API® Lesson 8 | Fish Respiration and Transport

This lesson plan provides a basic understanding how the respiration of fish during transport changes water quality, what is respiration in fish, why it is important, and how changes in water quality effects their health.

The care needed to transport fish from one location to another can greatly influence the ability of fish to acclimate into their new surroundings and the toxicity of the water they live in. People often take care to gently net a fish when they place them into a plastic bag for transport, and many are also gentle when receiving a fish but do not fully understand what happen during transit. At the conclusion of this activity a better understanding of what the fish needs in transit and the changes once the plastic bag is sealed.

For Instructor/Teacher/Parent

Make sure to read through the entire lesson plan before beginning this with students/family members as materials will need to be purchased and information prep will need to be done.

Learning Objectives

After completing the activities outlined in this lesson plan, students should be able to:

- Provide a definition of pH
- Clearly explain why pH is important in an aquarium and during transit
- Discuss the pH based on the natural environment ornamental fish are native to.
- Why it's important to test your water, how to test, what the results mean and how to correct them

Length

This activity takes place over a two-day time frame, the total classroom activities are about 3 hours for completion of this exercise.

Materials to complete activity

- Several drinking cups to hold 8 ounces (240ml) of tap water (one for each participant)
- Several drinking straws (one for each participant)
- Tap Water
- API® pH TEST STRIPS or API 5-IN-1 TEST STRIPS
- A 5-gallon Bucket
- Air Pump and air stone with hosing
- A timer (Watch/clock with second hand or stopwatch) to measure 30 seconds and 5-minute intervals

Key Terms

Review key terms (printable sheet included at the end of the lesson) with students/family members.

1) pH
2) CO_2
3) RESPIRATION
4) BASIC (ALKALINE)
5) NEUTRAL
6) ALKALINITY (KH or CARBONATE HARDNESS)
7) AMMONIA

Warm Up

Ask a couple of questions to warm up for the lesson:

1) Do you currently have any fish? If so, what kind? How did you get them to your aquarium?
2) How can you tell if a fish is breathing?
3) How do you think we can tell if a fish is stressed?
4) What is the proper pH range for the type of fish you are keeping?

Before You Start

1) For this lesson we're going to walk you through the parameter for different environments.
   a) Note: Determining different types of environments or ecosystems is dependent on the type of fish selected. As an example, fish from South America (like Angelfish, Neon Tetras Corydoras, etc.) prefer water with a lower pH (on average 6.5 or lower) and lower general hardness. Fish from African Rift Lakes are referred to as African Cichlids and prefer water with a higher pH (8.2 to 9.0) and higher general hardness. It is important to determine the type of fish early so you can maintain your aquarium to meet their specific needs.
   b) Most freshwater fish are tolerant of pH of 6.5 to 8.2. Even though they may have a preferred pH level they can survive a wide range of pH levels. It is important to note pH changes may happen during transit. When fish are outside of their preferred range the fish will be stressed.
2) The type of fish in aquariums is going to be a "Tropical" aquarium or "Cold water" aquarium. Tropical simply means warm water and this type of aquarium requires a consistent temperature. Most aquarium fish are tropical, however fish such as goldfish and Koi are considered cold water and do not require a heater. The temperature of the water does not interfere with or determine the pH but will affect their respiration. The higher the temperature, the higher the respiration of the fish.
3) A 'general community' aquarium has a cross selection of fish that will often live in a neutral pH of 7.0 to 7.5 and moderate hardness. A mixed or general community aquarium will not replicate any specific environment and is often kept at a neutral pH of 7.0 or slightly higher at 7.5.
4) The pH is simply the measurement of the acidity of any given solution. Technically pH is defined as the negative logarithm of the hydrogen ion concentration or $pH = \log 1/[H^+]$ or $pH = -\log[H^+]$. What this means is pH changes are logarithmic, so when pH changes on the pH scale it is a 10-fold difference. So minor changes in pH are drastic changes chemically to the fish.
5) The measurement of pH is applied to a scale of 0 to 14. The value of pH 7.0 represents neutrality or a solution where the hydrogen (H^+) and hydroxyl (OH^-) ions are in equivalent quantities. Below 7.0 is considered acidic and above 7.0 is alkaline or basic.
6) The consistency of pH is attributed principally to the buffering water. The buffering factors are carbon dioxide (CO_2), carbonate and bicarbonate ions in the water. pH is directly

associated with the carbon dioxide levels. The more CO2 within the water the more it will react with the available buffers causing a shift downward in pH. An aquarium with a high plant or algae activity will have an elevated pH during the day (photosynthesis is high) and a lower pH at night (when respiration is high). If the change in pH is drastic, major effects can take place within the fish being kept.

