Science Methods for Elementary Teachers

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Chapter 1 Introduction to Science

We are excited to welcome you to this methods course that will prepare you to teach science in the elementary classroom. You have taken science content courses among your general education courses. The content you learned in your general education courses is important for your well-rounded science background. The content we present in this course is be interpretation of what the children we are preparing you to teach will need to know. We do not include the depth and detail of content that a biology or physics professor might teach you in her/his course.

Any content we present for these courses is just a sampling of the complexity and detail the students you are being prepared to teach need to master.

Many elementary children see science as a fun and interesting part of their school experience.

Image 1: Elementary Science Class

Science lessons should include a time when students explore real things, which is not the case in most of their school work. We hope you will enjoy the class and the activities we work on together.

Working with real things can bring potential safety concerns would not be introduced when just reading about a concept. As role models for our students, we will begin these courses by addressing science safety for the elementary classroom. **It is expected that you will be using proper safety procedures in all of the activities we do in class and all of the lessons you prepare.**

Science Safety in the Elementary Classroom

Teaching is a complex job. To do it well, **a teacher has to wear many hats and will be constantly multitasking**. Among the greatest stressors teachers face is the need to weigh the costs and benefits of her/his actions. For example, teachers must weigh the advantages of giving students extra recess time (to burn off energy and help control their "wiggles") against the loss of instructional time this action causes.

In our experience teaching science methods for nearly three decades, focusing on science safety can cause teacher candidates to avoid hands-on science activities. Focusing on safety issues and procedures necessarily puts a focus on things that can go wrong. This focus on potential problems can make teacher candidates shy away from activities that are already concerned might not turn out well. *Focusing on safety could create a mindset that there is much less risk in having students read about science. Isn't that good enough?* **The short answer is NO!**

Image 1: Young student wearing safety goggles.

We must balance the benefits of great hands-on/minds-on science activities with the small risks to student safety that they create. This is non-negotiable. To do this, we must develop science safety standards and procedures that do everything possible to keep their students safe.

We start this course with a chapter on safety because we feel it is the teacher's most important responsibility to his/her students. Keeping students safe is even more important than improving their test scores. We know that the best way for students to learn is for them to be physically and intellectually engaged with real science. Therefore, I am caught in the same stressor described above. We want you to learn to love teaching safe, active science lessons!

Let's begin with your role as teacher. Please read the following excerpt from Britannica.com.

The doctrine of In Locos Parentis

When minor children are entrusted by parents to a school, the parents delegate to the school certain responsibilities for their children, and the school has certain liabilities. In effect, the school and the teachers take some of the responsibility and some of the authority of the parents. The exact extent and nature of this responsibility and power vary from one society to another and from one school system to another. This is spelled out to some extent in the law, but much of it is determined by local custom and practice.

Image 2: Teacher with students in calendar time.

There is, of course, a relation between the age of the child on the one hand and the teacher’s responsibility and liability for it on the other. The young child must obey the teacher, and the teacher may use the methods expected and tolerated in the community to control the child’s behavior. Furthermore, the child’s physical safety is entrusted to the school and to the teacher, who thus become legally liable for the child’s safety, insofar as negligence can be proved against them.

Let’s Get Started with Science Safety

General Classroom Rules, Routines, and Procedures: Safety is not just a concern when we do science. Safety is, in our opinion, a concern for all teachers in all situations. One of the most important ways to promote safety in the classroom is to establish clear, reliable expectations in the classroom. For elementary teachers who have the same group of students the entire day, this can be easier than it is for departmentalized middle level and secondary classrooms. The reason is consistency. It is easier for one teacher to maintain consistent classroom expectations and responses to student behavior than it is for several teachers to maintain consistent expectations and procedures.

Dr. Browne writes: "As an elementary classroom teacher, I found that establishing clear rules, routines and procedures was vital to a smoothly functioning classroom. In fact, I was "lucky" my first two years of teaching to be across the hall from a teacher whose management style was less defined than mine. In that classroom the noise level was high, and it was clear that students required multiple (sometimes many) "threats" in order to fall into line. The chaos that was evident in that classroom does not, in my opinion, lend itself to a safe classroom. Why? **When there is an emergency of any type, it is vital that the teacher is able to quickly and calmly provide direction to his/her students.**

Establishing Classroom Rules, Routines and Procedures: Experience tells us that involving students in the process of defining classroom rules and expectations helps them to understand and value these rules. On the first day of school, talking with students about why they come to school and what has to happen to help them learn is important. We feel that if the students engage in this conversation rather than having a list of rules read to them, they are more likely to remember and "buy into" them from the start. This may seem like a cliché, but we have found it to be useful. Dr. Browne's wife, Lisa, is a preschool teacher. For her, the classroom rules, routines, and procedures have to be very simple and practiced again and again. The same is true for elementary classrooms, (Of course, there will be differences kindergarten/primary classrooms and the upper elementary ones.)

Simple, well established, rules and procedures lead to classroom routines that make things easier for the students and the teacher. *(This is not a classroom management course, and this chapter is supplemental due to the safety issues that might crop up doing science in your classroom.)* Let's begin with classroom rules.

Classroom rules are essential for keeping order and safety in the classroom. Our experiences in elementary classrooms is mostly in the upper elementary grades. We have found that having a discussion about classroom rules on the first day of school is preferential to reading a set of rules that, you the teacher, had developed ahead of time. This is not to say that you don't "shape" the conversation to be sure it goes where you want it to. The idea is to explain the purpose of classroom rules (an effective and safe learning environment for all). Then, begin a conversation that allows students to express what they need the classroom to be like in order to help them learn. We suggest developing a few simple and general rules as opposed to many specific rules. A simple rule like: **"Respect Others"** can address many situations. A very specific rule like: **"Do not hit"** does not help when a student kicks his/her classmate. The offending student might argue the point that there is no rule against kicking. We suggest four to five rules such as: **Respect Others; Respect Property; Do your Own Work; Do your Best; Encourage Each Other**. These rules can address almost all classroom situations. However, because they are so general, many examples and non-examples will be needed to help students (especially younger ones) really understand them. Anchor charts with examples and non-examples are helpful. Titles such as ***Ways I Show Respect to Other*** or ***How I Do my Best*** are ways to begin the process. Many schools have their established "Management Plans" that are used to set high expectations. Your classroom rules should be shaped to fit within such school-wide programs.

Consequences for misbehaviors must also be addressed. This should be a part of the first day discussion of classroom rules. We do not suggest letting students set the consequences for misbehavior as they lack the judgement to establish fair and proportional consequences. In fact, we have found that elementary students tend to create much harsher consequences than their teachers would. In general, you should stay within the classroom management program established at the building level, with your own "tweeks". Your expectations should be clear. Following through when rules are broken is important. You will have some students "testing" your commitment to the rules in the first few weeks of the year. You want to establish a firm but compassionate posture to show that the rules have meaning and will be followed. However, this should not become a test of wills, nor should a teacher respond in anger. Firm, consistent, expectations help students learn that the classroom rules are for their benefit.

Classroom Procedures are also quite necessary for a class to function efficiently. While rules are something you want to establish with your students, procedures are often developed ahead of time by the teacher. The goal is to look at your classroom and the activities that will take place there and then think of how those activities can be facilitated in the most efficient, orderly and safest way. Each teacher should develop procedures for things such as: sharpening pencils; using materials like scissors and glue; turning in work; moving to the "rug"; using the restroom; getting a drink; before school starts activities; walking in the halls; getting ready for recess; indoor recess; getting ready for lunch; getting ready to go home. Of course there are other procedure you may need to establish. The key is explaining the procedure (and in some cases why it is as it is) and practicing them over and over until they become routine.

Rules and **Procedures** that are consistently followed and practiced lead to **Routines**. Why are routines so important? When a classroom is functioning with successful routines, several good things happen. **First**, students have a sense of security when they know what to expect and are not confronted with unexpected behaviors from their peers or changing expectations from their teachers. **Second,** the teacher can place more attention of the one or two students who really need her/his help when it is not likely that doing so will lead to the other students misbehaving. **Finally** well-established routines can be the expectation when the teacher must be away from the classroom and a substitute teacher is present.

Science Safety Rules, Procedures and Routines. When a teacher is doing a science activity, special care must be taken to ensure that it is being completed in as safe a manner as possible. Typically, there are three time frames to be considered. The first is **Before the Activity.** Then comes procedures for what happens **During the Activity.** Finally, there are procedures for the time immediately **After an Activity.**

Before the Activity Before conducting any activity the teacher should **complete a pilot run of the activity**, fully completing it to be sure that it will work as expected and that she/he knows how to help students successfully complete it. In doing so, the teacher the teacher should **note the materials needed** making sure they are present in sufficient quantity. He/she should also consider the **best groupings** for completing the activity so that all students will be actively engaged. (Many small groups will mean more activity for each student, but will require more material. Larger groups require less material, but limit individual students involvement.) Then, the teacher should **develop a list of directions** the students will need to complete the activity. These directions should be clear and geared to the age of the students. The teacher should organize the materials in a way that makes it safe and easy for students to access and transport them to their work area. **These materials should be stored in a area designated for science materials that are not to be touched by students until they are directed to begin the activity.**

Image 3: Storage area for Science Materials

Everything should be tested and prepared well before students arrive for the class or day. In addition while running the pilot and preparing the materials the teacher should be analyzing the activity for any possible safety hazard. Sharp objects, heat, fast moving parts, and chemicals (among other things) should be considered as potential safety hazards. This is not to say they make an activity unsafe to do in the classroom, but rather that these safety concerns should be identified, noted and explained to the students before they begin. The teacher should also develop a specific procedure for students to acquire, transport and otherwise work with the materials. These procedures should be explained prior to any materials being moved to the work areas.

During the Activity While the students are carrying out the science activity, it is vital that the teacher be circulating around the work areas to encourage students to participate, stay on-task, and stay safe. The teacher should also be checking for student understanding. It is best to stay to the outside of the room as much as possible, so that the teacher can be scanning the other work areas while working with one group. The point is, when doing science, the teacher cannot assign an activity and then go about doing something else. During science activities, teacher s must remain actively engaged in the activity.

After the Activity When an activity is completed, it is time to clean up. Again, the teacher should have clear procedures developed before doing the activity for material handling and cleanup after the activity is completed. These procedures should be written down. In general, safe disposal of waste material, the return of reusable materials and equipment, and clean up of the work areas should be addressed. **In all three phases of the activity, it is important to have as few people moving with equipment/materials as possible (at any one time).** Students should not be expected to wash dishes or clean equipment unless closely supervised by the teacher.

There are several very specific safety standards and procedures that we have not covered in this introduction to science safety. That is because we will be asking you to research and develop your own safety plans. **Below you will find things we expect you to read and view before we meet in class. They will assist you as you complete your safety plan during class time.**

Before Class

A) **More on in loco parentis**. After reading the material above, please locate two additional sources concerning the topic of “in loco parentis”.

In your Science Journals document the following:

1. Provide the bibliographic information I need to locate your sources.
2. Describe the doctrine of "in loco Parentis" in your own words.
3. Describe the ways that this doctrine can inform your teaching decisions concerning safety

B) Science Safety Recommendations Please review several published science safety guideline documents listed below **before you come to class**. In our next class session you will work in teams of three, to develop a draft set of guidelines for either a k-3 (primary) or 4-6 (upper elementary) classroom's science safety plan. Specific details are listed after the Science Safety Video links.

Please review these web resources:

http://www.csss-science.org/recommendations.shtml

https://www.labsafety.org/#G

https://safety.lovetoknow.com/Lab_Safety_in_School

https://safety.lovetoknow.com/Childs_Safety_Goggles

http://webstorage.k12albemarle.org/Instruction/Science/Resources/shared/K6safety.pdf

https://www.acs.org/content/dam/acsorg/education/policies/safety/safety-in-the-elementary-k-6-science-classroom.pdf

http://www.csss-science.org/downloads/scisaf_cal.pdf

https://betterlesson.com/lesson/617181/safety-in-science

Science Safety Lessons and Resources

https://betterlesson.com/lesson/617181/safety-in-science

https://docs.google.com/document/d/1tK11zkER03c4Vz7YovBq2Zh0oRXb_e7e_2kGkoAyeXM/edit#!

http://mjksciteachingideas.com/safety.html

https://www.pinterest.com/explore/science-safety/

Here are some safety videos on YouTube

Video 1: Waft to Whiff Science Safety (Click the image or address below.)

[LAB SAFETY Video - I Think School.com - Bing video]


Video 2: Lego Safety (Click the image or address below.)

[Lego Safety in the Lab - Bing video]

Council of State Science Supervisors

General Lab Safety Recommendations

1. Always perform an experiment or demonstration prior to allowing students to replicate the activity. Look for possible hazards. Alert students to potential dangers.

2. Safety instructions should be given orally and be posted each time an experiment is begun.

3. Constant surveillance and supervision of student activities are essential.

4. Never eat or drink in the laboratory or from laboratory equipment. Keep personal items off the lab tables.

5. Never use mouth suction in filling pipettes with chemical reagents. Use a suction bulb.

6. Never force glass tubing into rubber stoppers.

7. A bucket of 90% sand and 10% vermiculite, or kitty litter (dried bentonite particles) should be kept in all rooms in which chemicals are either handled or stored. The bucket must be properly labeled and have a lid that prevents other debris from contaminating the contents.

8. Smoke, carbon monoxide, and heat detectors are recommended in every laboratory. Units should be placed in the laboratory and related areas (storerooms, preparation rooms, closets, and offices).

9. Use heat-safety items such as safety tongs, mittens, aprons, and rubber gloves for both cryogenic and very hot materials

10. A positive student attitude toward safety is imperative. Students should not fear doing experiments, using reagents, or equipment, but should respect them for potential hazards. Students should read the lab materials in advance noting all cautions (written and oral).

11. Teachers must set good safety examples when conducting demonstrations and experiments. They should model good lab safety techniques such as wearing aprons and goggles.

12. Rough play or mischief should not be permitted in science classrooms or labs.

13. Never assume that an experiment is free from safety hazards just because it is in print.

14. Closed-toed shoes are required for labs involving liquids, heated or heavy items that may injure the feet.

15. Confine long hair and loose clothing. Laboratory aprons should be worn.

16. Students should avoid transferring chemicals they have handled to their faces.

17. Never conduct experiments in the laboratory alone or perform unauthorized experiments.

18. Use safety shields or screens whenever there is potential danger that an explosion or implosion of an apparatus might occur.

19. Proper eye protection devices must be worn by all persons engaged in supervising, or observing science activities involving potential hazards to the eye.

20. Make certain all hot plates and burners are turned off when leaving the laboratory.

21. Frequent inspection of the laboratory's electrical, gas, and water systems should be conducted by school staff.

22. Install ground fault circuit interrupters at all electrical outlets in science laboratories

23. A single shut-off for gas, electricity, and water should be installed in the science laboratory. It is especially important that schools in the earthquake zones to have such a switch.

24. MSDS sheets must be maintained on all school chemicals. Schools should maintain an inventory of all science equipment.

25. Laboratories should contain safety equipment appropriate to their use such as emergency shower, eye-wash station (15 minutes of potable water that operates hands free), fume hood, protective aprons, fire blankets, fire extinguisher, and safety goggles for all students and teacher(s).

26. Protective (rubber or latex) gloves should be provided when students dissect laboratory specimens.

27. New laboratories should have two unobstructed exits. Consider adding another to old labs if only one exit exists.

28. There should be frequent laboratory inspections and an annual, verified safety check of each laboratory should be conducted by school staff.

29. Give consideration to the National Science Teachers Association's recommendation to limit science classes to 24 students or less for safety.

30. All work surfaces and equipment in the chemical or biological laboratory should be thoroughly cleaned after each use.

31. Students should properly note odors or fumes with a wafting motion of the hand.

32. Chemistry laboratories should be equipped with functional fume hoods. Fume hoods should be available for activities involving flammable and/or toxic substances.

33. The several chemical authorities believe that contact lenses do not pose additional hazards to the wearer and that contact lenses are allowed when appropriate eye and face protection are used. The wearing of contact lenses in the science laboratory has been a concern because of possibility of chemicals becoming trapped between the lenses and the eye in the event of a chemical splash. Check with your state science supervisor for your state's recommendation.

34. All laboratory animals should be protected and treated humanely.

35. Students should understand that many plants, both domestic and wild, have poisonous parts and should be handled with care.

Criteria for scheduling special needs students into laboratory classes should be established by a team of counselors, science teachers, special education teachers, and school administrators. Aides or special equipment should be made available to the science teacher.

After you have reviewed these resources, and any others you choose, you will team up with others to develop a science safety plan in class. The plan will include the following:

- Introduction
- Scope of the Problem
- Legal Aspects of Safety
- Materials Handling
- Set Up
- Distribution of Materials

- Take Down/Clean-Up
- Accidents
- Electrical Safety
- Eye and Face Protection
- Biological and Animal Hazards
- Chemical Handling
- Chemical Storage
- Disposal of Chemicals
- Planning for Emergencies
- Safety Information Resources

This portion of the chapter will focus on the special ways that science is taught. It will undoubtedly differ from what you are learning about teaching reading and language. It will also differ from what you learn about mathematics and social studies. We will begin with a brief history.

Brief History

American education has an interesting history. Even before we became a nation our founders were legislating about education. In 1647, the **Old deluder Satan Act** was passed in Massachusetts. This law provided that when a town grew to more than fifty people it was required to hire a teacher to teach children reading and basic math. If the town grew to more than one hundred, the town was required to provide a grammar school which offered Latin and Greek. The idea was that children needed to learn to read, so that they could read the Bible and therefore avoid being deceived by Satan. While this reasoning seems very odd to us now, this was the first law that provided for funding for public education.

Original Size

Image 1: Old one room schoolhouse

Science was not a part of the curriculum in the very early American public school. Reading Writing and Math were all that was considered essential. Science was something learned at home. Girls learned about making soap and butter. Boys followed their fathers to the family business and learned how to make candles or wheels or copper pots. The science they needed was learned by doing what children's parents did. (We know that this was a sexist system. We are not endorsing it, just giving a simplified picture of what the schools did.)   This model lasted to some degree until the industrial revolution, when fathers could no longer take their sons to work to learn the trade. At this point, schools began to be more comprehensive.

As Americans moved westward, the same model (one room school houses focusing on reading, writing, and mathematics.). However, there were books with pictures of birds and trees. Science was taught through reading.

Now, let's skip all the way to 1950s. America and Russia were in the middle of the Cold War.   On October 4th 1957, Russia shocked the world by launching Sputnik1, a tiny artificial satellite which orbited for three weeks, sending a radio signal back as it circled the globe.

Original Size


Image 2: Sputnik 1

The American leadership was shocked and terrified. They had been trying to develop rockets that could reach space, but were falling behind in spectacular ways.

Original Size

Video 1: Rocket Failure (Click the blue link.)

So, in 1958, in reaction to the American's lack of success compared to the Russians, congress passed the National Defense Education Act. This act was the first time Washington had provided funds for science education in American schools. The act provide funds for universities to offer scholarships and provide salaries for academics to develop new science curriculum materials that engaged students in doing science. The product of this legislation included several curriculum "kits" that were to replace reading based textbooks. **Elementary Science Study** (ESS), **Full Option Science Study** (FOSS) **Science Curriculum Improvement Study** (SCIS) were but a few of the "Hands-On" kits that were published for use in elementary schools.

These kits were a great departure from traditional science teaching. They offered a richer experience for students if properly implemented. Unfortunately, this was a top-down curriculum process and most teachers were not ready for the change. There was a need for teachers to change their role from giver of science knowledge to guide as student learned by doing science. In addition, the kits needed to be resupplied and prepared for each class. Sadly, the impact of these kits on elementary science education gradually withered away.

In the 1970s and 80s the next major curriculum initiative occurred. It was the **Science Technology and Society** initiative. This initiative was an interdisciplinary approach to science education where science was connected with mathematics and social studies so that science was not taught in a vacuum. This initiative was also short lived, but served as the foundation for **Science Technology Engineering and Mathematics** (STEM) programs that are popular today.

This short history is truncated. There are many other factors that have led us to where we are today.

Standards Standards Standards

We live in an "age of standards". Teachers are often feeling pressure to teach to the standards that the students on which their students will be tested. There are National Standards which include the **National Science Education Standards** (NSES) and the **Next Generation Science Standards** (NGSS). These standards will be explored in class, along with the **Minnesota Science Education Standards**. They are brought up here because when we plan for teaching science we need to be aware of the standards that you are required to meet. This means that in Minnesota, educators should be following the Minnesota Standards first, and then looking to the NSES and/or NGSS.

Next Generation Science Standards

The final draft of the Next Generation Science Standards was first published in 2013. This document was developed by educators and administrators representing twenty-six states, representatives from the National Science Teachers Association, the American Association for the Advancement of Science, and the National Research Council. These agencies had worked together to produce the National Science

Education Standards in which were first published in 1996, and the Benchmarks for Science Literacy in 1990. The series of documents is listed to indicate how dedicated these organizations have been to improving science teaching and learning in science.

