built with special compartments to help stop flooding if the hull is ever damaged and taking in water.

Did You Know?
The *USS Constitution* got her nickname "Old Ironsides" thanks to her live oak hull!

Protecting the Hull

When a ship is completed and launched into the ocean, it doesn't just have to stand up to storms or the ocean itself. Mollusks like barnacles or mussels and other marine life love to latch on to the bottom of ships. One mollusk or two might not be a problem, but when it becomes thousands or even millions of mollusks, it can add a lot of weight to a ship! A buildup of sea creatures on a hull is known as **fouling**. Marine life can also severely damage a wooden hull: boring mollusks called shipworms drill holes in wood.

The U.S. Navy has developed several different techniques to help prevent marine life from growing on ship's hulls. Wooden ships like the *USS Constitution* had copper plating on their hulls. Although this helped stop the wooden hull from being eaten by shipworms, it did not prevent other forms of mollusks from growing on it. This meant hulls would still need to be cleaned, and it risked introducing invasive animal species to new ecosystems when the ship traveled to foreign waters.

When iron and steel ships began to replace wooden ones, shipbuilders had to worry about rust and corrosion. The U.S. Navy used paint to help protect the metal and prevent this from happening. Ships made of metal don't need to worry about shipworms, but other mollusks still like to grow on the hulls. By the 19th century, ship builders were coating the hulls of ships with chemicals that were poisonous to barnacles and other forms of sea life.

Shipbuilders began to mix these chemicals with paint to create a protective layer on the hull that would also discourage marine life growth. The U.S. Navy began developing its own anti-fouling paint in 1906. New formulas are always being tested to achieve the best results. Although some of these chemicals can be hazardous, the U.S. Navy has worked hard to ensure that the paint they use is safe for humans and the environment as well as the ships. Modern anti-fouling paints are made with copper compounds or special chemicals that can stop the growth of marine life. Even so, ships still need to be periodically scraped clean and repainted to make sure they are seaworthy.

Taylor Model Basin & Carderock

It is very important to test a hull's design before launching or even building a ship. This gives builders a chance to fix any problems that may arise when there is still time to do so. It also lets designers see how well their plans have worked. Will a ship move fast enough? Will it be steady in rough water? Will the hull leak?

Today, U.S. Navy designers can use computer simulations and models to help test new ideas. Before computers, they had to be a little more creative about how to solve this problem.

In 1896, U.S. Navy architect and engineer David Watson Taylor designed and supervised the construction of a groundbreaking new invention: an experimental model basin. The experimental model basin was designed to help recreate real life conditions a ship might be faced with. Scale models of vessels would be placed in the model basin and tested to see how well the hulls preformed in different kinds of water: smooth and calm, choppy and rough. If the model ship performed well, work would begin on the larger ship. If the ship did not work the way the designers were hoping, it was back to the drawing board!

The basin was 14 feet deep, 42 feet wide, and 470 feet long. It was filled with a million gallons of water. The ships that were tested in the basin were made of wood rather than iron or steel. As the U.S. Navy started to build its own aircraft, aircraft models were designed and tested in experimental model basins as well.

A new model basin named after Taylor was built in 1939 in Carderock, Maryland. It was much bigger than the original facility and has pools to test conditions in shallow water, deep water, and for high speed vessels. It was one of the first government facilities to begin using computers.

Although the original Taylor Model Basin is no longer in use, the building it was housed in still stands. Today, the building is the Cold War Gallery of the National Museum of the U.S. Navy (Building 70).

Did You Know?

After the sinking of the RMS Titanic in 1912, Taylor was asked to help brainstorm new ways to make ship hulls safer and more seaworthy.

Activity - Build Your Own Ship!

You Will Need:

- Aluminum Foil
- Scissors
- Dry Beans or Marbles
- A Bucket of Water

1. Cut a square or rectangle of foil.
2. Fold up the sides of the foil to make a ship's hull.
3. Place it in the bucket of water. Does it float?
4. Start putting the dry beans or marbles into your ship's hull. Is it still floating? How many beans can it carry before it begins to sink?
5. Try this experiment with your friends. Who can build a hull that holds the most beans?