7) Change in pH as a result of poor circulation is common. As an example, when fish are packed in a sealed plastic bag with a small amount of water and oxygen with a starting pH of 8.0, a decrease in pH occurs over time. The decrease is due to the CO2 exceeding atmospheric equilibrium because of the barrier of the bag. Once the bag is opened, if the water is aerated to expel the CO2, the pH will rebound. If an aquarium does not have proper circulation, similar conditions can occur. It is important to also understand changing the pH in the presence of ammonia can lead to toxic conditions.
8) pH tends to drop in aquariums because of biological activity. Acids are produced from the fish, food wastes, and decaying organics that are processed by the biological activity of reducing proteins to ammonia, then to nitrite and finally to nitrate during biological activity known as nitrification. Most bacterial action utilizes oxygen and produces CO2. The production of acids and CO2 from this biological activity of nitrifying bacteria and other bacteria will lower the pH with the aquarium. In the transport container the water will contain bacteria as well as the fish.
9) You will need to understand some very basic fish anatomy and movement of water over fish gills.
    a) Fish pump water into their mouth and over their gills. The gills are covered by a flap called the operculum. The more the fish breathes, the more times the operculum will open and close.
        i) If you have fish in the classroom, locate and identify the operculum. Count the number of times the fish breathe in a one-minute time frame.
    b) Fish are cold blooded and cannot regulate their own body temperatures. The colder the water, the slower the respiration, the warmer the water, the faster they will respirate and the more times they will inhale and exhale. This can be judged by the number of operculum movements, slower in cooler water and faster in warmer water.

Instructions for Learning Activity

1. Fill a bucket half-full with tap water
    a. Test the tap water for pH using the API pH TEST STRIPS and record your results.
    b. Obtain an air pump with an airstone attached to a piece of airline that will allow the airstone to be in the bottom of the bucket. Let the bucket sit overnight with the airstone bubbling.
    c. The next day, test the tap water for pH and record your results for later discussion.
2. Fill a plastic cup with 8 ounces (240 ml) of tap water
    a. Test the tap water for pH with the API pH TEST STRIPS and record your results.
3. Obtain a drinking straw and blow into the cup of water through the straw for 30 seconds.
    a. Test the tap water for pH with the API pH TEST STRIPS and record your results.
4. Pour out the water and re-fill with new tap water (8 ounces, 240ml).
    a. Test the Tap Water for pH with the API pH TEST STRIPS and record your results
    b. **Run in place for five minutes.**
    c. Immediately when finished running, blow into the water through the drinking straw for 30 seconds.
    d. Test the tap water for pH with the API pH TEST STRIPS and record your results.
5. Rest for two minutes
    a. **Now do 30 sit ups.**
    b. Immediately after finishing the 30 sit ups, blow into the water through the drinking straw for 30 seconds.
    c. Test the tap water for pH with the API pH TEST STRIPS and record your results.
6. Obtain the data from other students performing these tasks and compile everything into a single chart.
7. Looking at your combined chart from all students, answer the following questions:
    a. Was your tap water neutral, acidic or basic?
    b. Did your tap water change after sitting overnight?

c. Based on expended energy from exercise, did the pH in the plastic cups go up or down?

Understanding the water source and fish respiration

When you run in place or perform sit ups you are expending energy. You will intake oxygen and exhale carbon dioxide. This is a result of cellular respiration. When CO_2 mixes with water it forms an acid called carbonic acid. The more acid in the water the lower the pH will go. When you are stressed for any reason your cellular respiration goes up, requiring more oxygen and releasing more CO_2.

When you performed the exercises, your body cells used a chemical called ATP (adenosine triphosphate) to give you energy. During the process using ATP, your muscles require oxygen, and they disposed of waste products that were produced. The waste products include CO_2. CO_2 is carried out of your muscles in your blood, the blood goes to your lungs and releases CO_2, which is exchanged with more oxygen, which is noted by increased breaths. Fish are similar, except the CO_2 is carried in the blood to the gills where it is exchanged for oxygen in the water.