The Next Generation Science Standards do not supersede State Standards. Each state has the right, even obligation, to develop and monitor their own standards. While this is true, Arkansas, California, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Nevada, New Hampshire, New Jersey, New Mexico, Oregon, Rhode Island, Vermont, and Washington are states that have adopted the Next Generation Standards as their state standards. Other states have adapted the Next Generation Standards to meet their needs. These states include: Alabama, Arizona, Colorado, Georgia, Idaho, Indiana, Louisiana, Massachusetts, Mississippi, Missouri, Montana, Nebraska, New York, Oklahoma, South Carolina, South Dakota, Tennessee, Utah, West Virginia, Wisconsin, and Wyoming. So, in all, forty states have based their standards on the Next Generation Science Standards. Minnesota, where we live, has not yet adopted the Next Generation standards. However, while we, in Minnesota, need to be concerned about the Minnesota Standards, the Next Generation standards are still very useful. **This is because the Next Generation Science Standards is more than a listing of concepts to address.**

Minnesota Standards

Where would you look for Minnesota Science Education Standards?

Three-Dimensional Learning

The Next Generation Science Standards approach science from a position that students need to have deep understanding of core science concepts. Students also need to develop meaningful understandings of science processes and become able to evaluate the evidence presented as science. The Next Generation Standards do these things through three “dimensions” of science learning. These three dimensions include: **Practices**- are behaviors that scientists engage in as they investigate and explore. Scientists create models and theories about world. In addition, engineering practices are introduced and developed through the standards. **Cross Cutting Concepts.** These are concepts that can be applied in many ways in different parts of science. These concepts, which connect different “domains” of science, include: Patterns, Cause and Effect, Scale, Systems and Models, Energy and Matter and Structures and Functions. The final dimension is **Disciplinary Core Ideas**. These “Core Ideas” all include at least two of the following criteria: 1) they have broad importance in multiple science disciplines. 2) They provide a “Key Tool” for understanding or investigating complex problems. 3) They connect to the interests and life experiences of students and to the societal or individual concerns student perceive. 4) They are both teachable and learnable across multiple grade levels.

What does the Next Generation Science Standards describe as concepts that can be applied to several parts of science?

The entirety of the Next Generation Science Standards is based on these three ideals: Practices, Cross Cutting Concepts and Disciplinary Core Ideas. When one reads the standards, it is easy to see that the term Performance Expectation is used to describe what students should be able to do after instruction. The Three-Dimensional Learning concept is highlighted in the explanation of the expectation. The Science and Engineering Practices are underlined in blue, the disciplinary Core Ideas are underlined in orange, and the cross-cutting Concepts are underlined in green. This makes it easy to see these dimensions in every Performance Expectation.

This is a brief overview of the Next Generation Science Standards. You will be working with them and the state standards in class.

Process versus Product

Teaching science is not just about teaching facts. We all know four year olds who can describe every type of dinosaur without really understanding what they are saying. Reciting facts is not what we want form our students. We want understandings that come from doing what scientists do (in a simplified form).

So we teach both process and product. Teaching science processes involves teaching students to do what scientists do as they explore our world. There are several sets of lists of science processes that elementary students should practice and master. We are using a simplified list:

Classification: Placing objects or ideas into meaningful groups.

Observation: Using all of our senses to gather information.

Measurement: Adding precision to our observation by comparing things to a standard.

Inferences: Being able to use available data to draw a valid conclusion. (Also differentiate between inference and observation.)

Communication: Being able to use various methods to "tell" about what you learned. (sketches, writing, acting, singing...)

Experimenting: This is a complex skill which involves researching a topic, forming a hypothesis, developing an experiment to test the hypothesis, controlling variables, and collecting and analyzing data.

These are all process skills.

The **product side of science teaching** is the knowledge about the world that we need to pass on to our students. This might include: identifying parts of plants, naming moon phases and describing their cause,   describing the role of carbohydrates in a healthy diet, building a model or poster of an ecosystem. The product side of science teaching is the content we teach.

Objectives

Objectives are the way we measure the effectiveness of our teaching. We measure effectiveness by looking at what students can do or demonstrate after completing a lesson. Objectives are meant to be a measure of what each student has gained form the lesson. It is not a glimpse at what the majority of the students can do, but a look at each individual student has mastered.

We (Dr. Kimori, Dr. Browne, and Professor Sanderson) believe that clear objectives are vital for planning good lessons. We are teaching a simple model for writing clear objectives. It is called the ABCD method.

A stands for Audience. This is the part of the lesson where *the teacher **identifies the students to be taught.*** An example might be: Each second grade student, or “Each fifth grade student”. The objective begins with the audience” Each second grade student” to remind the teacher that each and every student is expected to master this objective, thought there may be accommodations. Objectives start "Each" to help us be sure that all students are learning.

B stands for Behavior. This is not about student conduct. Instead Behavior refers to ***the thing that the lesson is designed to help the student do***. Each fifth grade student **will light a bulb** ... The bold segment of the previous partial objective is the behavior portion.

C stands for Conditions. This portion of the objective ***sets the parameters for the lesson.*** Adding to our example: Each fifth grade student will light a bulb **given one bulb, one wire, and one dry cell.** In this example the Conditions are about the materials that students can use. In mathematics, there might be "given paper and pencil only" or "without the use of a calculator". Another condition might be **"Given twenty problems."** The conditions portion of an ABCD objective tells the parameters, whether they be materials to be used or disallowed, time allowed, or even whether the activity is done individually or in groups.

D stands for Degree. The degree tells ***how well the student must do to master the objective.*** The degree might be "with 80% accuracy", or four out of five times. Each fifth grade student will light a bulb **four different ways**, given one bulb, one wire, and one dry cell. (Note: the order of the ABCD is not essential.) Some things require a greater degree mastery than others. There can also be a difference in degree of an objective when the students are first learning a new skill or process, as opposed to when they are experienced with the skill or process. The degree allows the teacher to differentiate. There may be some student in a class for whom 60% might me an appropriate degree, while others might need a degree of 95% for the same lesson.

Audience, Behavior, Conditions, Degree.

Original Size

Image 3: Seeds for the exercise below.

Five E Lesson Plans

We have looked at standards, and objectives. Both are included in the lesson plan. In this section we examine the parts of a Four E or Five E Lesson Plan. The Five E design is the latest version of a planning tool that came about as a result of the National Defense Education Act described above. (So are ABCD objectives.) In its earliest iteration, it was called the "Learning Cycle". The idea is that one lesson should lead into the next . We will see this in the Five E format we use today. We will describe the format, but first we want to identify "Boilerplate" portions of a science lesson plan.

Generic Information included in start of the Lesson Plan:

Date (When the lesson is to be taught). **Class/Grade** (Tell who the students are). **Standards** (Use the standards that apply, such as the Minnesota Science Standards.) **Objectives** (Use ABCD format to inform what your students should be able to do as a result of the lesson.). **Materials** (List everything you will need to have ready and available.) **Safety** (List any safety precautions or concerns.)

First E: Engage

The first E is called the engage segment. This is where the teacher works to prepare the students to be active participants in the lesson. This will be different from what you do in language or reading lessons. In those classes, the teacher is asked to clearly state the objectives of the lesson. **In science, we want the students to learn through the inquiry process where they are not told the outcome in advance.**

The engage portion may be as simple as asking the students to recall a previous lesson. (Who can tell me what we worked on yesterday? Who remembers when we worked with our bean seeds last week?) It could also be question about something new. (Does anyone think it would be a good idea to chew on aluminum foil?). Another approach is to show students a discrepant event. A discrepant event is often a demonstration where the outcome is not what the student will expect to happen. (An example might be to float a paper clip in a cup of water.)

The idea of the engage portion of a lesson is to cause the students to want to be engaged in the lesson. In this portion of the lesson the teacher's role is to create an inviting situation to draw the students in so that will want to participate.

Second E: Explore or Exploration

The second part of a Five E lesson is the exploration part or phase. In this part for phase, the teacher presents a task that is just beyond the abilities of most of the students in class. This task should be something that a small groups can work on independently. This task should be interesting and clear, but not a recipe book, step by step activity. The idea is that if the students have time to try a task, but are not initially successful, they will have a desire to learn what then need in order to complete the task.

One way we show this is with **Batteries and Bulbs**. The explore phase gives student groups one dry cell, one flashlight bulb, and one short wire and asks them to draw diagrams of four ways they can make the bulb light. IN the process, the teacher takes on a sometimes uncomfortable role. During the explore phase, the teacher should not answer student questions about how to do the task. The teacher should monitor the classroom for safety and engagement of the groups. The students role is to be actively engaged in trying to complete the task.

Third E: Explain or Explanation

The Explain portion of a Five E Lesson is when the teacher gathers the students (or gathers their attention) and does some direct instruction of the content necessary to complete the task. In the **Batteries and Bulbs** scenario, the teacher describes and diagrams the way an electrolyte paste transfers electrons from a carbon rod to the Zinc can of a heavy duty dry cell. She/he also "Dissects" a light bulb to show the path that electrons flow in order to complete the circuit and make the filament glow. The teacher can even have the students act out the circuit, by holding hands and passing electrons (plastic chips) from person to person. (The point here is that the explanation phase does not have to be lecture...).

The teacher's role in the explain phase is to provide the instruction necessary for the student to successfully complete the task. The students' roles are to remain engaged and ask questions if something is not clear.

Fourth E: Elaborate

In the fourth phase of a Five E lesson, the students take the content they have just learned and apply it to the original task they were given for the exploration phase. The idea is that the new content they have been given will help the students to complete the task. This phase seems much like the explore phase, but the teacher role is different. **In the Elaborate phase, the teacher circulates among the groups and answers any questions the students have, guiding them toward the completion of the by reminding them of the content that was just presented.** If a group has successfully completed the task, they are given a slightly more advanced task to work on for the remainder of the class time.

Original Size

Image 4: Pre-service teacher s engaged in the the Elaboration phase.

Fifth E: Evaluation

Throughout the entire Five E Lesson the teacher is evaluating. In the Engage portion, the teacher is evaluating the effectiveness of the introduction to the lesson. She/he may need to adjust if the students do not seem to be engaging. In the exploration phase, the teacher is evaluating the students success or lack of success with the task, and watching for signs of frustration. this is necessary for him/her to know when to move on to the explanation phase. In the explanation phase, the teacher is evaluating students" engagement and attempting to evaluate learning. And in the Elaborate phase the teacher can evaluate which students have successfully completed the task. So, Evaluation is an ongoing, continuous process throughout the lesson.

However, it is important to look back to the lesson's objective(s). In the Elaborate phase, the teacher should be noting which students/groups had mastered the objective as part of an informal evaluation of the lesson.

Summary

This chapter is an outline of teaching science as inquiry. It is designed to prepare you for activities in class that will help you learn to plan for and carry excellent science lessons. Dr. Kimori, Dr. Browne, and Professor Sanderson all believe that students need to be actively involved with the science they are studying. The lessons should be **inquiry based** and as hands-on as possible. Both **process and product** will be addressed in science lessons. We believe that the Five E lesson plan format works well for elementary classroom science lessons, though it may need modification for the classrooms in which you teach.

Citations

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Chapter 2: The Nature of Science

Science is a term that elementary students often think of a subject, or a class. Of course, it is that, classes certainly teach about science. **Learning about** science is not the same as **doing** science. Science didn't begin as a class or subject. It began as an attempt to understand and cope with the world. People living in very ancient times needed to understand the world around them. They needed a grasp on the when to expect the snow to begin falling and when it should end. This became meteorology and astronomy. They needed to know how far they could shoot an arrow or throw a spear, physics. They needed to watch the signs the sky gave them about approaching weather, the start of meteorology. **Science came out of people's everyday need to better understand the world around them, and to adapt to it.**

Scientific Disciplines

Science is made of many scientific disciplines. Biology, botany, astronomy, physics, chemistry and geology are all "sciences". Each science focuses on investigating a particular set of "disciplines that help explain our world. In general, there are **two major branches of science**. The first branch includes the **Biological Sciences**, the second has all of the **Physical Sciences**. Additionally, sciences can be broken down into general and applied sciences. **General sciences** are sciences that describe the world as it is. **Applied sciences** are sciences that use what we know to shape our world in some way. General sciences seek pure knowledge. Applied sciences use that knowledge.

Image 1: Field Biologist

Image 2: Harvesting Corn (Agronomy)

So, botanists would be general biological scientists while agronomists would be applied biological scientists.

Scientific Methods and Practices

Scientists in all disciplines seek evidence

All scientists seek evidence. Scientists base their work on evidence. They gather evidence. They do not just gather evidence that helps them prove their own theories, but use the evidence that gather to prove/disprove, modify or shape existing theories. Evidence can mean many different things and can be gathered using differing methods, but evidence is the back-bone of scientific inquiry. So what is evidence? Evidence is how we know something is true. Evidence can mean many different things and can be gathered using differing methods. However, it is gathered, evidence is the back-bone scientific inquiry. **Evidence is the result of predictable, persistent result that can be replicated over and over given the same conditions.**

For the elementary student, this idea might be a difficult to understand. Yet, teachers can build opportunities for students to gather data and analyze it to draw conclusions, creating evidence.

Image 3 Kindergarteners

Even kindergarten students can gather data about the world around them. At daily calendar time children can look out the window to observe the weather conditions and include that "data" on their classroom calendar. This can create a "data set" about which months are the sunniest. In first and second grade, temperature can be added to their "data set" so that they can analyze which months are the warmest and which are the coldest. Precipitation measurements can be added in the upper elementary grades.

There is an interconnection between data and evidence.

Collecting data means collecting evidence. In the earlier weather example, no one piece of data, no one day's observation is sufficient to use as evidence. When many data points are put together over time, a pattern can emerge that "forms" evidence. But, scientists do not rely on a single set of data. They conduct **multiple trials** to ensure that the results they find are reliable.

Image 4: Multiple Trials

They also make sure that their methods are published, so that others can duplicate their procedures and verify their results. This is a vital part of the work scientists do. Reproducible data is an important safeguard against "fluke" and/or fraudulent results. In 1989 two well respected physicists from Utah names Fleischmann and Pons shocked the world by announcing that they had achieved a long sought breakthrough in the quest for cheap, safe renewable energy production, cold fusion. Their claim was truly earth shattering because cold fusion, using water as fuel would mean unlimited energy available to all. Fleischmann and Pons were heralded as scientific heroes...for a while. Unfortunately, no other scientists were able to duplicate their results. We bring up this incident, not to shame the scientists involved, but rather to show why multiple trials and duplicatable results are so important.

Scientific Investigations Use a Variety of Methods.

There are any ways that scientists test their ideas and gather their data. Some work in laboratories doing controlled experiments. Some gather data from the natural world. Yet others comb through data form previously published experiments to analyze what is called meta-data. Some scientists observe in real time, some work with recorded data. Astronomers study a gigantic structures that are so far away that the light they send us can be many millions of years old. Nuclear physicists study extremely small particles "decaying" in a very small space over a tiny fraction of a second.

Scientist sometimes use instruments such as microscopes, telescopes, seismometers, anemometers, hygrometers, and thermometers, mentioning but a few. So, there are many ways that scientists do their work.

What scientists all have in common though is a general method for investigating. The **Scientific Method** is a way of looking at scientific investigations in a way that helps students approach a problem in a scientific way. for the purposes of elementary science classrooms, the Scientific Method can be summarized into six steps. 1) Question 2) Research 3) Hypothesis 4) Experiment 5) Analyze Data 6) Summarize and Publish Results.

Let's break these steps down.

1) Start with a **question**. Ask the student researchers to think of something they want to understand. What are you wondering about that we can study.
2) **Research** the question. This is where the student researcher searches for information to read and digest about the topic being studied. The student needs to be as much of an "expert" on the topic as is appropriate for her/his age in order to write a meaningful hypothesis.
3) Create a **hypothesis**. A hypothesis is an if this/then that statement. *If* I use this detergent *then* the stain will come out. *If* I heat water, *then* more sugar can be dissolved in it. *If* I place one plant in the dark, *then* it will not grow as well as one that gets full sunlight. It is important to note and to stress to students that a hypothesis is not a random guess. It must be informed by prior knowledge. A hypothesis can only properly be properly developed after researching the topic.
4) Plan and carry out an **experiment**. An experiment tests a hypothesis. This is why developing a solid hypothesis is so important. The experiment is designed around the hypothesis. The experiment should be designed with two things in mind. First, the student researcher needs to **identify and control any variables** they can think of. The reason is that properly developed experiments test a single variable, while all other aspects of the experiment remain the same. Second, there must be multiple trials so that the student/researcher can be certain that he/she gets similar results in each trial. This also allows for data to be aggregated, or averaged for easier, more meaningful analysis.

5) **Analyze** the data. This is where the student researcher compares the results of the experimental trials to the hypothesis that was developed in step two. If the data collected support the hypothesis, then it was proven. If the results do not, then the hypothesis is to be rejected and revised for a later experiment.
6) To **summarize and publish** the results, the student researcher should do several things. First, she/he should write an outline of the procedures and materials used to test the hypothesis. This should include a statement of the hypothesis and the research used to develop it. Then, the student researchers should show the raw data collected in each trial. An explanation of the meaning of the data comes next. It should address any outlying data from any single trial, and the aggregate data, usually in the form of the mean of all trial results (for elementary student researchers). It is often helpful for the data to be presented in a graphic format. This might be a simple line graph or bar graph. Finally, there should be a clear statement of the results. Was the hypothesis proven or disproven?

Scientific Knowledge is Open to Revision in Light of New Evidence

One of the biggest ironies about children's understanding of science is that they tend to think that scientists know everything. They have had science trade books read to them since they were very young. Because of this, they begin to think that there is a body of correct knowledge and "science" has right and wrong answers . While this perhaps true in some instances like "The sun rises in the east and sets in the west." it can be harmful to the concept of revision in the light of new evidence.

In essence, the idea of being open to revision when new evidence demands it is central to the nature of science. Scientists are continually revising their theories and understandings based on new evidence. In the last few years revisions about our understanding of Neanderthal man, the number of planets in our solar system, the plight of bees in North America, and the best treatments for many diseases have all been modified as data provided new evidence. Scientists continually revise their theories based on new evidence. When those of us in our sixties were in elementary school, it was believed by scientists that we were heading into a new "Ice Age". This turns out have been untrue. It is not that the scientists were not smart enough to get it right, but the data pointed in the direction of global cooling. New evidence has changed many scientists minds. ere has been a revision in the theory based on new evidence. This has happened throughout the history of science.

Scientific Models, Laws, Mechanisms, and Theories

Scientists use pretty specific terms for the work they are doing. Some of these terms are used in general conversation in ways that are not as precise as scientists would use them. Let's talk about models, laws, mechanisms, and theories. **Models** are ways that scientists try to explain concepts that are difficult to understand as they really are. They are not intended to be "true" representations of what is being described, but rather a way to think about really complex and elusive truths. Examples of models include the "solar system" description of the parts of an atom.

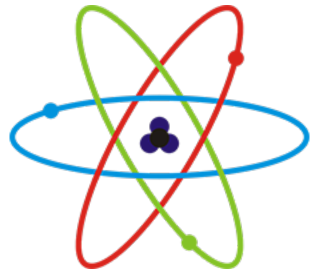


Image 5: Bohr's Model of the atom.

We know that the nucleus of an atom is is way different than the sun. We know that electrons don't follow an orbit like the planets.

Yet, we still think of the atom in this way because the model makes it easier to "locate" the particles in a three-dimensional space than the "electron cloud" seen below. The Electron Cloud model is more accurate according to current theory, but is more difficult for children to visualize.

Image 6: Electron Cloud Model

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

This is a simple statement. However, it is really important to help students understand that the way plants create sugar through photosynthesis (for example) is the same in New Mexico as it is in Mongolia. Scientists believe that their ways of knowing are applicable in all similar situations. Gravity works in today's earth as it did a million years ago. Order is a vital aspect of the scientific mindset. When results don't quite match up, the scientist looks for the reason why.

Scientists would not be able to do this when (for example) water boils at the wrong temperature. Scientists don't chalk differences up chance differences. Rather, the scientist digs in and try to find the reason for the differences. Order and consistency is really important to scientific investigations. This is different from the way we humans interact with each other. When a friend reacts to something in a way that is unexpected we typically chalk it up to differences in personality.

What to Primary Children (k-3) need to know about the Nature of Science?

Primary children are moving through the pre-operational phase (according to Piaget) and moving into the concrete operational phase. This means that they are not ready for abstract reasoning. Since primary students are excited about doing science, they need to be actively engaged in measuring, recording and explaining what they are doing. They need to see that scientists do these things and more. They also need to understand that scientists are always learning. They do not have all of the answers. Primary children need to know that they will be developing skills that will allow them to better explore and think about the world around them.

What do Intermediate Children (4-6) need to know about the Nature of Science?

Intermediate children are firmly into Piaget's concrete operational stage development. Because of this they need a lot of hands-on experiences. These students need to "do" science instead of watching others or listening to an adult. This means that science should be filled with very active experiences for students where they try things out. They also need to begin to think about the measurement and recording aspects of their work. Because they. are working with multiplication and division in math, they can begin to find the mean (average) of multiple trials of the same activity. They can also begin to understand the reason for repeated measures and recognize that outliers can skew data. Intermediate children can begin to do their own experiments based on what interests them. They must be guided to learn the importance of persistence in scientific inquiry.

NATURE OF YOUNG SCIENCE LEARNERS

The next generation science standards (NGSS) provides an opportunity to improve science and lays emphasis on student achievements. In trying to understand young learners, the learning process achievement will not only be determined by test scores but how students are able to interact with nature and question nature. As teachers we should be able to employ strategies that can elicit the young learners to critically examine and analyze phenomena.

We should also understand how the young learners learn from either exposure or curiosity. How do we expose young learners to scientific knowledge? How do we turn learner's curiosity into a scientific learning moment? This chapter explores how teachers can understand young learners to assets to expose them to scientific knowledge and create curiosity in understanding basic scientific concepts,

In this Chapter, we will explore understanding learning process and teaching of young learners, based on theories on how young learners learn. The rest of the chapter will give strategies on how effectively teachers can deliver science content to young learners.

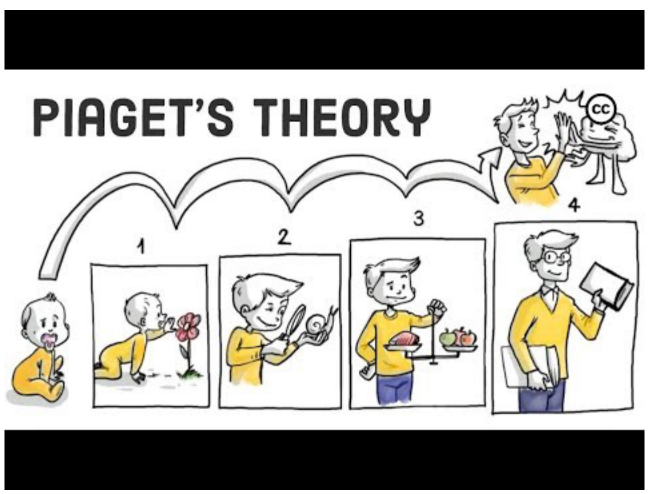
How Children Learn Science

Since time immemorial philosophers and scholars have theorized about how humans acquire knowledge. Educators have reflected on these theories over time. Notable learning theories include Skinner Behaviorism Theory, Piaget's Cognitive Development Theory and Constructivist Theories of learning. In recent decades developmental psychologists have revealed that children are capable of abstract thinking than had been proposed before in Piaget's developmental stages.

To understand these neo-theorists, let's first examine Jean Piaget's Cognitive Development Theory. Piagets development theories have made great contribution to the early childhood education elementary teachers, there are three stages that we should be concerned with:

- The Preoperational Stage:2-7 years.
- Concrete Operational Stage: 7-12 years
- Formal Operational Stage :12 years and older.

For more information on these stages, please watch the video below:



Piaget's Theory - https://www.youtube.com/watch?v=IhcgYgx7aAA

As an elementary teacher, you will work mainly with children at the preoperational and concrete operational stages of mental growth. Learning how children think will help you reflect on what they do and say; and more importantly how they learn science.
The modern cognitive development theories are based on rationalization and empiricism (Kail,2004). These theories are:

1. Domain Specific Cognition Theory
2. Domain General Cognition Theory
3. Situated Cognition Theory

Let's now examine each of the following in depth:

1. Domain Specific Cognitive Theory

This theory proposes that we have innate ability to think from the beginning of life and that we acquire knowledge by reasoning alone (Rivian,2012). Researchers Elizabeth Sperke and Susan Carey have carried extensive laboratory studies of responses by infants and young children to testing events. Domain Specific Theory proposes that core systems of thinking and knowing are innate and begin during infancy and begin to develop throughout their lifetime. However; in Spelke's view, their presence at birth can only be inferred (Spelke & Kinzler,2009).

2. Domain General Cognition Theory

This theory proposes that all knowledge starts with experience and evidence from the senses rather than building on innate ideas alone. Domain General Cognitive Theory identifies cognitive strategies and mechanisms that even infants begins to use ;like doing cause/effect thinking about their physical world and trusting the effect of their actions on the actions of others (Gopnix, Meltzoff & Kuhl,1999).According to Domain General Cognitive Theory recognizes that adults have a big role in promoting children's cognitive development.

3. Situated Cognitive Theory

This theory states that all knowledge is part of the wider social and physical environment, which shapes an individual's thinking, knowledge, attitudes, motives and skills (Duschl, Sweingruber & Shause,2007).

Learning Science in Early Years

For children to learn the content, disposition and processes in science teachers need to device and understand ways to help children better. The National Association for the Education of Young Children (NAEYC) gives out the skills young learners should have as to be able to:

A kid exploring in a Classroom

· Raise questions about objects and events around them,
· Explore materials, objects and events by acting upon them and noticing what happens.
· Make careful observations of objects, organisms and events using all their senses
· Describe, compare, sort, classify and order in terms of observable characteristics and properties.
· Use a variety of simple tools to extend their observations (e.g. hand, lend, eye droppers, etc.)
· Engage in simple investigations including data investigations including making prediction, gathering and interpreting data, recognizing simple patterns and drawing conclusion s.
· Record observations, explanations and ideas through multiple forms of representation.
· Work collaboratively with others, share, discuss ideas and listen to new perspectives (NAEYC,2001 p.24).

For an elementary teacher to help young learners with these skills they will need to understand how young learners learn and best strategies to use in learning process.

Some of the well-researched strategies that can work well with young learners are:
· Guided Discovery Learning
· Inquiry
· The outdoors as context for learning
· Guided Explorations.

Guided Discovery Learning

Guided discovery learning involves helping young learners know about the physical world by organizing materials so that they can explore, question, reason and discover answers through their own physical and mental activity. Discovery learning emphasizes how to find answers and what can be learned (Harlan & Rixin,2012). To learn more on guided discovery learning please watch the video below:

https://www.youtube.com/watch?v=QjBomAG63L0

Inquiry

Inquiry allows students to focus on a special phenomenon with a deep a focus to question and explore ways answer the focus question. Inquiry allows students investigate a given phenomenon further with a lot openness and flexibility. The teacher needs to encourage the young leaders to explore their curiosity.

Outdoors as context for Learning

Most children in the US send their time indoors. Providing outdoors opportunities to students gives them a renewed experience and can be used as context for learning, it is through this outdoor environment that children can learn about plants, animals, the weather, ecosystems.

By providing different contexts of learning, the children can relate to the knowledge context learned in the classroom and what they experience outdoors. This not only promotes their understanding but also promotes their memory retention.

A 2nd grade kid experiencing outdoors

In the next chapters, we will explore how we can utilize these theories of learning and understanding on how we can apply theories of learning and the understanding of how children learn various topics in life science in elementary grades.

Reflection Questions:

1. Write down your memory of elementary science experiences. From your narrative list which of these experiences were hands-on, which ones were memorization and which ones were outdoors? What makes you remember one more than the other?
2. What can elementary teachers help children grow their science knowledge throughout elementary school?

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Chapter 3: The Basic Building Blocks of Life.

This chapter will focus on what makes up living things. It is a general overview and will focus on characteristics of living things, the classification system we use for plants and animals, and the systems that makeup animals. It will follow the progression from the smallest parts of animals and builds to the whole organism. There will be more of a focus on plants in a different chapter.

Organic/Inorganic. Alive or Not Alive

In today's society, the term organic is most commonly used as an advertising tool. We most often hear the word used to describe agricultural practices that are less dependent on artificial chemicals in the production process. So, there are several ways to correctly use the word Organic. In one way we are speaking here means "Relating to or derived from living matter." Organic material is alive or is made from things that were once alive. Mushrooms are organic matter. So is a coconut.

Image1: A cow and her calf are made of organic material.


Image 2: Cows produce organic wastes.

Bones are organic materials, as are hair and fur. What do you think about chalk?


Image 3: Chalk cliffs above Dover, England.

Attributes of living things

When we ask children what makes something a living thing, a likely response is that it is not dead. Yet, there are more systematic ways to define what a living things are. This is something we can teach to elementary children. We have chosen to highlight seven characteristics of living things, though you may find lists that differ from ours.

1) **All living things move** in some way. This can be a tricky concept for children who may not see movement in a shelf fungi.

Image 4: Even fungi move as they grow.

Even though we can't see it all living things move at the cellular level. This means trees and fungi that don't move "around" still can have movement within.

2) **All living things grow and develop.** Living things, even single celled organisms, grow and/or develop. It is easy for children to see this in chicks and bean plants.

Image 5: Foals grow up to be horses.

Children can tell you that foals grow into horses. But, what about amoebas? Children may find the concept of microscopic organisms growing or developing. This is probably beyond their focus, but even single cell organisms "mature" over time.

3) **All living things respond**. Every organism will respond to some type of stimuli. Most animals respond to their environments in visible ways. Children get "goosebumps" when they feel a cold breeze. Plants grow toward a source of sunlight. You hear a certain combination of note and reach for your phone. There are many more obvious examples.

4) **All living things reproduce**. Children are aware that animal babies match their parents. They know that rabbits have rabbit babies that grow into rabbits. They also know that plants reproduce through seeds. They may not know about the spores that spread fungi and ferns. The probably are not aware of asexual reproduction of single cell organisms.

5) **All living things use energy**. Every living thing gets energy from its environment. Some, such as green plants, can turn energy from the environment (sunlight) directly into energy. These are known as "producers" because they can produce energy directly from the environment. Others, such as insects must get their energy from other organisms. These are called consumers because they must consume a portion of another organism to get the energy they need to survive. Some consumers eat other consumers, such as bats who eat mosquitos, or brown bears who eat salmon.

Image 6: Brown Bear walking a river in Alaska.

6) **All living things rely on some form of cellular structure**. Living things are made up of cells. Some organisms are made of billions of cells, while others are made of only one. Cells are thought of as the basis for all life. They contain structure (organelles) that carry out functions necessary for their survival. In single cell organisms, all f the life processes are achieved in a single cell. More complex organisms have specialized cells such as nerve cells that have specific functions and would not survive on their own.

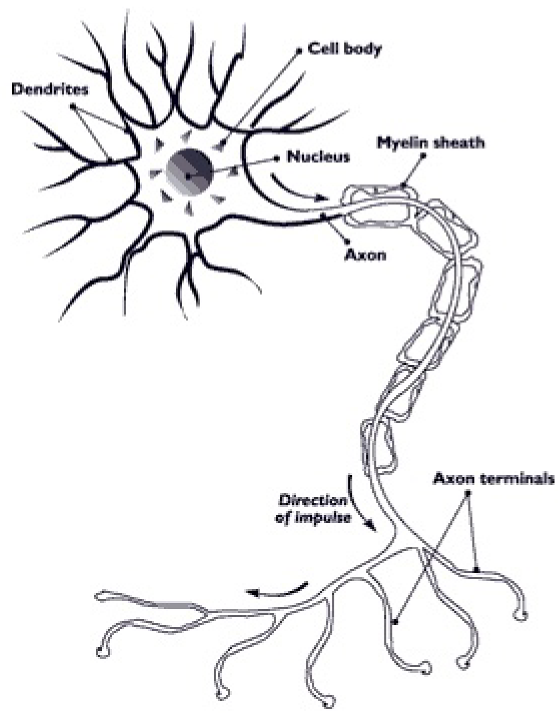


Image 7: Diagram of a nerve cell.

More will be discussed about cells later in this chapter.

7) **All living things eventually die.** This is one of the things children will tell you is true of living things. Eventually everything dies. Certain insects have very short lives, measured in days. Some trees live for hundreds of years. But, eventually even these giant trees die. There are giant masses of underground fungi that have been growing from a single spore for as long as ten thousand years! But eventually these will also die.

Producers, Consumers, and Decomposers

As stated above, all living things use energy. Organisms can be divided into categories that describe how the get the energy they use to live. The first of these categories is **Producers**. Producers are organisms that can create their own energy by converting solar energy onto chemical energy through **photosynthesis**. Photosynthesis occurs as chlorophyll uses energy from sunlight to recombine the carbon dioxide and water into glucose and oxygen. All green plants are producers and are responsible for all food that exists on earth. This is because **Consumers** eat producers directly, or eat other consumers that have eaten producers. Animals are consumers. Some are *first order consumers,* or herbivores, who eat plants. An example of a herbivore would be a cow, which eats grass and other plant materials. Others are s*econd order consumers* which eat other consumers that are herbivores. *Third order consumers* eat second order consumers. In this way, plants, or producers are the foundation which feeds the entire food web. Food webs will be addressed in great detail in class. The third category of organisms are **decomposers**. These are organisms that get their energy from rotting plants and animals. Mushrooms, bacteria, and earthworms are examples of decomposers. Some consider **carrion eating scavengers** such as vultures and raccoons as decomposers, but they can also be considered consumers.

Classifying Plants and Animals

While there have been classification systems going back to ancient times, eighteenth century Swedish Botanist Carl Linnaeus is considered by most as the fonder of our modern classification system. There have been "tweaks" to this system over time, but Linnaeus' developed a binomial system that organized plants and animals into ever narrower (smaller and more similar) groups. We are not going into the details here, but the progression is from:
Kingdom to **Phylum** to **Class** to **Order** to **Family** to **Genus** to **Species.**

This video describes this system.

Video 1: Description of the Taxonomy System

(Click on the image or the link below.)

Taxonomy, Classification of organisms - Bing video

Parts of Living Things

We have looked at the system of organizing plants and animals. Now let's examine an organism from the smallest parts to the largest.

Cells

Cells are the smallest intact building blocks of living things. There are big groups of cell types, Prokaryotes (with no nucleus) and Eukaryotes which have a nucleus and organelles inside each cell. **Plants and animals are all eukaryotes**, having nuclei and organelles inside their cells.

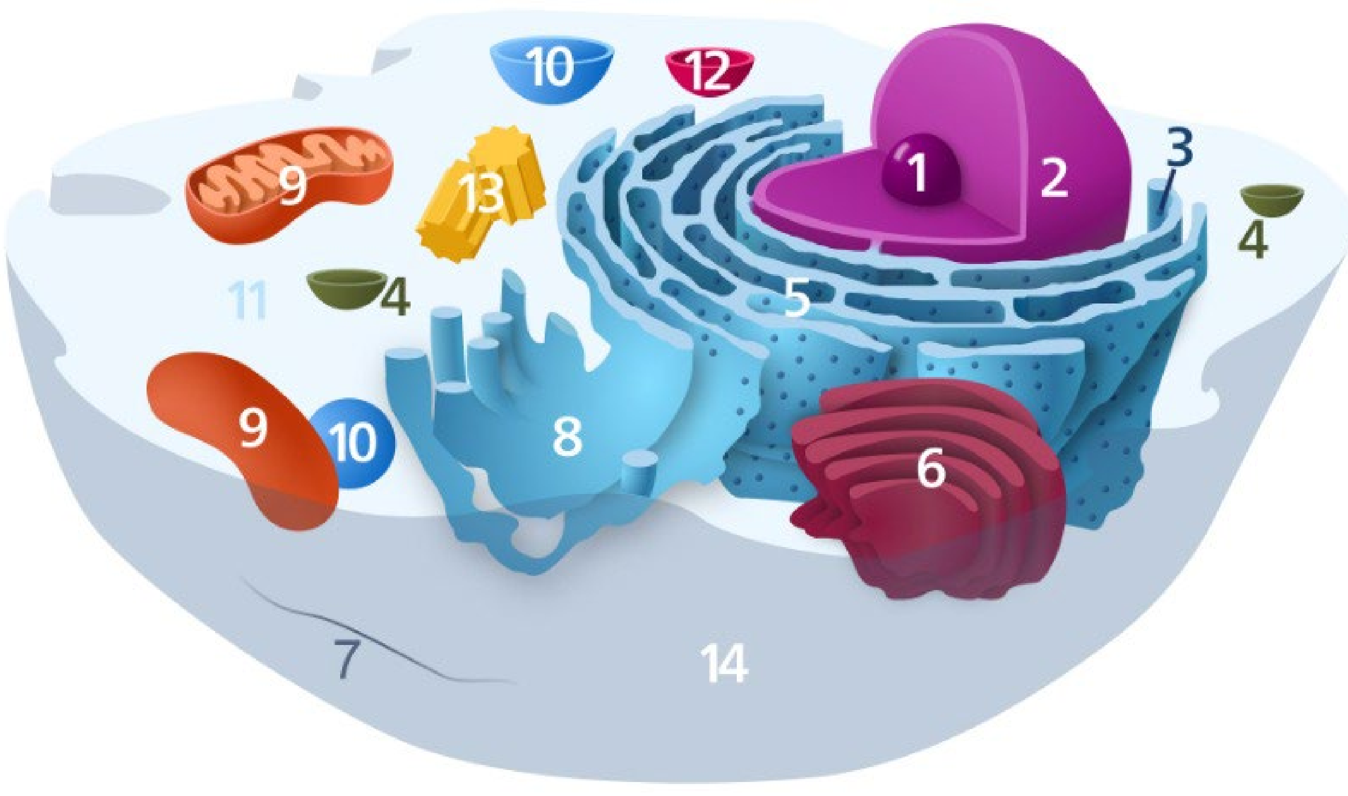


Image 8: Diagram of a Cell

Components of a typical animal cell: 1. Nucleolus   2. Nucleus   3. Ribosome (little dots)   4. Vesicle   5. Rough endoplasmic reticulum   6. Golgi apparatus (or "Golgi body") 7. Cytoskeleton   8. Smooth endoplasmic reticulum   9. Mitochondrion   10. Vacuole   11.   Cytosol (fluid that contains organelles, comprising the cytoplasm)   12. Lysosome   13.Centrosome 14. Cell Membrane

But, they differ as **plant cells have a cell wall** that animal cells do not. The organelles contained in eukaryote cells include:

Nucleus which contains the genetic information in complex molecules called RNA and DNA.

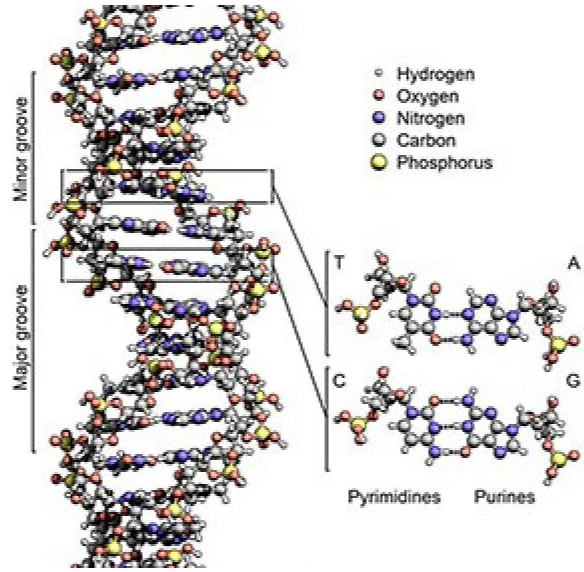
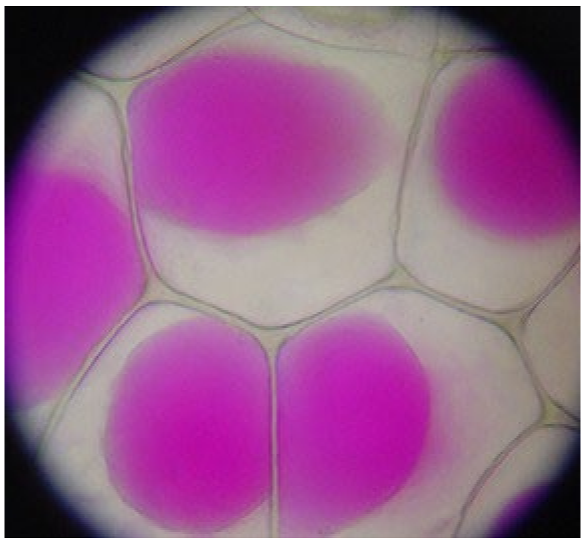


Image 9: DNA structure

Mitochondria the powerhouse of the cell, where fuels such as glucose are "oxidized".

Image 10: Cells

Endoplasmic Reticulum which is a type of transport system for moving materials around in the cell. **golgi bodies** which build and process the complex materials made by the cell. **Vacuoles**, the structures that trap wastes and store water for the cells. (In the photo below, the vacuoles are purple.)



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There are other minor bodies which we will be investigating in class.

Tissues

Tissues are groupings of specialized cells that have grown together to form a specific function. Tissues are not organs but can be parts of organs. There are nerve tissues throughout the body, all am part of the nervous system. There are tissues that form the nephron tubes which are a part of the organs we call kidneys.

Organs

Several types of specialized tissues together form the organs we find in animal bodies. There are many organs which make up the body. Some of these are the heart, lungs, brain, liver, stomach, kidneys, and pancreas. There are of course others. We will be looking at these organs in more detail in class. There are organs we seldom think of, such as our skin, which is perhaps our body's largest organ.

Body Systems

There can be multiple organs in a body system. The heart and lungs, along with the arteries, veins, and capillaries make up the cardiovascular system. The mouth, stomach, pancreas, large and small intestines are all a part of the digestive system. It is worth noting that some organs are a part of multiple body systems. The lungs for example are the most obvious part of the respiratory system. Yet, because they are responsible for expelling carbon dioxide, they can also be considered a part of the excretory system. There are several lists of body systems, but for elementary students we can stick to the list suggested by the mnemonic **Dr. MicSneer**. Using the letters in **Dr. MicSneer** we get the following list of body systems:
Digestive; **R**espiratory; **M**uscular; **I**mmune **C**irculatory, **S**keletal; **N**ervous; **E**ndocrine; **E**xc retory; and **R**eproductive. Of course, this is a simple list that does not address all of the functions of the body. It is a generally accepted list for an elementary curriculum, however. We will also be working on body systems these in more detail in class.