Fish have very similar needs to humans regarding oxygen and exhaling CO_2. When we aggressively chase a fish with a net, we increase the energy needs of fish, very similar to when we run or perform sit ups. When fish are scared or stressed, they require more energy to cope. The biggest difference between fish and humans is they obtain their oxygen from the water and expel their CO_2 into the water. Oxygen is as important to the survival of fish as it is to the survival humans and other terrestrial animals. Water only contains about 3% of the oxygen found in air. As water is denser than air it is also requires more energy to obtain oxygen from water through the gills. To obtain the adequate supply of oxygen fish must continuously move water across their gills, expelling CO_2 in the process. And as you have seen the more CO_2 that goes into the water the lower the pH.

Something else also is released through fish respiration, they release ammonia. Free Ammonia is toxic to fish. The higher the pH the more toxic free ammonia is in the water. So, in the transport water within the bag with fish we will have accumulated CO_2 and ammonia excreted from the fish. It is important to measure the ammonia and if the bag water has elevated ammonia levels, raising the pH can be very detrimental as a result from the accumulation of free ammonia.

In the bag the pH of the water will change gradually, because of respiration. When placing fish from the bag to any aquarium it is important to also do it gradually allowing the water condition to slowly adjust. Appropriate pH control in an aquarium is important because overly acidic or alkaline water can have harmful effects on aquarium life. Appropriate testing and adjusting of aquarium pH are crucial for the maintenance of fish health – for good color, wholesome appetite, successful breeding and disease resistance. Any change to pH to the proper level in an aquarium should be a gradual change overtime.

When water is sourced from the tap it is often under pressure. When water is under pressure and placed in the atmosphere, such as the open bucket, certain gases can enter or escape. One of the gases is Carbon Dioxide (CO_2). As the water sits excess CO_2 will balance to the air or CO_2 can enter from the air to equalize the pressure. This is important because quite often the pH measure directly at the source (i.e. tap water) may not the "true" pH of the water. If CO_2 decreases the pH will up and if the CO_2 increases overtime the will go down. By letting the bucket sit overnight with the air stone and measuring the pH the next day you have found the "true" pH of your source water.

What is pH?

The pH level refers to the level of acidity in water using a scale of 0 to 14. A pH of zero is most acidic, while pH of 14 is most alkaline. Water with a pH of 7.0 is neither acidic nor alkaline and is considered "neutral". Most freshwater fish live in a pH range of 6.0 to 8.0, depending on their natural habitat. Marine fish and most African Cichlids come from environments with pH levels of 8.0 or higher.

Freshwater fish are found in habitats in all climatic regions of earth. Aquarium fish are primarily from the tropics and subtropics from six main regions. The main regions are 1) Amazon, 2) Central America 3) Congo River Basin 4) African Rift Lakes, 5) South and Southeast Asia, 6) Coastal (brackish and saltwater). We will generalize for the sake of discussion the pH of each region.

1. The Amazon varies between river systems such as the Rio Negro can have a lower pH than the Amazon itself. Fish from the Amazon depending on time of year can see lower pH values such as 4.5 to slightly above 7.0. We generalize the pH average of Amazonian fish at 6.5 for most aquarium keeping.
2. Central America cichlids and livebearers from this region typically are found in harder water with a pH value of 7.5
3. Congo River Basin (Zaire River) is close to the tropical rain forests of the Amazon. Because of the jungle like character of the region we can generalize the pH at 6.5 for most aquarium fish from this region
4. African Rift Lakes are primarily from Lake Tanganyika, Malawi and Victoria, noting there are others as well. Because of the geology of this region the water tends to be harder, higher in salts with a general pH value of 8.2. Some regions of the lake can be even higher.
5. South and Southeast Asia includes southern India, Sri Lanka through Indonesia and the Philippines over to New Guinea. Much of this region are heavily mountain streams that include dense forests. It also receives strong monsoons bringing voluminous tropical rains. The water is commonly soft acidic water with a lower pH. We generalize the pH average of South and Southeast Asia fish at 6.5 for most aquarium keeping.
6. Coastal and Marine environments is relatively constant, ordinarily staying with a pH range of 7.6 to 8.4, with an average pH level of 8.2. This would include saltwater fish only aquariums and reef aquariums.

One very important fact to remember about the pH scale is that it is logarithmic. Therefore, gradual changes are essential. Sudden changes in pH of great amounts can be stressful or even lethal to your fish. To keep tropical fish and goldfish healthy and colorful, it is necessary to maintain a stable pH in the correct range.