Individual Organisms

So, cells form tissues, which combine into organs, which interact as complex body systems. The progression is from the simple to the more complex. Organisms are able to live on their own. Many organisms are single celled, so they have no tissues, organs or systems as described above. They carry out all necessary functions of life within their single cell. Multi cellular organisms rely on the tissues, organs and body systems to some degree.

Many multicellular organisms can survive as individuals, but are more likely to thrive in groups. Some are highly social organisms such as humans, bees and ants.


Image 12: Leaf cutter ants carrying leaf material to their nest.

Leaf cutting ants chew bits of leaf from trees and carry them to underground nests where they are used to cultivate fungus which becomes the colony's food supply. Other than humans, they create the most complex social organizations of animals on earth.

The benefit of living with similar individuals also extends to plants. The Quaking Aspen form vast groves of genetically identical plants made up of thousands of individual trees. These large groves discourage different plants from growing among the Aspens, competing for resources.


Image 13: Aspen

There are different types of relationships that occur between organisms. The general term is symbiosis, which refers to two or more different types of organisms living together in close proximity. There are **different categories of symbiotic relationships**. Some are **mutually symbiotic**, meaning that there is a mutually beneficial relationship and app parties "win". Sharks and pilot fish are an example of this type of relationship. This is also called **mutualism** where both organisms benefit. The second, where one organism benefits, but the other neither benefits nor is harmed. The third category is **parasitism**, where one organism benefits while the other is harmed. The final is type of symbiosis is **competition**, where both organisms seek to use the same resources.

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Chapter 4:Plant Life

This chapter is about plant life. Plants are the foundation for all life on earth as they are at the bottom of any food chain or web. In this chapter, we will examine the common structures most plants share; why plants are producers; the many and varied types of plants; and how plants are used by humans.

Plant Parts

There is an amazing variety of plant life on the earth. This is vital to all life because plants provide the vast majority of the energy needed to support life that comes directly from plants. This occurs as the plants produce their own energy sources through the process of photosynthesis, converting sunlight, carbon dioxide and water into glucose. This process allows plants to grow, they in turn provide food for all of the animal life on the earth. Later in this chapter, we will discuss the variety of plants found on earth.

Vegetative Structures

While the great variety of plant life is amazing, the basic structures found in these different plants are remarkably similar. Almost all plants have the following vegetative structures: stems, leaves, and leaves. While they might not look similar, most all plants have at least one stem. Some have several. The stem can be a very slender structure in plants such as asparagus or quite stout as in the redwood.

Image 1: Asparagus


Image 2: Redwood

The function of stems can differ from plant to plant, but in general stems do the following: support the plant and place the leaves is the best place to collect sunlight; allow water, food, and other nutrients to move between parts of the plant; produce new living tissue (as in wood) and possibly store nutrients. Stems are often located above the ground, but some are below. Some stems store water, such as the stem of the barrel cactus. Some stems grow from year to year, typically in bushes and other woody plants. Others die off in autumn.

As almost all stems have some sort of stem, they also have leaves. This is extremely important because it is the leaves that do most of the work of photosynthesis. Like stems, leaves come in a great range of shapes and sizes. Pineapples and palms have relatively large leaves, while clover have leaves that are quite small.


Image 3: Variety found in leaves.

We know that leaves are the "factories" that produce most of the glucose that fuel plant growth. Almost all stems eventually lead to leaves. These leaves form on special structures on the stems, called "nodes". Deciduous trees which drop their leaves in the fall of the year, develop new leaves each spring from nodes that have been waiting for conditions to be right to "awaken" in the spring.

The final of the common vegetative structures in plants are the roots. Roots are found on almost every plant. They have a couple of major functions. **First, roots anchor the plant.** They work their way down into the ground and spread to help the plant withstand wind and rain by anchoring the plant in place. Some plants have root systems that grow very deep, while others are more shallow, spreading just below the ground. The other major function of roots is to **draw water and nutrients into the plant.** Most roots are found at the "ground end" of the plant's stem(s). However, some climbing plants will have roots that grow from the stems above ground to anchor the plant to an external support structure.

Image 4: Ivy roots growing from the stem.

Reproductive Structures

For elementary students, the reproductive structures of plants are typically described as flowers and fruit. There are spore bearing plants such as ferns whose reproductive structures are found on the underside of their leaves. These "sporangia" produce spores which can grow into new fern plants.

Image 5: Ferns

Other plants are called seed plants. There are two types of seed plants, conifers and angiosperms. Conifers, like pine trees, are cone producers. Each conifer produces two types of cones, seed coned=s and pollen cones. The pollen cones produce the pollen which is air-borne and falls into the seed cones to pollenate them, allowing new seeds to begin growing when the conditions are right. Anyone who has been in areas with a large amount of pine trees would see yellow pine pollen on ground and especially on the water in early summer when the trees are developing seeds.

Image 6: Pine Cones

Flowering Plants (Angiosperms)

Flowering plants are the main focus in the elementary science curricula. There are several reasons, including how familiar flowers are to most children and teachers. Also, there are several flowers that are large enough to allow young children to see the reproductive structures. In the diagram below, the major reproductive structures of flowers are labeled.

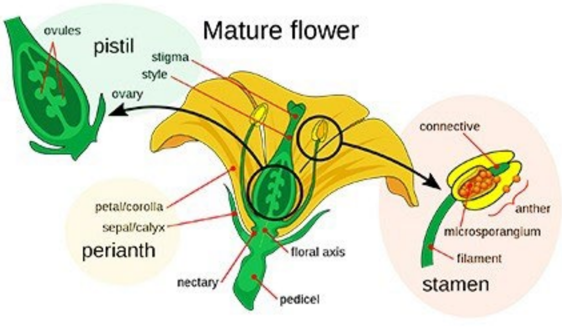

Image 7: Diagram of a flower.

The structures in a flower can be broken into three separate catergories: the Perinath; the Pistil; and the Stamen. The **Perinath** is the part of the flower that does not directly produce reproductive cells . It consists of sepal and the petals. These parts help to protect the pistil (female structures) and stamen (male structures). The petals, also known as the corolla, also help attract pollenating insects and birds.
The **Pistil** is the female portion of the flower. The bottom of the pistil contains a widened area called the ovary where "placentas" produce the ovules which can be fertilized by pollen. Pollination occurs when a bee, or other pollinator, picks up pollen from a flower and rubs it against the upper portion is pistil called the stigma. The stigma is attached to the ovary by the style. When pollen is attached to the stigma, it grows, "pollen tubes" that grow through the style to reach the ovary and fertalize the ovules, which grow into seeds.
The **Stamen** is the male portion of the flower. The stamen grows on a stalk called the filament. The top is the anther, inside which is the microsporangium where pollen grains are produced. This pollen is collected on the anther where pollenating insects and birds "gather" the pollen accidentally as they seek the nectar for food.

This is a very generalized and simplified account of the parts of a flower. It should be remembered that flowers are reproductive structures. Their purpose is to attract pollenating agents to move pollen form flower to flower, fertilizing the seeds.
Some flowering plants produce fruit when fertilized. There are at least two ways that fruit is advantageous to the plant. First, the fruit provides organic material which when rotting provides essential nutrients for the baby plants as they grow. A second purpose is to help disperse the seeds. An apple that falls from a tree may be eaten by a horse. The seeds will survive the horse's digestive tract and be deposited by the horse some distance from the tree.

Photosynthesis

There are actually a few types of plants called parasitic plants that do not produce their own food. The vast majority of plants use **chlorophyl** (a complex chemical that is contained in specialized organelles in plant cells found in the stems and leaves) to convert carbon dioxide and water into glucose and oxygen. Chlorophyl is the green compound that gives plants their green leaves. It is contained in **chloroplasts** which are found in cells in the leaves and also the stems of green plants. This process uses sunlight for the energy to split the molecules apart and rearrange the atoms.
Elementary students are typically not ready to understand the chemistry involved in photosynthesis, except in very simplified ways.
Here is a simplified explanation:

- CO_2 is carbon dioxide. It has one carbon atom and two oxygen atoms.
- Water is H_2O. Each water atom has two hydrogen atoms and one oxygen atom.

- In photosynthesis, sunlight activates the chlorophyl to rearrange CO_2 and H2O to create glucose ($C_6H_{12}O_6$) plus O_2 (oxygen).
- It takes **six CO_2 molecules** to provide the six carbon molecules needed for glucose (**C_6**$H_{12}O_6$) Note: there are 12 Oxygen atoms left over from the CO_2.
- It takes **six H_2O** molecules to provide the **twelve hydrogen atoms** and **six oxygen atoms** needed for glucose. (C_6**$H_{12}O_6$**)
- The twelve "extra" oxygen atoms from the CO_2, form six O_2 (oxygen molecules).
- So, through photosynthesis six CO_2 molecules and six H_2O molecules recombine to make one glucose molecule ($C_6H_{12}O_6$) plus six O_2 molecules.

This may seem complicated. It is actually much more complicated that this simplified explanation. But, it is important for you as a teacher to have a general understanding of the process. In class, we will be showing you ways to deal with this complex process in ways that are easier for elementary students to understand.

Variety of Plants

Earlier in this chapter, plants were divided into two groups, spore bearing and flowering. Actually, we can add to this list.

Algae: There are thousands of kinds of algae, found all over the world. Algae can be single cell green algae such as the algae that makes so many Minnesota lakes green in the summer. It can also be giant brown algae which includes giant kelp which can grow up to 250 feet tall. (See Below)

Image 8: Brown Algae

Liverworts: Liverworts are small, simple plants that live in very damp areas, such as in the rainforests of northwest Washington state, or along waterfalls. They are small and lack the vascular structures found in flowering plants. (See Below)

Image 9: Liverwort

Mosses Misses are closely related to liverworts. The live in very damp areas. Sphagnum Mosses can even grow on top of water. Mosses are more complex than liverworts in that they grow through special structures similar to stems and not out in all directions. (See photo below.)

Image 10: Mosses

Ferns Ferns were discussed earlier in this chapter. Ferns are vascular, spore bearing plants. There are many varieties of ferns found in damp cool climates.

Cycads Cycads are somewhat exotic plants for those living in cooler climates. They have woody stems and long slim leaves. Their seeds are formed in cones.

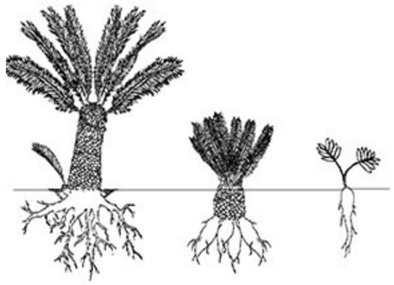

Image 11: Cycads

Ginkgo Ginkgoes are trees. They seem to be "living fossils". This is because the fossil record contains Ginkgoes that seem to be identical to modern examples. Some scientists feel that the Ginkgo used to be a very wide-spread tree, covering large areas of the world. It is also believed that all flowering plants are descendants of the Ginkgo.

From:By Toshihiro Matsui, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=51392057

Conifers Conifers were mentioned earlier. They are seed bearing plants that are similar to Cycades because they have woody stems and seed cones. However, they live in cold northern climates. They are shaped in a way that easily sheds snow cover.
Flowering Plants Flowering plants were also mentioned earlier. They are what many young children will think of when you mention plants.

Uses for Plants

Children can learn a lot about how plants are used. Foods, fuels and materials all come directly or indirectly form plants.
Plants and Food All foods come form plants. Whether a person is a vegan, or a serious carnivore, the food we eat all begins as plants. Of course, fruits, grains, and vegetables are obviously plant foods. Chicken, pork, beef all eat feed made form plants. Fish eat water plants or other creatures that eat water plants. Without plants, we would eventually run out of all foods.

Fuels It is easy to see how ethanol comes from plants. Yet all coal and oil also comes from ancient plants. Coal and oil here formed when ancient forests died out and were over a very long time covered by soil. Over millions of years, the heat and pressure put onto the ancient plant matter compressed it into coal, oil and gas, which we use for all types of fuels. Wood and other biomass is also being used for fuel.

Materials Plants are also used to make all kinds of materials. We use plant fibers for cotton thread and cloth. We use wood fivers to make paper. We use sap from the rubber tree to make tires.

This chapter has been an overview of the "Plant" related content that might be addressed in an elementary school science curriculum. In class we will be working with you to work on ideas you can use to teach these concepts to elementary student of all ages.

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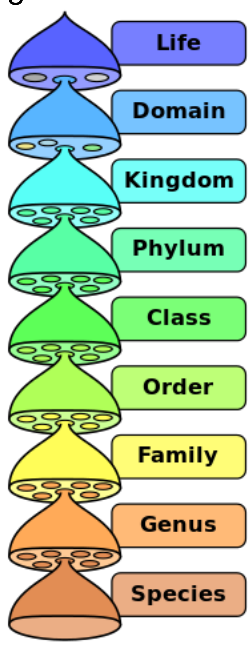
Chapter5: Animal Life

In this chapter, we are going to discuss animal concepts. Children are always curious to learn about animals, but some are also anxious about animals. In this chapter, we will examine the best ways to teach animals concepts to curious students with accommodation to anxious students.

Classification of animals

There are about 1,000,000 different types of animals on earth. They have different features and sizes ranging from microscopic organisms to large animals like whales.

Scientists classify animals according to a classification system that groups animals into:



1. Kingdom
2. Phylum
3. Class
4. Order
5. Family
6. Genus
7. Species

In elementary level we generally group animals into two groups:

I. Animals with backbones(vertebrates)

II. Animals without backbones(invertebrates)

Let's now investigate these two categories into more detail:

I. Vertebrates:

Vertebrates are animals that have backbones. Generally, children are mostly familiar with vertebrates and they mostly refer to them as animals. Vertebrates make up to about 5% of the total animal population on earth. There are five classes of vertebrates:

1. Mammals
2. Birds
3. Reptiles
4. Amphibians
5. Fishes

Let's now investigate characteristic features of each of these classes:

1. Mammals

Mammals represent the most advanced life forms on earth e.g. human beings, dogs, cats, lions, elephants, bats, etc.

Picture of lions

Characteristics of Mammals

1. All mammals have hair on their bodies
2. Both male and female mammals have mammary glands
3. They have the highest levels of intelligence than all animals
4. Mammals give live birth to young one except the spiny ant eater and duck-billed platypus that lay eggs.
5. They are warm blooded. Their body temperature stays relatively same through variations of warm and cold air.

6. Their heart has four chambers
7. They have modified teeth to suits on how and what they eat

Picture of platypus an example of mammal that lays eggs

2. Birds

Birds are also known as aves or avian dinosaurs

Characteristics of birds

1. They have feathers covering their bodies
2. They have toothless beaked jaws
3. They lay eggs with har shells
4. They have metabolism rates
5. They have a heart with four chambers
6. They have strong but light skeleton

Birds can fly because

- o They have hollow bones
- o They have streamlined bodies.
- o They have flight feathers

Birds also have a good hearing and eyesight but don’t have a good sense of smell or taste. The bird’s beak and feet are structured to support their feeding and where they live. Birds use their beaks for scooping or digging for food and they use their legs for swimming, grasping or holding prey.

Picture of red-tailed hawk

3. Reptiles

Reptiles include animal like snakes, lizards, alligators, crocodiles, turtles.

Characteristics of Reptiles

1. They have dry scaly skin
2. They have lungs
3. They are cold blooded
4. Their heart has three chambers
5. They lay eggs
6. They are most commonly found in warmer regions and will hibernate below ground during wintertime.

Picture of a lizard

4. Amphibians:

Amphibians are animals that mostly spend their time in water and partly on land. Examples include frogs, toads, salamanders, etc.

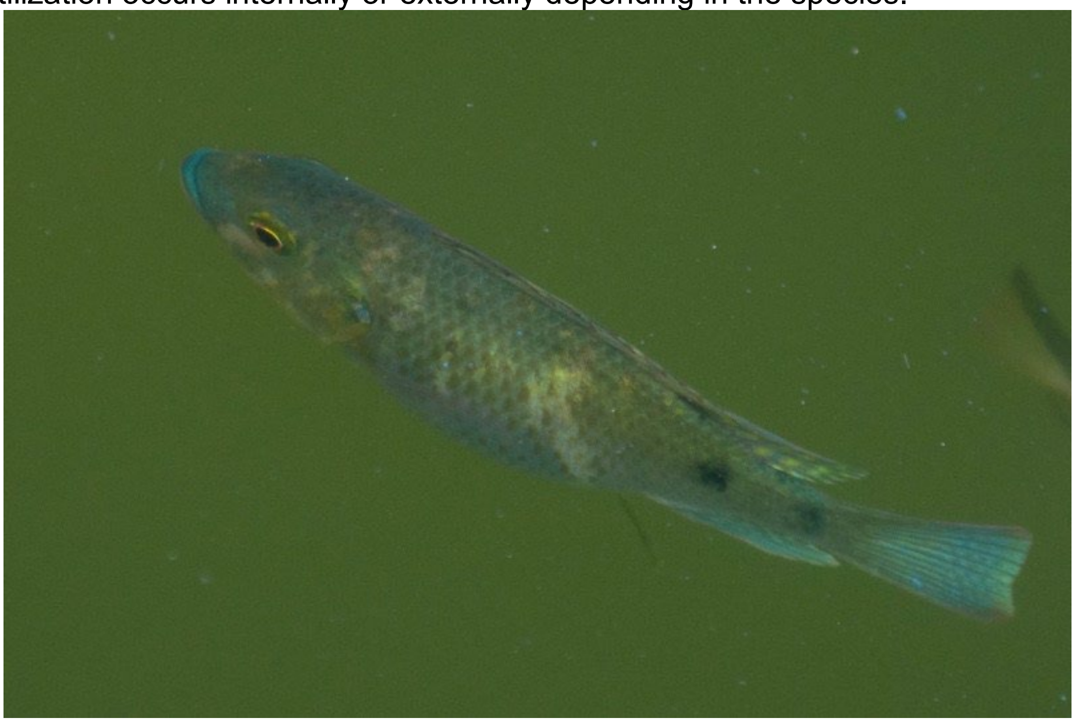
Characteristics of amphibians

1. They are coldblooded
2. They lay eggs but the eggs are fertilized externally
3. They go through growth stages of development called metamorphosis e.g. the frog goes through egg to tadpole to adult frog.

Picture of a frog

5. Fish
Fish are gill bearing aquatic animals that have limbs without digits

Characteristics of Fish
1. They are coldblooded
2. They have hearts with only two chambers
3. They breathe through gills instead of lungs; by opening and closing their mouth to allow water to pass through their gills
4. They have streamlined bodies and fins to suit the aquatic environment.
5. Their eyes have no eyelids
6. They have no external ears, but rather auditory capsules in the ear that aid in hearing
7. Fertilization occurs internally or externally depending in the species.



Picture of a fish

II. INVERTEBRATES:
Invertebrates are animals without a backbone. They make up about 95% of all animal population. These include insects which make up 70% of all animals.
o Invertebrates are mostly important for agricultural pests, parasites or agents of transmission of parasitic infections to humans and other animals.
They also serve as a source of food for humans and other animals.
There are many groups of invertebrates like crustaceans, snails, earthworms but we will only look at the characteristics of insects.

Characteristics of Insects

1. Insects have jointed legs and segmented bodies: head, thorax and abdomen except spiders.
2. They have external skeleton made of *chitin,*a tough and protective fibrous covering.
3. Insects shed outside covering from time to time to allow growth
4. Insects survive successfully because:

a. They can fly to access a wide range of food

b. They have compound eyes for a wider field of view

c. They have a small body size that enables them to get adequate shelter as needed

d. Quick reproduction rates

5. Insects grow through growth stages in their life cycle.

Picture of Texan long-legged fly

Reflection Questions:

1. What are the reasons that make the insect population stable and high all the time? Give 3 reasons
2. Match the following animals with the correct category in which they belong.

Premise	**Response**
1. Frog	A. Amphibian
2. Hornbill	B. Mammal
3. Lizard	C. Reptile
4. Bat	D. Bird
5. Shark	E. FISH

3. As an elementary teacher, what factors should you consider before bringing animals to class or keeping an animal pet in your classroom?

Chapter 6: Biomes and Ecosystem

In the previous chapters, we explored plant and animal life and how they adapt to various environments they live and grow in. Helping young children to understand various ecosystems and giving them opportunities to explore and play in the environment nurtures their lasting affection to nature and the systems that surround them.

Defining ecology

Ecology can be defined as the study of interactions between living things and their physical environment.

Defining ecosystem

An ecosystem can be defined as a composition of living and non-living things that interact with each other and their surroundings. Ecosystems can be as large or small. Examples of a large ecosystem include the Sahara Desert while an example of a small ecosystem can be a puddle. Climate, weather, and other geological factors also affect the relationships and interdependence within the ecosystem.

Biomes

A biome is created from related ecosystems combined.

Major Ecosystems include:

1. Desert

2. Rainforest

3. Ocean

4. Coniferous forest

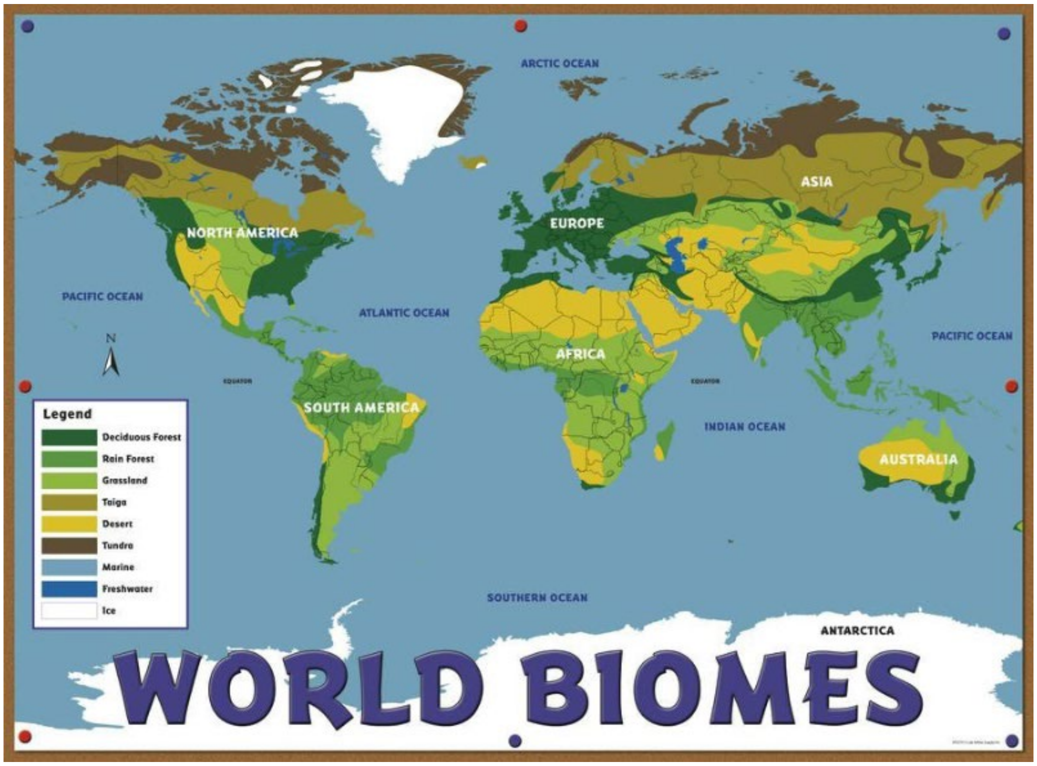
5. Tundra

6. Mediterranean forest

7. Grassland

8. Temperate forest

The map below shows the world's major ecosystems



Source: https://i.pinimg.com

1. Desert

Deserts are areas of land that are arid, or dry, and get less than 10 inches of rain per year. These areas can be covered by sand, rock, snow, and even ice. Additionally, they do not have a lot of vegetation cover. Deserts' ecosystems cover approximately 25% - 30% of the land on Earth. Deserts can be divided into two main types: hot and cold.

Hot Deserts

Hot deserts are warm year-round and very hot in the summer. During the day, temperatures often reach over 100 degrees Fahrenheit. In the evening, the temperatures drop sometimes below freezing. Much of the time rain does not fall, but when it does, it is only for a short amount of time. The ground is usually rocky or sandy.

Most of the hot deserts in the world are located just north and south of the equator, where it is the hottest. The largest hot desert is the Sahara Desert in northern Africa. Other well-known hot deserts include the Arabian, Mohave, and Sonoran deserts.

Pink Coral Sand Dunes National Park in Utah is a small desert surrounded by a forest

Cold Deserts

Cold deserts are cool year around with very cold temperatures in the winter. Temperatures in cold deserts are often below freezing. Heavy snows happen during the winter, with most of the rainfall happening during the spring months. The ground can be solid ice in colder temperatures and rocky or spongy soil in milder temperatures.

The cold deserts of the world are mostly located on the coasts near oceans and closer to the north and south poles. The largest cold desert, and the largest desert in the world, is the continent of Antarctica. Other cold deserts include the Gobi, Great Basin, and Namib Deserts.

Antarctica is a desert, but there are no camels or sand dunes.

2. Rainforest

Rainforests thrive on every continent except Antarctica. Tropical rainforests are found in regions that lie near the equator. Tropical rainforests are found around the Amazon River in South America and the River Congo in Central Africa, the tropical islands of Southeast Asia, parts of Australia, North America's Pacific Northwest and Northern Europe.

"Rainforest Gully" by Doug Beckers is licensed under CC BY-SA 2.0

3. Ocean

Oceans covers cover most of the earth's surface and they form home to millions of aquatic plants and animals. The main oceans on earth surface include: The Pacific Ocean, Indian Ocean, Atlantic Ocean, Arctic Ocean and AntarcticOcean. The ocean water mass covers about 70% of the earth's surface extending to an average of 2.4 miles deep.

"Ocean" by The Sands Kenya is licensed under CC BY-NC 2.0

4. Coniferous Forest

The coniferous forest is also known as a taiga. It is a forest of the cold, subarctic region. These forests are located typically between the temperate forest biome and the tundra biome which is largely the Arctic Circle. The largest coniferous forest covers much of northern Russia, Siberia, Canada, Alaska, Scandinavia, Finland, Norway, and Sweden.


"the taiga sleeps tonight" is licensed under CC BY-NC-ND 2.0

5. Tundra

Tundra ecosystems are treeless regions found in the Arctic and on the tops of mountains, where the climate is cold and windy, and rainfall is scant. Tundra lands are covered with snow for much of the year, but summer brings bursts of wildflowers.

"Tundra at Sturmanov, 76.00N 96.30E, Coast of Taimyr, Russia, July 1989" by GRID Arendal is licensed under CC BY-NC-SA 2.0

6. Mediterranean

The Mediterranean is found in pockets of most continents, like: the west coast of the United States, the west coast of South America, the Cape Town area of South Africa, the western tip of Australia and the coastal areas of the Mediterranean. The Mediterranean forest are known to be very hot and dry with most rains experienced during winter. Summers are usually dry and hot.

7. Grassland

Open lands with grasses and grass like plant species form Grassland ecosystems. It should be noted that other forms of vegetation like trees don’t thrive well in the grassland's dry environment. Major types of grasslands include: Tropical Savannah and Temperate Grassland. Tropical Savannah Grasslands are found in Africa, Australia, South America and Indonesia while Temperate Grasslands are found in North America, Ukraine and Russia.


"Grassland" by Khem is licensed under CC BY-NC-SA 2.0

8. Temperate forest

A temperate forest is located in the temperate zone that lies between the tropical and boreal regions. Temperate forest have four seasons namely: winter, spring, summer, and fall. These seasons are as a result of tilting of the Earth’s axis. The temperate forests are found in Russia, China, Japan Canada and Eastern parts of United States.

"Coastal Temperate Rainforest" by NikiSublime is licensed under CC BY 2.0

Abiotic Factors

The non-living component of the environment forms what we call an abiotic factor. Examples of abiotic factors include: water, sunlight, oxygen, soil and temperature. We will examine each of this abiotic factors in detail in the sections below.

"River Seridó" by grungepunk2010 is licensed under CC BY-SA 2.0

Water as mentioned early oceans form about 70% of the earth's surface, if we include the water bodies water will be about 75% of the earth's surface making water a very important abiotic factor. Plants and animals need water to grow and function well. Animals and plants in different habitats with different amounts water develop adaptation mechanisms to thrive in these conditions.

"by the sun" by grungepunk2010 is licensed under CC BY-SA 2.0

Sunlight produces rays that are the main source of energy on Earth. Plants make their own food using sunlight through a process called photosynthesis. Some animals also feed on plants making them indirectly benefiting from the sun.

Oxygen (O_2) is an important component for plant and animal life. Just like human beings most living organisms will not be able to live without oxygen. Plants produce oxygen during the day through photosynthesis which is used by animals. Animals in turn produce carbon dioxide which plants use for photosynthesis. We will discuss this relationships in the section below on balance of the ecosystem.

"Well drained red soil profile" by NSW DPI Schools program is licensed under CC BY-NC-SA 2.0

Soil is often considered an abiotic factor since it is mostly made up of small particles of rock (sand and clay) mixed with decomposed plants and animals. Plants use their roots to get water and nutrients from the soil. Soils are different from place to place – this can be a big factor in which plants and animals live in a certain area.

"hot" by Keithius is licensed under CC BY-NC-SA 2.0

Temperature of an ecosystem is largely influenced by sunlight and vegetation cover. abiotic factor that is strongly influenced by sunlight. Temperature helps animals to regulate their body temperatures. Both cold blooded and warm blooded animals have bodies that respond to temperature changes differently. This makes temperature a very important abiotic factor in the ecosystem.

Biotic Factors

Biotic factors refers to all livings things in a ecosystem which mainly consists of plants and animals. Biotic factors in an ecosystem interact with one another in various ways, these interactions can be grouped into three levels namely: producers, consumers and decomposers. Let us now look into these levels into more detail.

1. **Producers**. Producers comprise of plants like grass and trees that are able to make their own food through photosynthesis. Producers absorb the sun's energy and convert the energy into food for their growth and flower and fruit production.

"summer" by baklavabaklava is licensed under CC BY-NC 2.0

2. **Consumers**. These are organisms that eat producers, they are mostly animals. In the interactions consumers can also eat other animals or sometimes decomposers. For example a deer eats plant while a lion eats animals. Animals that only eat plants are

called herbivores and they referred to as primary consumers while those animals that only eat other animals they are called carnivores and they are referred to as secondary consumers.

"Deer" by Lutrus is licensed under CC BY-NC-ND 2.0

3. **Decomposers**. These are organisms that prey on dead material by breaking it down through a process called decomposition. The end product of decomposition often results to nutrients into soil which can be used by producers to for rapid growth. Examples of a decomposers include mushrooms, lichens fungi etc..


"Mushroom" by Cahroi is licensed under CC BY-SA 2.0

Ecological Balance

An ecosystem is constantly changing. Sometimes the changes work together to keep the ecosystem stable. Ecological balance refers to how ecosystems create stability for organisms to coexist with their surroundings. Ecological balance ensures there exists a conducive environment for organisms to reproduce and live. In nutshell, ecological balance ensures survival, existence and stability of the organisms and the environment.

Food Chain

A food chain in an ecosystem refers to a serial relationship where of organisms feed on each other. The sun is the main source of energy in a food chain, producers convert the sun's energy into food which is passed to the primary consumers when they eat the producers. The primary consumer is then eaten by a secondary consumer. And the secondary consumer may be eaten by a tertiary consumer, making it a chain of transferring energy from one organism to another in the next higher level of consumers. This relationship can be illustrated below:

Producers →Primary consumer →secondary consumer→ Tertiary consumer

Examples of food chains are:

Plants →Gazelle →Lion

Plants →Worm→Fish →human being

Plants→Grasshopper→Frog→Snake→Hawk

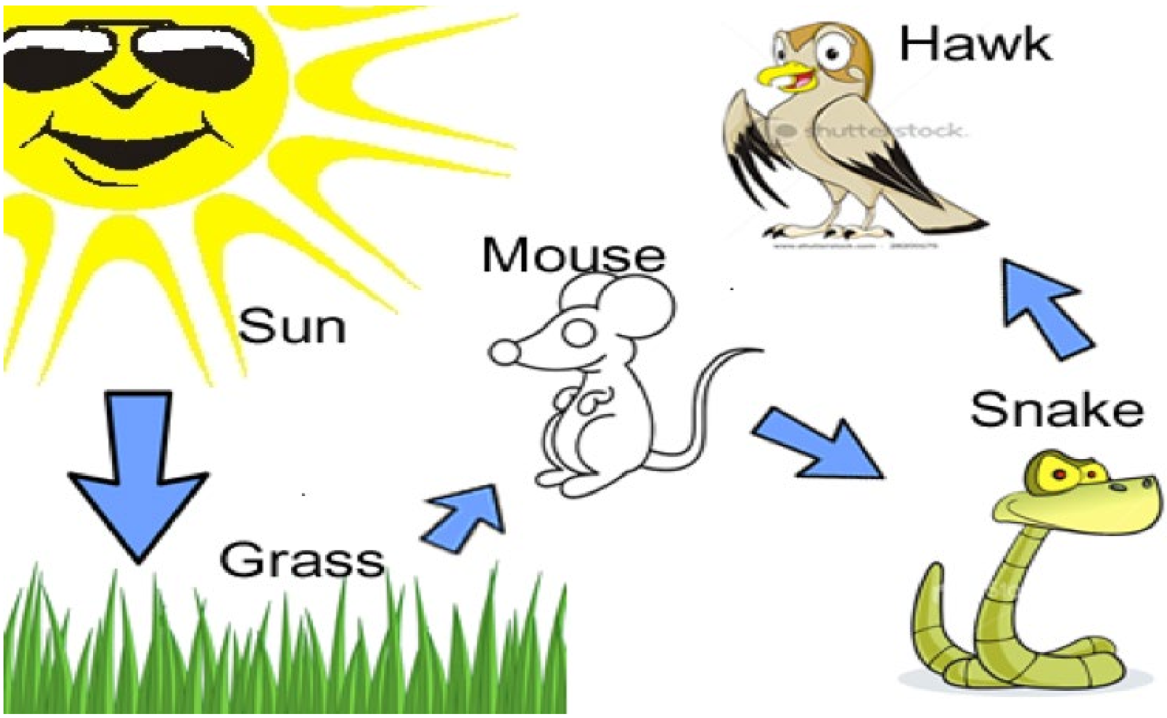
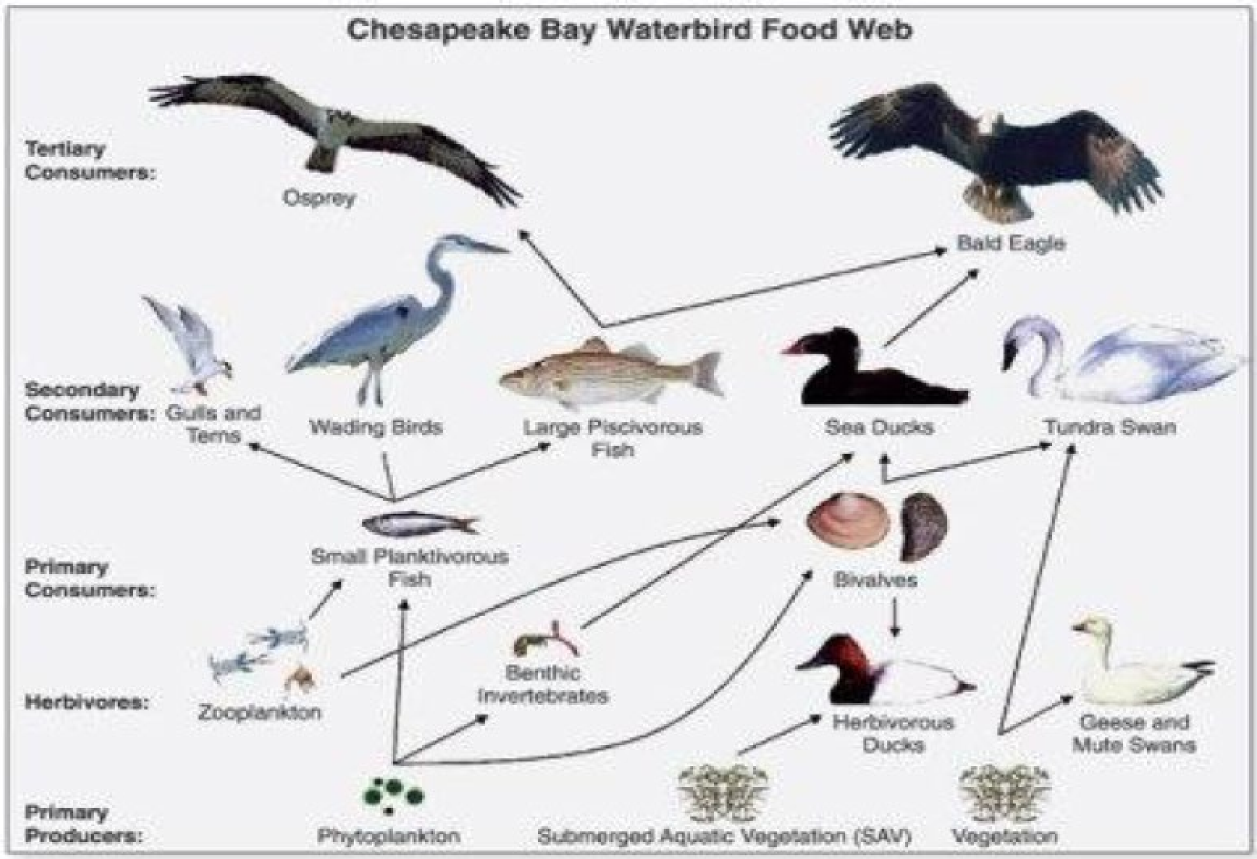


Photo Credit: enotes.com

Food Web

A food web is made up of many food chains that are interconnected. Food web represents a more realistic model of energy flow through different organisms in an ecosystem and the randomness of the ecological balance.



Picture Credit:ducksters.com

Engineering Connection to Ecosystems

Knowledge of ecosystems helps engineers to modify designs for residential houses, cities, and many types of buildings according to the existing environments. Engineers also use knowledge of biomes to study ecosystems and model the interactions of living and nonliving things in natural environments. Knowledge of ecosystems also helps engineers who collaborate to predict the availability of resources such as water for communities

From the following list identify which one is an example of the main ecosystem.

A
Rainforest
B
Tundra
C
Grassland
D
Taiga
E
All the above

Question

4
Show Correct Answer
Show Responses

Describe an activity that you have do to help them interact and explore the environment

Question 5
Show Correct Answer
Show Responses

[ ] is the study of relationships between living things and their environment

Chapter 7: The Human Body

This chapter deals with teaching elementary students about the human body. This is particularly important and may be particularly interesting to students because it is about ***them*** in a way that no other science topic is. Of course, there are different things that are addressed at every grade level and we will be working on this in class, but in general, the elementary curriculum generally includes anatomy and body systems which includes growth and development and exercise/nutrition. **These topics are not necessarily all that would be addressed in any particular school's curriculum**.

Anatomy and Body Systems

I have found that most of the time spent dealing with the human body in elementary classrooms is spent on anatomy and body systems. There are some systems that are seldom addressed, such as the Lymphatic, Integumentary, and Exocrine systems. They will be discussed after looking at the common body systems addressed in the typical elementary science curriculum.

As previously stated, body systems that are commonly addressed in elementary school science. I find it easy to remember them using the name Dr. MicSneer. Using the nine letters in this name, it is easy to remember: **D**igestive, **R**espiratory, **M**uscle, **I**mmune, **C**irculatory, **S**keletal, **N**ervous, **E**ndocrine, **E**xcretory, and **R**eproductive.

Digestive System

The Digestive System is the system through which we absorb energy, and nutrients from the things we eat and drink. The digestive system begins with the **jaws and teeth** which help to physically digest food. This physical digestion is aided by the beginning of chemical digestion which begins as the **salivary glands** and **serous glands** (located in the tongue) produce digestive enzymes called *amylase* and *lingual lipase* which begin to break carbohydrates down into sugars.

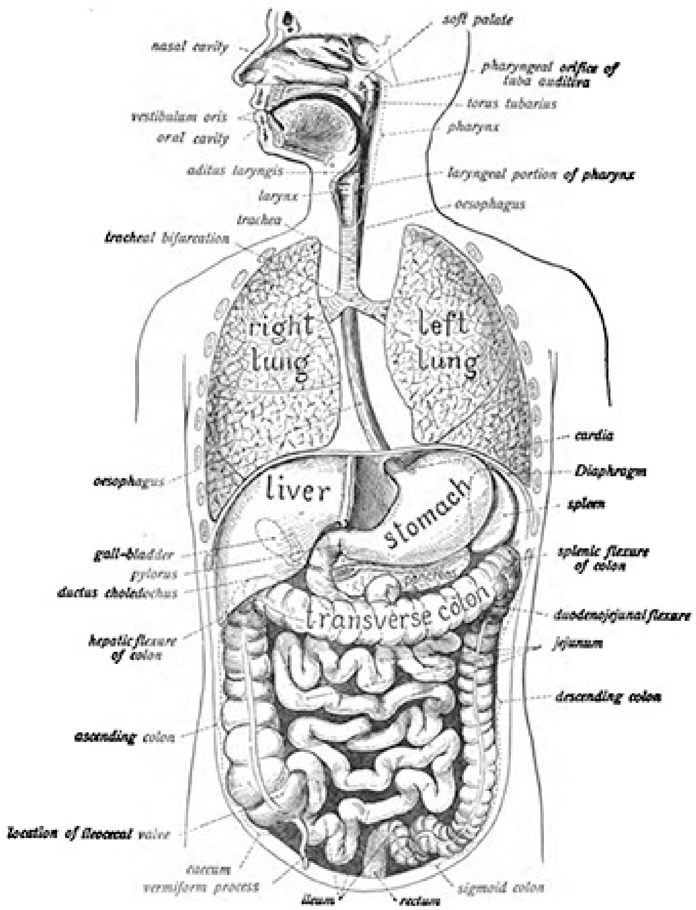


Image 1: Digestive System

Food that is physically broken down is then pushed down the esophagus into the stomach. The **esophagus** is a tube made of smooth muscles that contract rhythmically to push the chewed food into the stomach. In the **stomach**, the food is mixed with gastric acids and "kneaded" into a soupy material called chime. This chime passes into the **small intestine**, where the nutrients are extracted, entering the blood stream to feed the body. After passing through the small intestine, the remaining material enters the **large intestine** where fluids are extracted, and the remaining waste material is prepared for elimination.