Reducing Stress during transport

The key to healthy fish starts long before they are transported. Care must be taken to assure they are housed in good water quality and continuously fed a nutritious, complete, and balanced diet long before transit. Depending on the length of travel it may be advised to limit their food intake days prior to travel to limit the excretion of waste into the transport bag water. We must consider the amount of biomass (number of fish) per volume of water. The lower the biomass to water ratio the easier it will be to maintain good water quality during transit. But a key component to reducing stress is using water conditioners during transit. API Stress Coat has been proven to reduce stress by up to 40%. So, adding API Stress Coat to the shipping water supports and helps to protect the fish during transport.

Acclimation of fish after transport

When fish arrive at their new location in sealed fish bags they are stressed. During transport oxygen has decreased, CO2 has increased, pH may have changed, and toxins have accumulated in

the sealed fish bags. Depending on how much time they have spent during transport the exact handling will vary.

Before we receive any fish, we must have their new environment or aquarium established in advance of their arrival. The water quality must be such that is suitable and safe based on their preferred needs, such as temperature, pH, and hardness.

Unpacking of the fish bags should be performed at a slow pace. We must be careful not to be too aggressive when handling the fish bags as this will add further stress. If the bags have been shipped in sealed box, absent of light, we must also consider not to have the light too bright when opening the box. The fish should be removed from the bagged water (poor water quality) into clean water. Remember when we open the bag it may contain high CO_2, low pH, and elevated levels of ammonia. If the water was to suddenly shift pH quickly the free ammonia will become more toxic, this is often referred to as "bag burn" with fish.

A best practice is to put the sealed bag in the new water and let it float to adjust to the temperature change. When the bag water is less than 4°F (2°C) from the new tank water the fish can be released. We should consider the water quality in the bag is poor quality and it is important to discard this "bad" transport water. Therefore, it is always advised to net the fish from the bag water into their new environment. Be sure that water in their new environment is well aerated.

Questions

- Pass out the Questions worksheet (printable sheet included at the end of the lesson) to each student/family member.
- Review the answers to the questions during the discussion section of the lesson.

Discussion

- After finishing the items above including the questions and key terms, engage students/family members in a brief discussion about the lesson:
    - Why is respiration during fish transit a concern?
    - Name two materials that can accumulate in the transit water inside the bag and how they affect water quality?
    - What is the desired pH level for the fish you are keeping or desire to keep?
    - How can we keep the fish calm to lower overall respiration?

Quiz

- Once you've finished the discussion, pass out the Quiz worksheet (printable sheet included at the end of the lesson) to each student/family member.
- Have them complete the quiz and then review the answers/have an open discussion about the answers with them. Answers are below.

1. Describe your favorite fish in your aquarium and what region of the world they are found and the pH of the region.
    - As an example: Swordtails are commonly found in Central America and produce live bearing babies. The pH of this region is generally 7.5
2. Is testing the pH direct from the tap source a concern? What does testing for pH tell us?
    - pH can change as a result of CO_2 gases; they could increase or decrease overtime. When tap water is first put into a container the CO_2 may not be

equal to the atmosphere. Overtime the CO2 will stabilize, and the pH of the water will know.
    - The pH of the water will tell us if it is suitable for the type of fish we are keeping.
3. If water is acidic where would the pH be found on the pH scale?
    - Below 7.0
4. How does the temperature change in water relate to the pH level?
    - Temperature does not have any effect on the pH of the water.
5. Define the pH scale?
    - The pH scale ranges from 0 to 14. 7.0 is neutral, below 7.0 is acidic and above 7.0 is alkaline/basic.
6. What is the pH ranges that most aquarium fish are commonly kept at?
    - Most aquarium fish live in ranges from 6.5 to 8.2. The desired pH range that is ideal for specific fish species can vary greatly from species to species. Fish from the Amazon normally prefer a pH of 6.5 or even lower. Fish from the African Rift Lakes called African Cichlids prefer a pH of 8.2 or even higher. Fish from Central America normally do best at a pH around 7.5. When we mix a grouping of fish from around the world together, we call that a community aquarium and normally target a pH of 7.0. It is easy to test the pH of your water using the API FRESHWATER MASTER TEST KIT.
7. How does respiration affect water quality?
    - During respiration animals' uptake oxygen and release CO2. The more CO2 in the water the lower the pH. Lower the pH levels makes ammonia more toxic.
8. How can low the stress of fish during transit?
    - Assure the transit water quality is correct and keep the biomass low (volume of fish to water volume low)
    - Avoid any aggressive movements or handling when capturing the fish or place them into their transport bags
    - Use a water conditioner such as Stress Coat designed to protect the fish during transit and lower stress.
9. How can we observe if the fish are stressed?
    - Count the operculum movements of the fish. If their operculum movements are elevated above normal, they are most likely stressed.