There are other organs that are involved with digestion. The liver produces *gall*, which is stored in the **gall bladder**. Gall is a chemical which helps digest fatty materials. It is extremely caustic and leaves a very uncomfortable sensation in a person's throat if it is ever "burped up". The **pancreas** also produces several digestive enzymes.

This has been a simplified description of the digestive system and is parts. It has been written at about the level of complexity that students in the sixth grade should be able to understand. A more in-depth description of the digestive system can be found on several excellent web sites.

Respiratory System

The Respiratory System is where oxygen is absorbed from the air and carbon dioxide (a waste product and poison in the blood stream) is removed from the blood stream. The respiratory system' major components are the nose, mouth, sinuses, trachea, lungs made up of: bronchi, bronchioles, and alveoli. The following is a description of the structure and function of the components of the respiratory system.

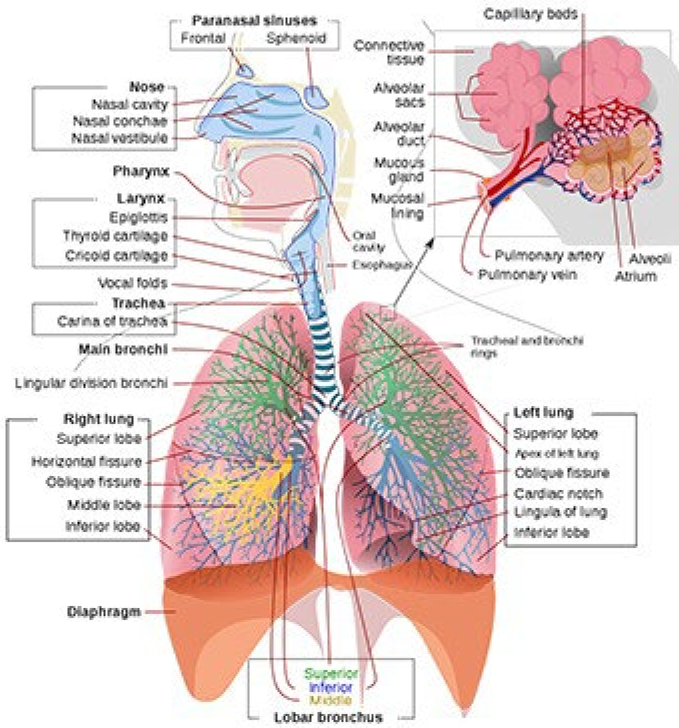


Image 2: Respiratory System

Breathing

The respiratory system is a specialized body cavity with a structure that allows for the exchange of gasses between the blood stream and the atmosphere outside the body. The largest part of the respiratory system is made of the **lungs**. People are typically born with two lungs which are located in the chest cavity and above the **diaphragm**. The lungs are delicate organs and are surrounded by the **pleura**. The pleura are two linings of the thorax and diaphragm that surround each lung and contain a small amount of air. As the diaphragm contracts and the ribcage expands, the <u>air pressure in the pleura decreases and allows the lungs to expand</u>. This is needed for inhalation. Conversely, as the diaphragm relaxes and the rib cage contracts, the air pressure in the pleura increases and the lungs are compressed causing an exhalation. This way, the lungs are never in direct contact with the diaphragm or rib cage as a person breathes. **Pleurisy** is a condition in which fluids build up in the pleural sack, making breathing difficult and painful.

Bronchial Tree

The lungs obtain access to the atmosphere through a series of branching tubes which get ever smaller. We often call this arrangement the **bronchial tree**. As a person breathes, air enters the mouth/nose and is routed through the **trachea**. The trachea is a flexible tube that carries gasses from the atmosphere to the lungs and also gasses form the lungs to the atmosphere. A specialized part of the trachea is the **larynx** or voice box, a specialized organ that allows humans to speak. Past the larynx, the trachea breaks into two **bronchi**. These bronchi each lead to one of the lungs. Each of the bronchi branches off into ever smaller **bronchiole** which at last lead to the **alveoli**. It is in the alveoli that gasses are exchanged. The alveoli are extremely small air sacks which are surrounded by capillaries. It is through these capillaries that oxygen is added to the blood stream and carbon dioxide is extracted from the blood stream. The alveoli are coated with a "soap-like" substance called **surfactant**. This surfactant keeps the walls of the alveoli from sticking together. In this way, red blood cells are renewed with oxygen while ridding themselves of carbon dioxide. It should be noted that because carbon dioxide is removed from the blood stream by the lungs, they (the lungs) can be considered a part of the excretory system.

Muscular System

The muscular system makes up a large portion of the body mass of an individual. Muscles are necessary for motion, support, and for protection of some internal organs. Muscles are made up of specialized cells that can contract, shortening their length. These cells are organized into bundles and groups of these bundles are organized in specific areas of the body for special purposes. There are three major types of muscles.

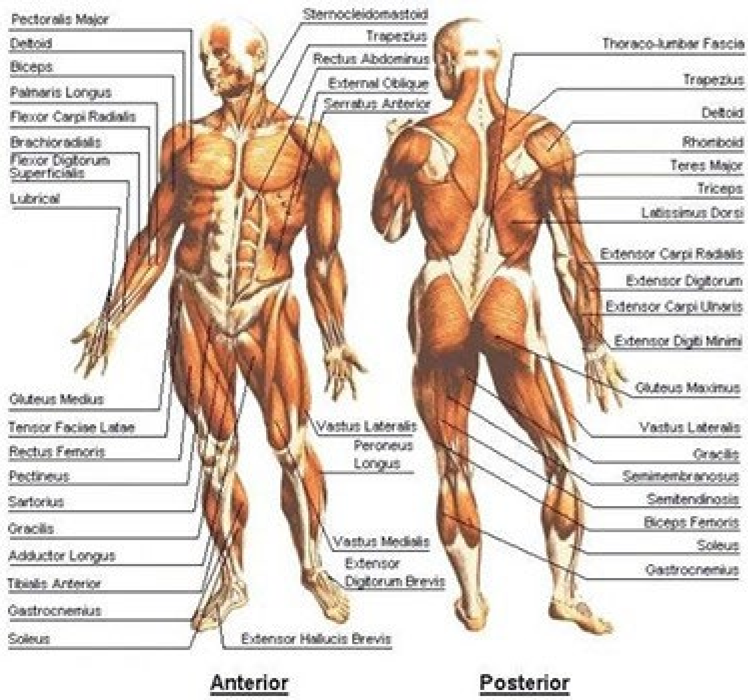


Image 3: Muscular System

Skeletal muscles are ones that attach to bones and are used for motion and support. Examples of skeletal muscles include the deltoids, biceps, and quadriceps. Skeletal muscles are controlled voluntarily, meaning that a person thinks about moving these muscles. Skeletal muscles respond to exercise by toning and strengthening. Exercise can also add to these muscle's mass. On the other hand, they will atrophy, or shrink if not used.

Smooth muscles are different from skeletal muscles in that they are not attached directly to the skeletal system and are involuntary. These muscles are controlled by the nervous system without thinking on the part of the person. Smooth muscles make up the esophagus, stomach and bladder. They are made of layers of muscle placed on top of each other to form tissues that can contract. As noted in the discussion of the digestive system, smooth muscles in the esophagus contract in rhythmic waves that push food and liquids from the mouth into the stomach. The stomach and bladder are muscular pouches that can stretch to hold food and liquid waste. In the case of the stomach, the smooth muscles contract to "churn" its contents. The bladder muscles can stretch until the bladder is full and need to be emptied.

Cardiac muscle is found in the heart. This specialized muscle is able to contract rhythmically and continuously. The heart beats around sixty times each minute. The fibers bet their "rest" between contractions. (Contract- Rest-Contract-Rest)

Immune System

The immune system is our defense against disease. It is made of many parts. The first is a physical barrier made up of the skin and hair. This barrier keeps bacteria and other pathogens out of the blood system and tissues. This is why, when we cut our skin, we use antibiotic creams and band-aids to keep bacteria out. Within the body, the immune system is made of innate and adaptive components. Innate components respond to threats immediately, but in a non-specific way. They do not lead to long-term protection against an invader. The other type of internal defense is the adaptive system. This system is target to specific pathogens and can build long-term defenses to these diseases. It requires specific cells that can identify invading "agents". This is what we mean by building up immunity.

There are specific cells that are a part of the immune system. Leukocytes is the general term for white blood cells. There are several types of leukocytes which include: phagocytes, dendritic cells, granulocytes, macrophages, and lymphocytes (part of the lymphatic system). These types of cells are typically not included in the elementary curriculum.

Immunodeficiencies

There are different immune system disorders that students should know exist. The general term general immunodeficiency's describes a condition where part of (or all of) the immune system is not working properly. Auto-immune disorders describe situations where the immune system attacks parts of its own body instead of an invader. Hypersensitivity occurs when the immune system responds with great "force" to small threats. Allergies are an example of hypersensitivity.

Circulatory System

The circulatory system is what pushes blood throughout the body. The major components are the heart, arteries, veins, capillaries and blood.

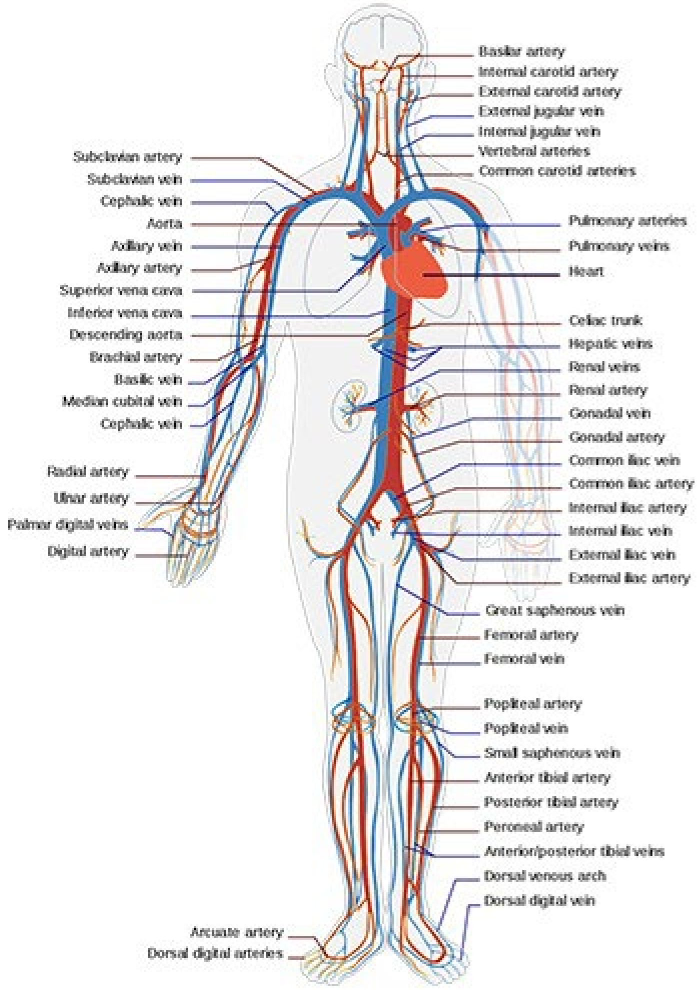


Image 4: Circulatory System

The **heart** is a pump that ensures that blood circulates through the entire body. It has four chambers, two atriums on top that receive blood and two ventricles that pump blood to either the lungs in one case, and the rest of the body in the other. There are special valves that control the flow of blood between the atriums and ventricles.

Arteries are blood vessels that carry blood away from the heart. You feel a pulse in some arteries that are close to the skin. Arteries branch into smaller and smaller vessels called arterioles. These eventually branch into the smallest of blood vessels called capillaries. Capillaries are vessels that are embedded in every tissue in the body. It is through capillaries that gasses such as oxygen and carbon dioxide are exchanges, along with nutrients, hormones, and other chemicals are passed between the cells and blood. Veins are the final type of blood vessel. Veins connect the capillaries to the heart, returning “spent blood”, which is pumped to the lungs to absorb oxygen and release carbon dioxide. Veins do not have a pulse, and rely of valves within them to push the blood back to the heart. The blood is made of several materials. Plasma is a clear liquid that carries the other types of cells. Red blood cells are the cells that carry oxygen to the cells and carbon dioxide away. White blood cells are part of the immune system and fight disease by tracking down and “killing” harmful cells. Finally, platelets are parts of the blood that will form a clot to help control bleeding.

There is a second system which circulates fluids around the body. The lymphatic system is a separate but connected circulatory system that allows lymphatic fluids to circulate throughout the body. The lymphatic system is part of the immune system, but is often left out of the elementary curriculum. Notably, the lymphatic system is often an area of concern for the treatment of people with cancer. When cancers invade the lymph nodes, these cells often circulate around the body through the lymphatic system.

Skeletal System

The skeletal system has several important functions. The first is to protect internal organs, next the skeletal system provides shape and form to the body, and, the skeletal system also helps to provide blood cells through the bone marrow.

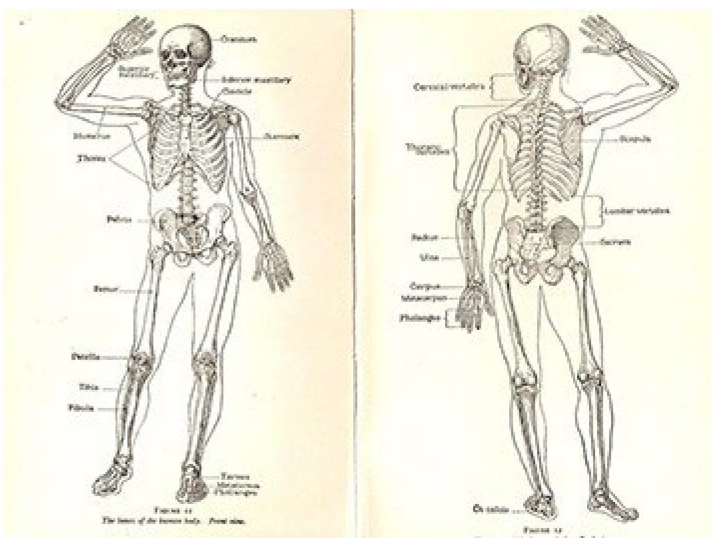


Image 5: Skeletal System

The skeletal system **protects internal organs** including the brain, spinal cord, lungs, heart, liver and spleen. The skull is a very complete protective cover for the brain. It has openings for the eyes, ears, and nose. These openings allow for sensory input necessary for people to deal with the outside environment, yet the skull surrounds the brain nearly completely. The skull is made of plates that grow together through joints. In these joints, **cartilage** both cushions the connections between the plates and grow more bone. In this way, the skull can grow in capacity. The **rib cage** provides protection for the organs of the thorax, such as the heart, the lungs, liver and spleen. They are arranged in such a way that they can expand, to allow the lungs to fill, while protecting these organs at the same time.

The skeletal system **provides shape and form for the body**. The shin and thigh bones provide structure for some of the muscles needed to walk. The muscles are attached to the bones and, through **cartilage**, **ligaments** and **tendons** the muscles allow the bones to move. Cartilage is material that forms between bones at joints. One major function of cartilage is to cushion the places where bones come together. In the knee, the meniscus is a disk of cartilage that cushions the bones of the shin from the thigh every time a step is taken. Ligaments are very strong, even hard strands that attach muscles to bones. If you think of a Thanksgiving turkey, the hard structures that stick out of the drumstick are ligaments. The have to be very strong because they have to handle a lot of pressure. Tendons are the final type of connective tissue in the joints. They are stretchy and hold joints together. There are four types of joints in the human skeleton. The first is the hinge joint. Knees and elbows are hinge joints. The shoulder and hip are ball and socket joints, where one bone has a ball at the end that fits into a socket on the other bone. Gliding joints are joints were several bones slide along each other. The hands contain many gliding joints in the palm and wrist. The spine and neck are also made of gliding joints. The final type of joint is the fixed joint which is where two bones are connected in ways that keep them solidly connected. Fixed joints do not move

The final function of the skeletal system is the **production of blood cells**. Inside then hard outside shell of bones is a soft spongy material called **marrow**. It is in the marrow that some of the bold cells that need constant replacement.

Nervous System

The nervous system in humans has three major functions. The first function is to create a way of interacting with the external environment. The second is a command and control system to regulate and control body functions. The third is in the area of thinking and communicating with others.

Structurally, we can study the central nervous system and the peripheral nervous system. The central nervous system consists of the brain and spinal cord (a thick bundle of nerves that runs down the spinal column and branches out to reach app parts of the body. The second part is the peripheral nervous system which extends from the central nervous system and out to all parts of the body.

This text includes sensory organs such as eyes and ears, among others, as part of the nervous system because they are directly connected (by nerves) to the brain.

The brain is a soft organ that is made up of billions of nerve cells and is connected to the rest of the body by a complex of nerve bundles that branch out in a way that is not unlike circulatory system. There are specific areas of the brain that have specific functions. The cerebrum, the cerebellum and the brainstem are the three major structures that make up the brain.

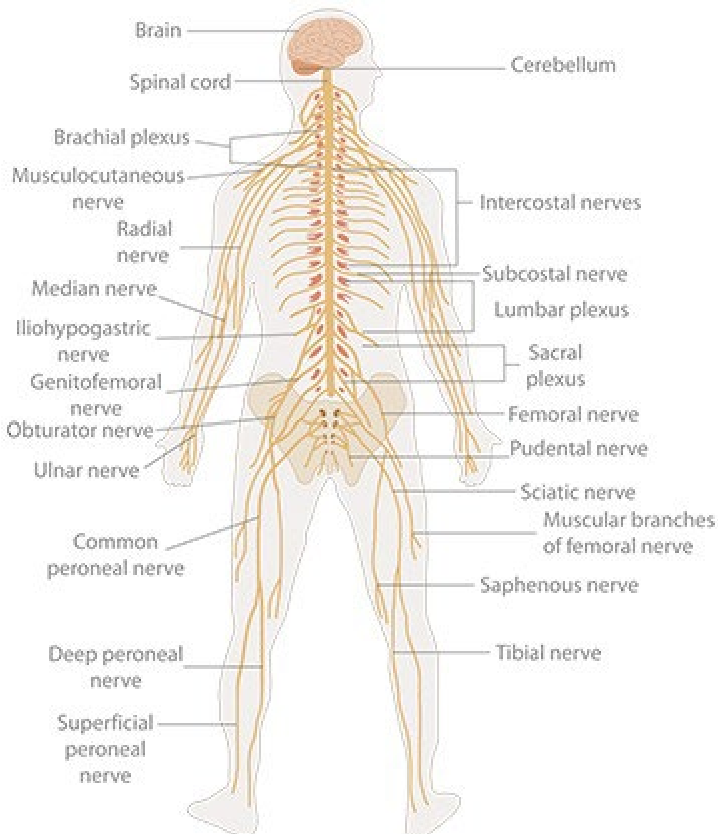


Image 6: Nervous System

The cerebrum is the biggest part of the brain. It has what is called grey matter on the outside and white matter on the inside. The cerebrum is divided into two halves called hemispheres. In general, it can be said that the left hemisphere controls the right side of the body and the right hemisphere controls the left. Also, the left hemisphere has more to do with language functions while the right hemisphere has more to do with spatial and visual functions.

Each of these hemispheres is also divided into four "lobes". They are the frontal, temporal, parietal and occipital lobes. The frontal lobe is associated with higher functions such as reasoning, planning, self-control and abstract thought. The occipital lobe is where vision is processed. The parietal and temporal lobes integrate sensory information.

The cerebellum is a smaller portion of the brain which is located in the lower back area of the brain. It is largely concerned with motor functions. It is in the cerebellum that our ability to walk and chew gum at the same time is controlled. The cerebellum automates these types of motor actions so that we don’t really have to attend to them in order to walk or run.

The brainstem is a small portion of the brain that connects directly to the spinal cord. It has some motor regulation and is responsible for controlling the cardiac, respiratory, and digestive processes that occur without any thought on our part.

The rest of the central nervous system consists of the spinal cord which is protected within the spinal column. It branches out to connect to the peripheral nervous system through gaps between the vertebrae that make up the spinal column.

The peripheral nervous system is the network of nerves that connect to the spinal column and spread out to all parts of the body. This is where sensations of heat/cold, pressure and pain are perceived and sent to the central nervous system for processing.

The nervous system’s second function is command and control. As mentioned earlier, the brain controls heart rate, respiration and digestion. Much of this type of activity occurs in the brainstem without any conscious processing on the part of the individual. This is not typically presented in any depth in the elementary science curriculum.

A third function of the nervous system is thinking and processing communications with others. This simple statement is about as far as most elementary science programs go in this area.

Endocrine System

The Endocrine system controls the production and distribution of hormones to help the body function properly.

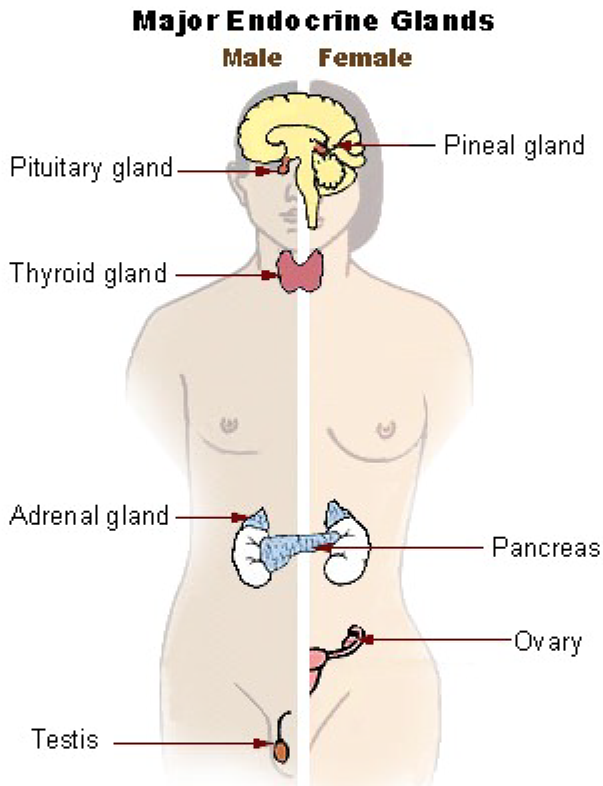


Image 7: Endocrine System

The endocrine system controls human growth hormone, insulin, testosterone, estrogen and many other hormones. The main organs of the endocrine system are the pancreas, thyroid, parathyroid, adrenal glands ovaries (in females) and testes (in males). The hypothalamus is an area in the brain that controls the glands that make up the endocrine system. The elementary science curriculum typically contains little more than this about the endocrine system.

Excretory System

The excretory system is the body's system for removing waste products. It includes the large intestine, the kidneys, the bladder and even the lungs and sweat glands.

The large intestine was described in the section about the digestive system. As an excretory organ, the large intestine removes fluids from and consolidates the material moving through the digestive tract after the nutrients have been removed. This is about as far as you want to go with elementary students.

The kidneys are filters for the blood. As the blood flows through the kidneys a process that involves osmosis filters salts and other wastes from it in special structures called nephron tubes. There are over one million nephrons in each kidney. Their job is to filter both wastes which are removed from the blood stream and helpful materials which are reintegrated into the blood stream. In this way, the kidneys: help maintain volume of fluids in the blood, help maintain electrolyte balances within the blood, and remove toxic cellular by-products such as urea, ammonia, and uric acid from the blood.

The waste products removed by the kidneys are passed from the kidneys to the urinary bladder through strong muscular tubes called ureters. It is from there that urine is expelled from the body.

The liver is another organ that acts to remove wastes. Unlike the kidneys which filter the blood, the liver metabolized, or breaks down toxins and removes them from the blood. Many drugs and alcohols are removed from the bloodstream through the liver. These toxins can build up in the liver and lead to liver failure or other diseases. This is why physicians will conduct liver tests when certain drugs are prescribed.

Reproductive System

The reproductive system is a sensitive part of the elementary curriculum. In many ways, the human reproductive system is ignored until upper elementary classrooms. (Although this is not always true.) In lower grades, the reproductive system is often presented in ways that are not human specific. Students will study life cycles of plants and animals. The ***egg to tadpole to frog*** is a popular example of how animal reproduction is presented to younger children.

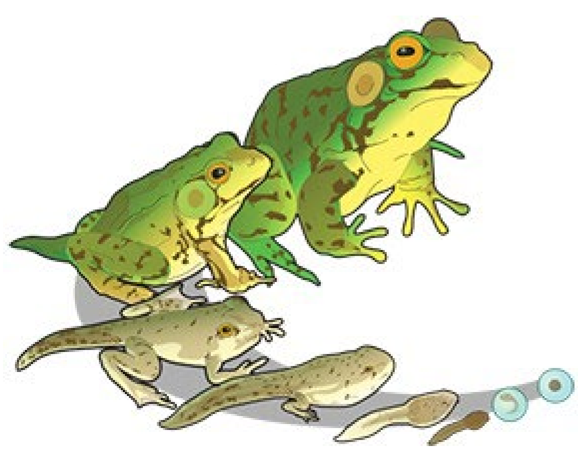


Image 8: Frog Life Cycle

There are some schools that include the anatomical aspects of human reproduction in the upper elementary grades. In these lessons, the anatomical terms such as ovary, uterus, fallopian tubes, breasts, penis, testes and scrotum are presented and described.

Another aspect of human reproduction that often occurs in upper elementary science is "sex education". This is typically necessary as girls first and then boys begin to move into puberty. "Sex-education" can be a very sensitive part of the curriculum. IN many states it is mandatory for schools to have an advisory committee to review the sex-education curriculum in the elementary grades. These advisory boards typically include a school administrator, a medical professional, one or two parents, a member of the clergy and the teachers who will deliver the instruction. An annual meeting of this board is usually conducted just before the instruction will be delivered. In this way, the teacher has less personal risk if a parent (or group of parents) objects to what is taught.

The usual pattern for "sex-education" is for a male teacher to work with the boys and a female teacher to work with the girls. The girl's curriculum may include: their changing bodies, menstruation and hygiene, and sexually transmitted diseases. The boy's curriculum similarly focuses on their changing bodies and sexually transmitted diseases.

It must be noted that there is a lot of anxiety and controversy around what schools should include in sex-ed. There are parents who feel that the entire issue should be their responsibility. Some are against a school/teacher presenting a biased picture of what human sexuality is and should be. There are also parents on the other side who feel that schools are the appropriate place for broad explorations of what sexuality is, even at the elementary level. If you are charged with teaching sex-education, be sure you are working within the parameters set by your administrator and or school board.

So, we have briefly described the human body systems as presented in elementary science classes. Because this is such a large part of the elementary science curriculum, there is more to know about the systems than what is presented here.

Health, Exercise, and Nutrition

A second part of the human body presented in the elementary science curriculum might be called health. There are many aspects of health that will be covered in class, but thins book includes a mention of health in this chapter on the human body. Aspects of health that are included in typical elementary science programs are: drug, alcohol and tobacco awareness; physical safety; personal safety; first aid; poison prevention; on-line safety; healthy eating/eating disorders; exercise and nutrition. These topics will be a part of a project you will be completing toward the end of the semester.

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Chapter 8: Classical Physics

Before we dive into classical physics it is important to understand what is physics? Physics is the study of matter and its interactions with force. Physics explains things that are very large and Physics explains things that are very small, in short physics explains the world around us. The world around us is unique and the complex, to understand it well physics is divided into various branches.

Branches of Physics

1. Mechanics
2. Thermodynamics
3. Electromagnetism
4. Atomic physics
5. Sound of the waves
6. Relativity
7. Light and Optics
8. Quantum physics

For the purposes of this course, we will not discuss each of the branches of physics listed above, instead we will focus only focus on mechanics.

Mechanical Physics

Mechanical physics branch of physics that deals with motion of objects, what causes it and its effects. There are two branches of mechanics: classical mechanics and quantum mechanics

Classical mechanics deals with the study of macroscopic objects (large objects) while quantum mechanics deals with microscopic object (small objects).

In this chapter we will focus on classical mechanics. Classical mechanics is the study of the motion of bodies in accordance with the general principles first proclaimed by Sir Isaac Newton in 1687. Classical mechanics is the foundation upon which all other branches of Physics are built. It has many important applications in many areas of science including:

- Astronomy (movement of stars and planets)
- Molecular and nuclear physics (collisions of atomic and subatomic particles)
- Geology (the generation of seismic waves)
- Engineering (structures of bridges and buildings)

Classical mechanics is subdivided into two branches: kinematics and dynamics. Kinematics deals with the study of motion without discussing its cause while dynamics deals with the study of motion, its cause and its effect.

In kinematics we will explore all the following:

- speed
- velocity
- acceleration
- examples of different types of motions

In dynamics we will explore the following:

- types of forces

- Newton's Laws of motion
- momentum
- laws of conservation of momentum
- gravitation and gravity
- fluid mechanics
- density
- pressure in liquids

In the following sections we will explore each of the areas of kinematics and dynamics into detail. But before we do that, we will explore two types of quantities: scalar and vector quantities.

Scalar and Vector Quantities

A scalar quantity is a quantity that is described by magnitude (size) only. Examples include: time, distance, speed, mass etc.

A vector quantity that is described by both magnitude and direction. Examples include: displacement, velocity, force, momentum etc.

Distance and Displacement

Distance is a scalar quantity describes the extent between two points i.e distance is the length between two points or places. Displacement is a vector quantity that refers to the overall change of position of an object. To understand the difference between distance and displacement let's take an example of a student who walks 4 meters West and then 3 meters North in the classroom.

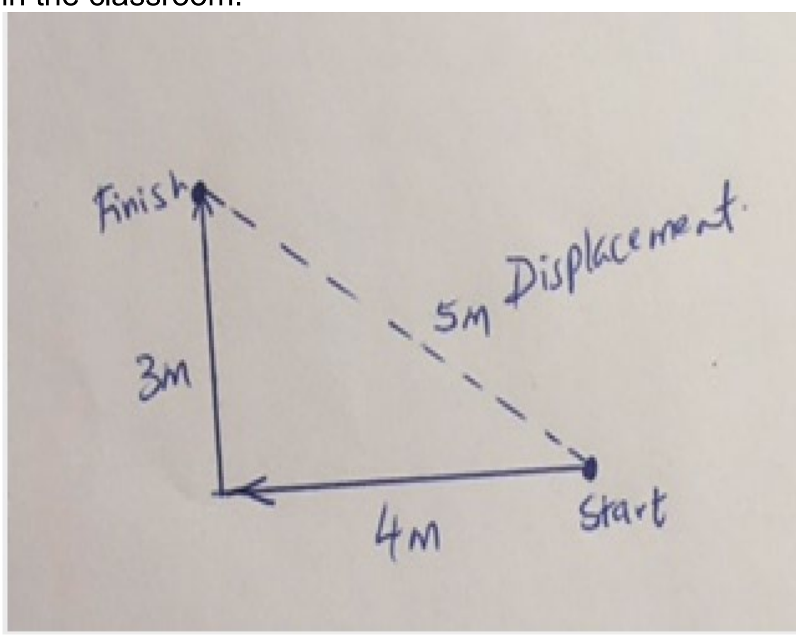


Figure1: Distance vs displacement

In this case the total distance covered by the student is 4 meters + 3 meters= 7 meters but the displacement is only 5 meters. Look at it this way even if the student has covered 7 meters the student has only changed the position by only 5 meters. Therefore, overall direct change of position is 5 meters.

Distance, Speed and Velocity

Speed

Speed is a scalar quantity that refers to how fast an object moves. It can also be defined as the rate at which an object covers distance. An object moving at high speed covers relatively a longer distance within a short amount of time. Conversely, an object moving at a low speed covers relatively a shorter distance within the same amount of time. An object with no movement has a zero speed and it is said to be at rest stationary. The relationship between distance and speed can be given by the formula:

speed=distance/time

$s = d/t$

The units for measuring speed are meters per second (m/s)

Practice Question

How far can a car moving at a speed of 20m/s travel in 5 seconds? (Write your numeric answer only without units)

Velocity

Velocity is a vector quantity that refers to the rate at which an object changes its position (displacement). Velocity can simply be defined as a speed in a given direction. Direction is the basic difference between speed and velocity.

velocity=displacement/time

The unit for velocity is meters per second (m/s). Note that speed and velocity have the same units except that velocity will include direction. For example, we say an object has a speed of 20 meters per second, if the same object is moving towards the east then we could say object has a velocity of 20 meters per second East. Specifying the direction East differentiates between speed and velocity for this object.

Acceleration

Acceleration is a vector quantity that refers to the rate at which an object changes it is velocity. It is worth noting that when an object is moving fast it is not accelerating. Acceleration has nothing to do with moving fast. An object can be moving fast but still not accelerating if its velocity is not changing. Acceleration as to do with the change of velocity from the initial to the final over a given period of time. Acceleration is given by the formula:

Acceleration= Change in velocity/time

Acceleration=Final Velocity-Initial Velocity/time

The unit for acceleration is: m/s^2

When an object is slowing down the final velocity is usually less than the initial velocity. This results to a negative acceleration which we refer to as *deceleration*. A good example of deceleration is when a car is braking, normally it slows down and if it comes to a complete stop the final velocity is zero.

Practice

A car starts from rest and accelerates to a speed of 40 meters per second in 4 seconds. Calculate the car's acceleration during this time interval.

Types of Motion

1. Translational Motion

Translational motion is a motion by which the body moves from one point to another. For example, kicking a ball from one point to another is translational motion.

2. Rotational Motion

Rotational motion is a motion that revolves around an axis for example a wheel and rotor of a motor.

3. Circular Motion

This is a type of rotational motion that occurs when a body moves in a circular path around an axis of rotation.

4. Oscillatory Motion

This is a motion that is repetitive motion at a fixed point. For example, a pendulum, spring or a swing.

Types of Forces

The words push, shove, lift, pull and drag are everyday synonyms that are used to describe force. We have different types of forces that we encounter in our everyday life. Examples of forces include:

- fictional Force
- electrical force
- centripetal force
- centrifugal force
- magnetic force
- gravitational force
- electrostatic force

Newton's laws of motion

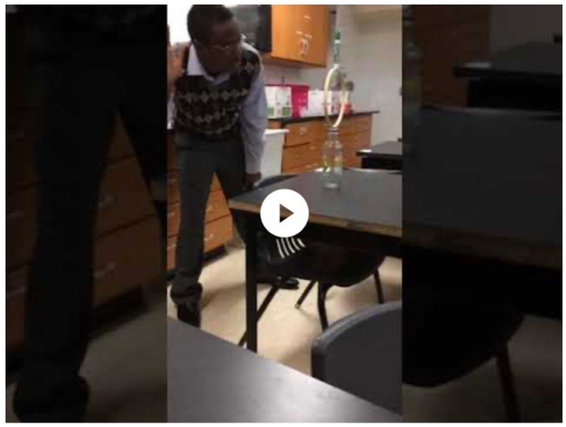
We mostly attribute Sir. Isaac Newton with the law of gravity. But Isaac Newton also contributed to the laws of motion. There are three types of Newton's laws of motion: first law of motion, second law of motion and third law of motion.

1. Newton's First Law of Motion

Newton's first law of motion states that an object will remain at rest or in uniform motion with a constant velocity unless acted upon by an external force. An object at rest obviously remains at rest and this does not make this law unique, but also the law states that an object already in motion with certain velocity will not increase or slow down its velocity unless acted upon by an external force.

Why then in our natural observations we see objects slowing down by themselves? For example, if you kick a soccer ball across the field it will keep moving and eventually

slow down or it will come to a complete stop by itself. The external force that we don't see here is called ***frictional force***. Frictional force is the force that acts in opposition of movement and it slows down a body in motion.
It is because of Newton's first law of motion that objects tend to resist change of motion and instead continue moving in the direction they were initially moving to. This phenomenon is called ***inertia***. Inertia is the ability to resist change in motion. For example, when you are in a car and suddenly the driver steps on the emergency brakes your body jerks forward because of inertia. Watch the video below that demonstrates this property of inertia



https://www.youtube.com/watch?v=3ms1AI16ujo Video 2: Demonstrating Inertia

Why do you think did marker pen fell into the bottle and did not fly towards the direction of the embroidery ring?

2. Newton's Second Law of Motion

Newton's second law of motion explains the behavior of objects in which all existing forces are not balanced. The law states that the acceleration of a body depends on the net force and mass of that body.
This can be presented by the equation:

$$F = ma$$

$$a = F/m$$

Practice Question

A 10 kg bowling falls to the ground with an acceleration of 10m/s/s. Calculate the force with which the bowling ball hits the ground.

3. Newton's Third Law of Motion

Newton's third law of motion states that for every action there is an equal and opposite reaction. please watch the video clip below and then use Newton's third law of motion to explain what is happening.

https://www.youtube.com/watch?v=wSuaTXwl08E Video 2: A balloon powered car

Question

Using Newton's third law explain what make the balloon car move it the video above?

Momentum

Ever heard of the phrase *"the team has got the momentum"* during a football game? Well, in physics we define momentum as the mass of the object times its velocity.
Momentum= Mass x velocity
Momentum=mv
The unit for momentum is $kg.m/s$

Laws of Conservation of Momentum

The law of conservation of momentum states that the total linear momentum of the object in a system before collision is equal to the total linear momentum of objects after the collision.
Total momentum before Collision= Total momentum after Collision
$m_1v_1=m_2v_2$

Fluid Mechanics

A fluid can either be a gas or a liquid. Liquids and gases have the ability to flow. Fluids obey certain laws and principles such as Boyle's Law, Archimedes principle, Bernoulli's principle Pascal's principle and others.

Density

Regardless of form (solid, liquid or gas) density is defined as the quantity of matter (mass) in a unit volume.
Density= Mass/ volume
$D=v/m$

Pressure

Pressure is the amount of force exerted on a given service area.
Pressure= force/ area

$P = F/A$

Pressure in a Fluid

The pressure in a fluid is just the weight of all the fluid above any given point. Atmospheric pressure is just the weight of air above the surface of the Earth. In a swimming pool the pressure you experience depends on the depth you are, the deeper you go the more pressure you experience. Similarly, when you climb a mountain, your pressure keeps decreasing as you climb up the mountain top. Therefore, pressure in a fluid depends on height, the deeper you go the more the pressure you experience and vice versa.

This can be given by the relationship

Pressure= height x density x gravity

$$P = hdg$$

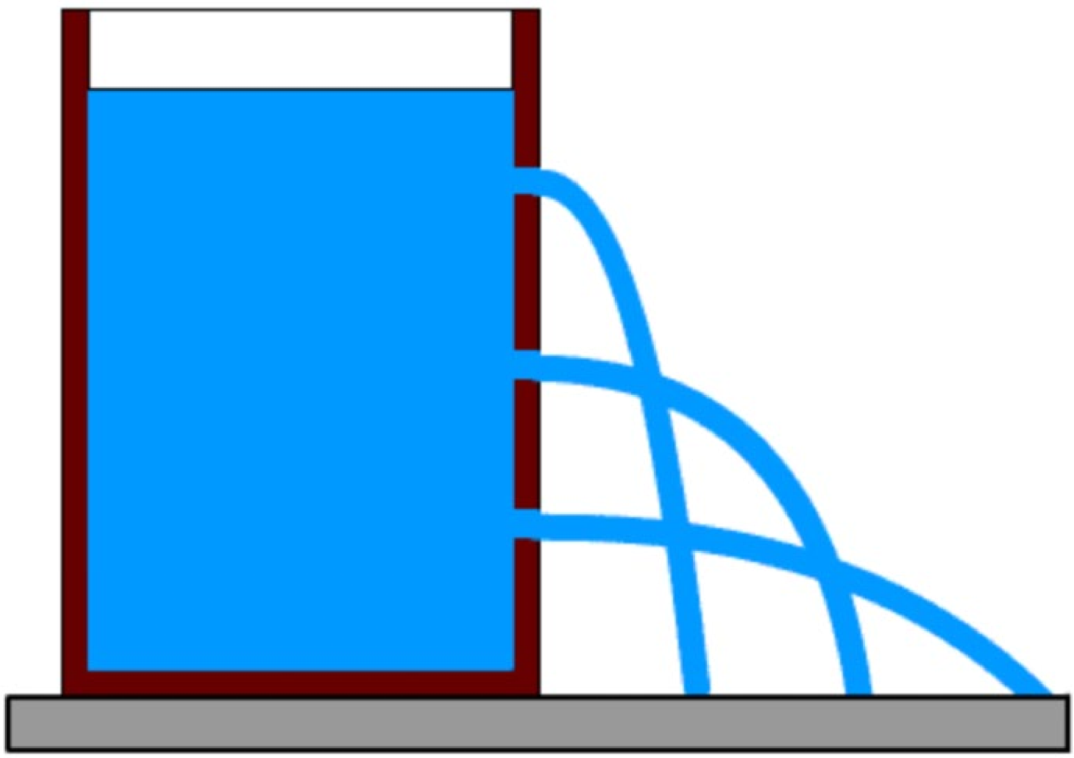


Figure 2: Water squirts further at greater depths

Question

In constructing a dam or a barrier across a river why do think the constructors should build the wall to be thicker at the bottom of the river than at the top of the river?

Waves Particles, Sound and Light

In this chapter we will explore the anatomy of a wave and the properties of waves. We will also look at the concept of sound as a wave and light as a form of wave.

What is a wave?

A wave is a disturbance that travels through a medium from one location to another. A wave can also be defined as the motion of a disturbance. For example, if you drop a rock in a pool of water it will create waves. The force of the rock is the disturbance that creates waves in this case.

Waves are everywhere in nature. Examples of waves include:

- sound waves
- visible light waves
- water waves
- radio waves
- stadium waves
- microwaves

Types of Waves

There are two main types of waves:

1. longitudinal waves
2. transverse waves

1. Longitudinal Waves

Longitudinal wave is a wave in which the medium particles vibrate parallel to the motion of the pulse of the wave. Sound wave is an example of longitudinal wave.