APPENDIX

See items below to be passed out to the family members or students for the lesson.

KEY TERMS

pH – The measurement of acidity. The pH scale ranges from 0 to 14. 7.0 is neutral, below 7.0 is acidic and above 7.0 is alkaline/basic.

CO2 – Carbon Dioxide, an odorless, colorless gas that is present in the atmosphere and formed during respiration.

RESPIRATION - a chemical reaction that happens in all living cells, including plant cells and animal cells. It is the way that energy is released from glucose so that all the other chemical processes needed for life can happen

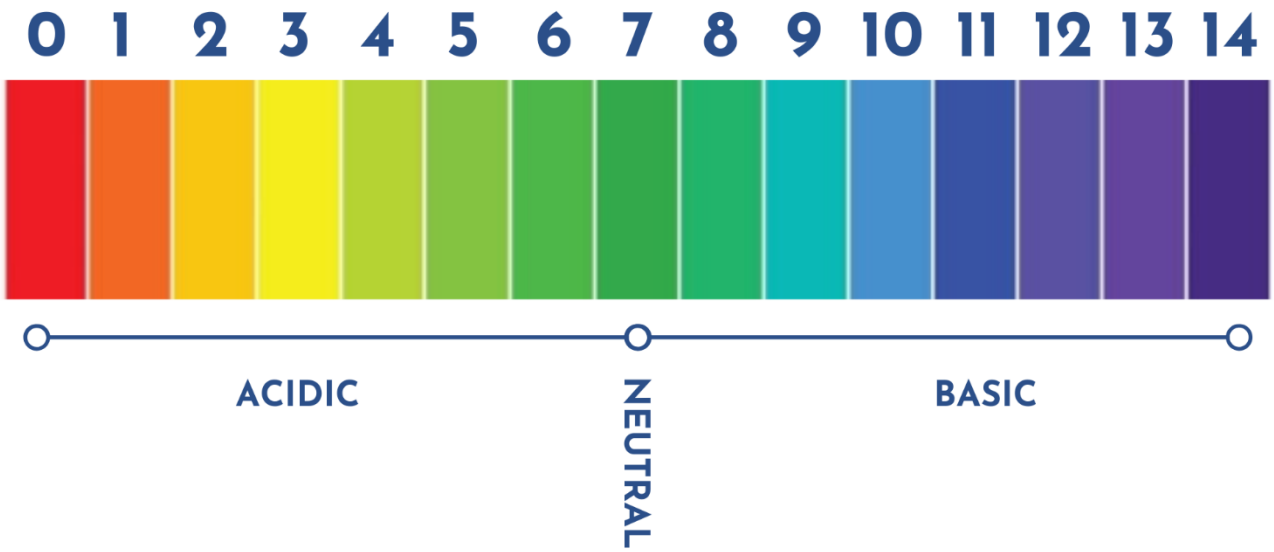
BASIC (ALKALINE) - substance with a pH greater than 7

NEUTRAL – substance with a pH of 7

ALKALINITY (KH or CARBONATE HARDNESS) - the ability of water to neutralize acids without an increase in pH. This parameter is primarily a measure of bicarbonates (HCO_3^-) and carbonates (CO_3^{--})

AMMONIA – NH_3, Toxic compound excreted by fish.

pH SCALE



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QUIZ

1. Describe your favorite fish in your aquarium and what region of the world they are found and the pH of the region.

2. Is testing the pH direct from the tap source a concern? What does testing for pH tell us?

3. If water is acidic where would the pH be found on the pH scale?

4. How does the temperature change in water relate to the pH level?

5. Define the pH scale?

6. What is the pH ranges that most aquarium fish are commonly kept at?

7. How does respiration affect water quality?

8. How can low the stress of fish during transit?

9. How can we observe if the fish are stressed?

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