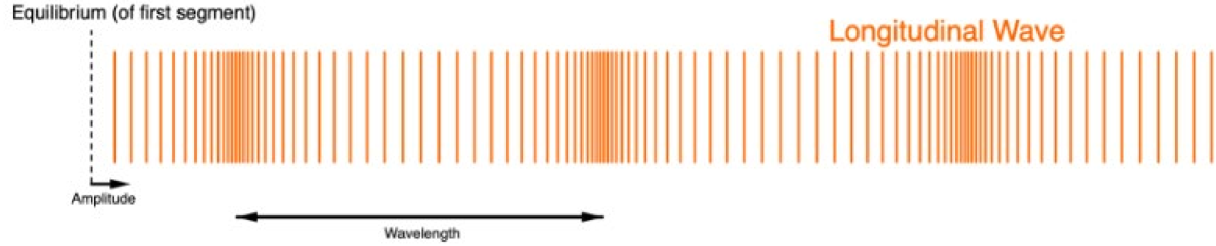


Figure 3: Longitudinal wave

2. Transverse Waves

Transverse wave is a wave in which the pulse travels perpendicular to the disturbance causing the wave.

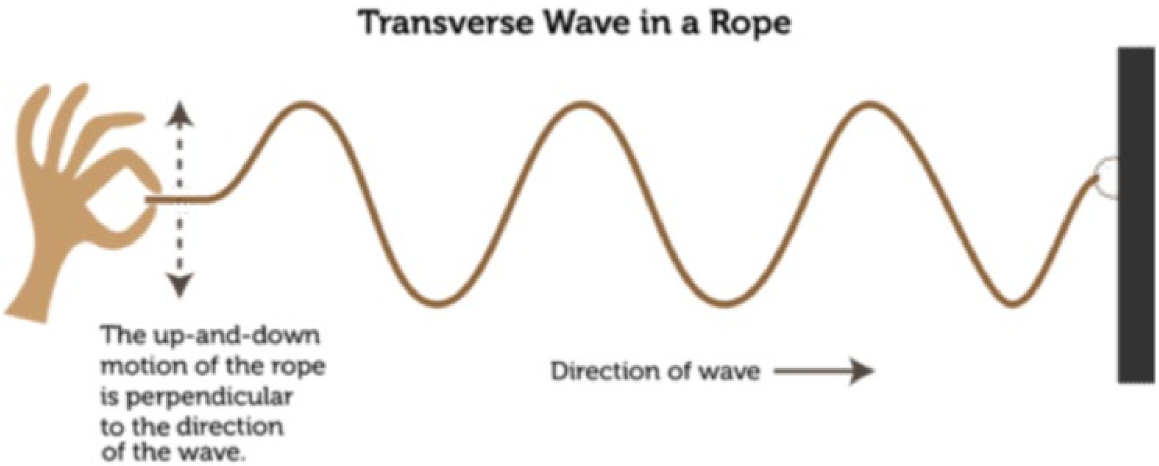


Figure 4:Transverse wave

Anatomy of a Wave
Just like when we talk of the anatomy of our bodies, we seek to understand each of our body parts, similarly, the anatomy of a wave deals with understanding the different parts of a wave.

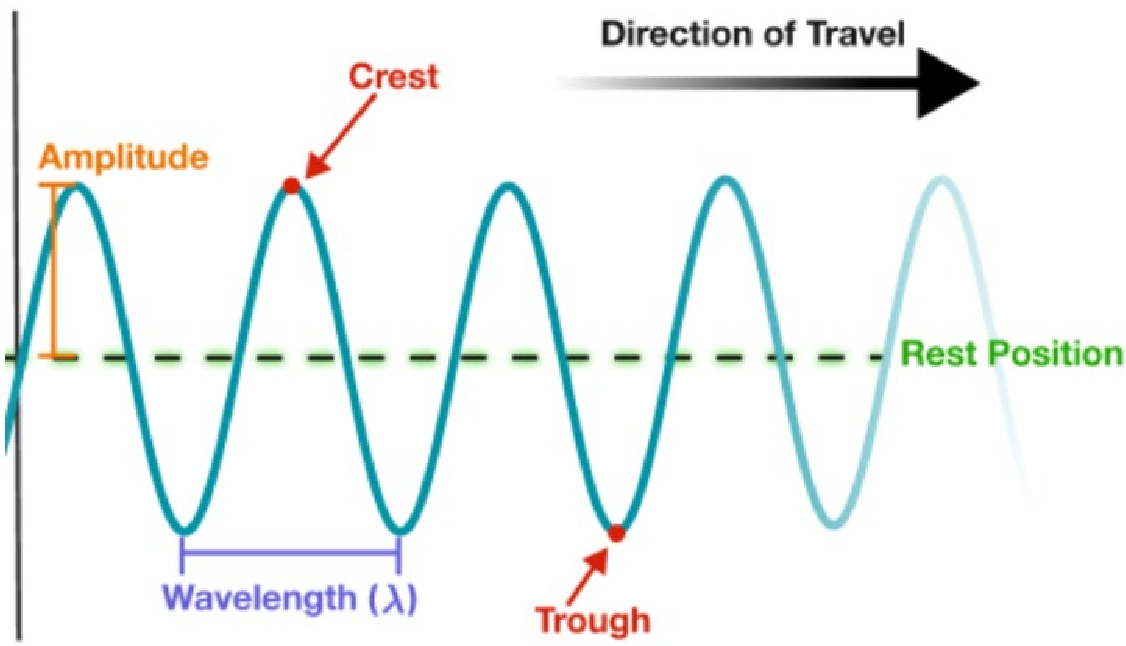


Figure 5: Typical wave parts

Equilibrium position- the equilibrium line is usually presented by the dotted line and it indicates the position in which the wave is not experiencing and disturbance. If the medium is disturbed the wave moves from the equilibrium position and once the disturbance energy has gone the wave returns to equilibrium position again.
Crest- Crest is a point where a wave as maximum upward or positive displacement. It is also referred to as the peak.
Trough -Trough is a point where the wave has maximum downward or negative displacement.

Amplitude- This is the maximum displacement a wave moves away from the equilibrium position. It is the distance between the crest and equilibrium line.
Wavelength- Wavelength is the distance between two consecutive similar points. These points can either be peaks or troughs.
Wave frequency- Frequency is the measure of how often something happens over certain amount of time. Wave frequency refers to the number of complete wave cycles a wave covers in a given amount of time.
Frequency is measured in ***Hertz (Hz)***
Example: A student wiggles a rope back and forth and counts that 8 waves pass a point in 4 seconds. What would the frequency of the rope be?
Frequency =number of waves per second.
Frequency =8 waves/4 seconds
2 Hz
Wave period- wave period is the time it takes for one complete cycle of a wave to take place. Wave period is the reciprocal of the frequency.
$T=f1$
also, frequency is the reciprocal of wave period.
$f=1/T$
Wave speed- wave speed is how fast a wave moves within a given distance. The distance of a wave called the wavelength. Wavelength is represented by the symbol lambda (λ)
therefore,
wave speed= wavelength/ period
$v=\lambda/T$
but $T=1/f$
Therefore, $v=f\lambda$
velocity= frequency x Wavelength
This is the general wave equation

Practice Question

If the speed of a wave is 12m/s and the wavelength is 4m, what is the frequency of the wave?

Sound

Sound is produced by anything that is vibrating and causing the air molecules around it to vibrate. Hold your voice box by the throat with two fingers and say *aah!* as loud as you can.

Question

What do you feel? Do you feel any vibrations?

Sound is a form of energy that can be heard and it travels in the form of a wave. Sound waves can travel through solids, liquids or gases.

Volume of sound is how loud or soft the sound is. The volume of sound is determined by the amplitude. The higher the amplitude the louder the sound the lower the amplitude the softer the sound.

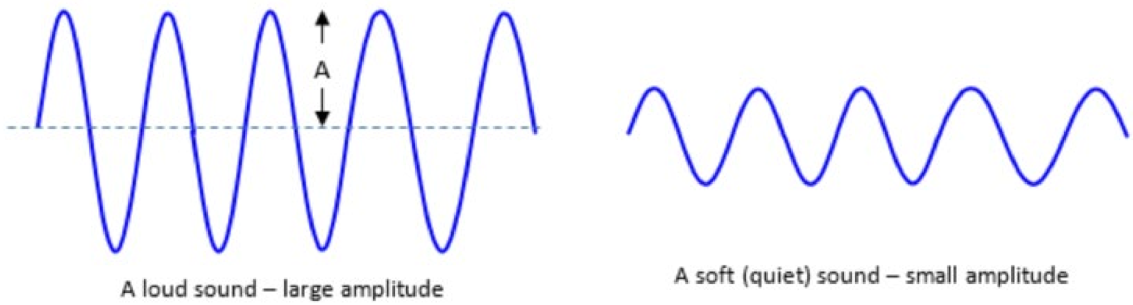


Figure 6: Loud and soft sound

Question

Between a high frequency sound and a low frequency sound which one has a longer wavelength?

Doppler Effect

An ambulance heads to an emergency in San Diego. U-T file photo

Picture 1: An ambulance responding to an emergency

This is the change in frequency or pitch of sound that is caused by the movement of the source or the observer of the wave. For example, when an ambulance passes by you the sound of the siren fades as it goes fast and far in this case the ambulance is the source and you are the observer. As the ambulance keeps moving the pitch of the siren decreases this phenomenon is called the Doppler effect.

Resonance

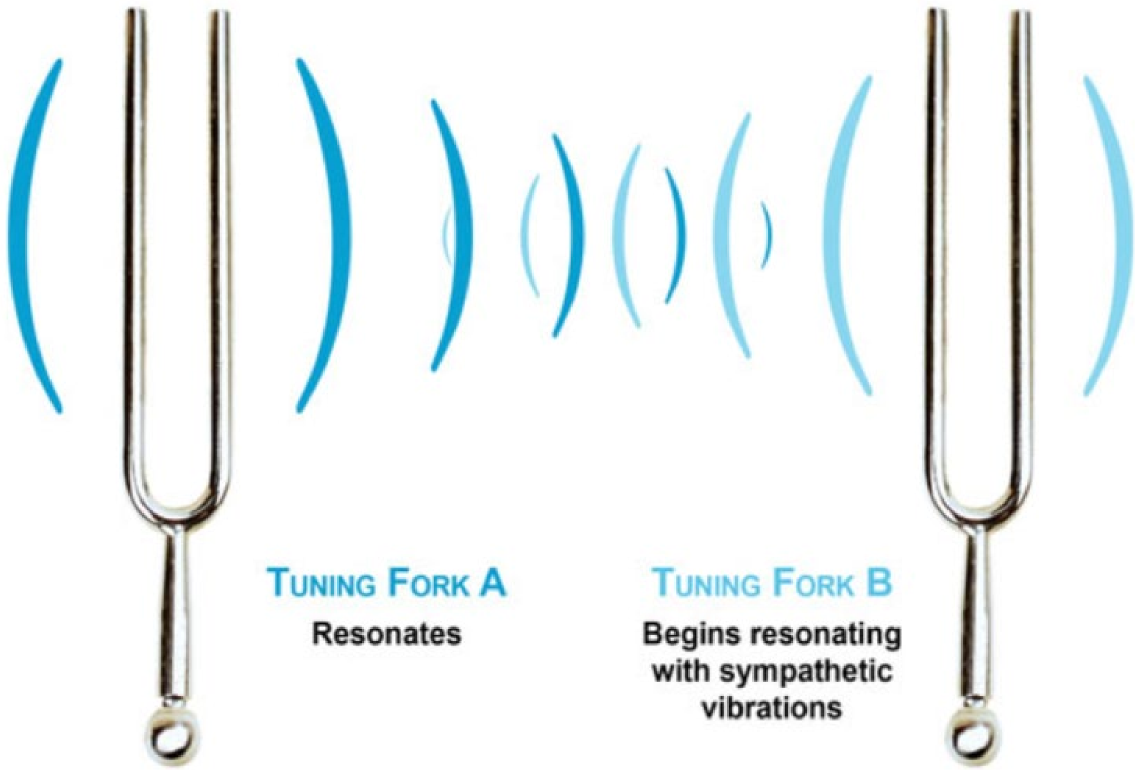


Figure 7: Tuning fork showing resonance

Resonance is the vibration of an object at its natural frequency. For example, buildings near the railway track rattle when a train passes by. This is because of resonance.

Light Waves

Light refers to the electromagnetic waves that can be seen by human eyes. Light is an example of transverse waves that travels at an extremely high speed and has extremely short wavelength. The speed of light in a vacuum is 3.0×10^8 m/s.

Reflection of Light

Picture 2: Light reflected on a building

Reflection of light is the bouncing back of light waves when they hit a shiny surface like a mirror. A mirror is a shiny service normally made by coating glass with aluminum or silver layer.

Law of Reflection

The law of reflection of light states that the angle of incidence equals the angle of reflection.

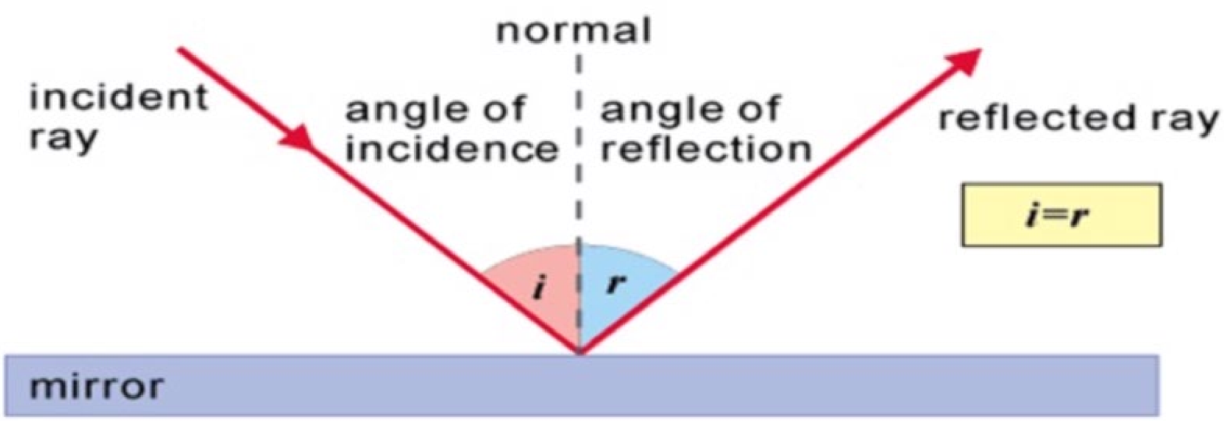


Figure 5: Law of reflection of light

Citations

Figure 1: Distance vs displacement courtesy of David Kimori
Figure 2: Pressure liquids increases with depth picture courtesy of school for champions.com
Video 1: Inertia courtesy of David Kimori
Video 2: Newton's third law courtesy of David Kimori
Figure 3: Longitudinal wave courtesy geogebra.org
Figure 4: Transverse wave courtesy of ck12.org
Figure 5: Typical wave parts courtesy of brilliant.org
Figure 6: Loud and soft sound courtesy of school physics.co.uk
Figure 7: Law of reflection of light courtesy of jagrajosh.com
Picture 1: An ambulance responding to an emergency courtesy of sandiegouniontribune.com
Picture 2: Light reflected on a building courtesy of Wikimedia commons

Chapter 9: Work, Power, Energy and Simple Machines

Introduction

Picture1: Pyramid

Have you ever wondered how ancient people build massive structures like pyramids of Egypt? What kind of machines did they use to build these structures? In this chapter we will explore the concept of work, power, simple machines and how machines make work easier. Also, we will explore some of the activities that you engage elementary students in to explore more about machines.

What is work?

Work is when a force applied causes an object to move in the same direction as the force.

Force is a push or pull.

Photo 2: Pushing a cart using force

Compare the following scenarios:

1. A teacher teaching a class
2. A mouse pushing a piece of cheese with its nose across the floor of a room.

In the two scenarios what is work and what is not work? To answer this question, think of the force applied in each scenario and what to direction? Obviously, force applied by the mouse is in the same direction as the direction of motion. According to science a mouse is doing work and the teacher is not!

Question 1
Suppose you try to push a brick wall for one minute. Is this considered work? Why or why not?

Formula for Work

Work= force x distance

W=Fd

The unit for work is a ***Joule (J).***

Example: If you push a concrete block 10 meters with a force of 200N, how much work will you have done?

Work= force x distance

Force=200 N

Distance = 10 m

Work=200 N x 10 m

Work = 2000 J

Power

Power is the rate of doing work

Formula for Power

Power=work/time

P=w/t

The unit for work is Joules (J) and the unit for time is seconds (s). Therefore, the unit for power is J/s.

The unit for power is also ***Watt (W)***

1 J/s=1W

Practice solving the question below.

Question 2

How much power is required to move a 10 N block for 2 meters in 5 Seconds? (Give your numeric answer only without units)

Energy

Energy is the ability to do work. Teaching energy concepts is easy when you connect energy concepts to what students know through their: senses, everyday experiences and hands on activities. Energy is measured in the same units as work: Joule (J). Objects gain energy because work is done on them.

Energy is all around you:

You can hear energy as sound.
You can see energy as light.
You can feel energy as heat.
You use energy when you hit a softball.

Forms of Energy

1. Heat
2. Chemical
3. Electromagnetic
4. Nuclear
5. Mechanical

Heat energy

Heat energy is the energy possessed by the internal motion of atoms. Heat energy can be produced by friction and also heat energy can cause changes in temperature. Examples of heat energy include: The Sun, hot stove etc.

Chemical energy

Atoms are bonded together by chemical energy. When these bonds are broken energy is released. Examples of chemical energy include: fuel, batteries and food.

Electromagnetic energy

Electromagnetic energy is the energy that is generated by interaction of electricity and magnets. Light is a form of electromagnetic energy. Other forms of electromagnetic energy include: X-rays, radio waves and microwaves.

Nuclear energy

Nuclear energy is the energy produced from the nucleus of an atom. When the when the nucleus splits through a process called fission, energy is released in the form of heat and light. Similarly, when the nucleus joins in a process called fusion, energy is also released. The sun's energy is produced through nuclear fusion of hydrogen nuclei to form helium nuclei. Nuclear power plants convert nuclear energy into electromagnetic energy that we use as electricity and in many other ways.

Mechanical energy

The energy that is required when work is done on an object is called mechanical energy. There are two types of mechanical energy: kinetic energy and potential energy.

Kinetic Energy (KE)

Kinetic energy is the energy of motion. The amount of kinetic energy of an abject has is determined by two factors: mass and speed of the object. The faster the object moves the more the kinetic energy it has and also the greater the mass of the object the more the kinetic energy it has. Therefore, kinetic energy depends on both mass and the velocity of an object. This relationship is given by the formula:

$$KE=1/2mv^2$$

KE= ½ Mass x velocity^2

Potential Energy

Potential energy is stored energy. It can be stored chemically in fuels or because of work being done on the object. Potential energy that is dependent on height is called ***gravitational potential energy*** and is given by the formula:

$$PE=mgh$$

PE= Mass X gravitational acceleration X height

Potential energy that is being stored due to an object being stretched or compressed is called an ***elastic potential energy*** and is given by the formula:

$$PE=kx^2$$

PE= elastic constant x distance^2

Kinetic Energy- Potential Energy Conversion

Picture 3: Mantis Roller Coaster at Cedar Point, Sandusky, Ohio

Kinetic energy can be transformed to potential energy and vice versa. Take an example roller coaster, before it moves it has potential energy and when it starts moving potential energy is converted to kinetic energy. This transformation keeps on as the roller coaster loops around. At the maximum height the roller coaster has a maximum potential energy and at the lowest point the roller coaster has a maximum kinetic energy as shown in the figure.

The Law of Conservation of Energy

The law of conservation of energy states that energy cannot be created nor be destroyed but it can be transformed from one form to another. In 1905 Albert Einstein said that, mass and energy can be converted to each other. He demonstrated that if matter is destroyed then energy is created and if energy is destroyed then matter is created. He came up with this formula:

$E=MC^2$

Energy= Mass x speed of light^2

Simple Machines

A machine is a device that makes work easier by changing the size or direction of force. Examples of machines include:

- can opener
- door knobs
- brakes
- knife

There are simple machines and complex machines. A complex machine has two or more simple machines. In the section below, we will explore the various types of simple machines.

Types of Machines

1. inclined plane
2. wedge
3. screw
4. levers
5. pulley
6. wheel and axle

1. Inclined plane

Picture 4: Playground Slide

An inclined plane is a straight slanted surface. An inclined plane makes work easier by moving objects to a higher or lower place. Examples of inclined plane include: ramp, steps, slopping roads, playground slides, wheelchair ramp and etc.

2. Wedge

Picture 5 Axe (example of a wedge)

A wedge is looks like two inclined planes joined back-to-back. One end is thicker than the other. A wedge makes work easier because it is able to cut or split objects apart. Objects that a wedge splits may also include air and water. Examples of wedges include: axe, knife, boat stern, door stop etc.

3. Screw

Picture 6: Drywall Screws

A screw is an inclined plane that is wrapped around a cylindrical rod with a wedge at the tip. A screw makes work easier by applying more force with little effort. Also, a screw makes work easier by holding things together. Examples of screws include: drill bits corkscrew, bottle caps etc.

Inquiry Question

Please respond to question 3 below and explain your reasoning

Question 3
Do more threads on a screw make easier or harder? Explain

4. Lever

A lever is made up of a bar that pivots at a fixed point called the *fulcrum* or *pivot*.

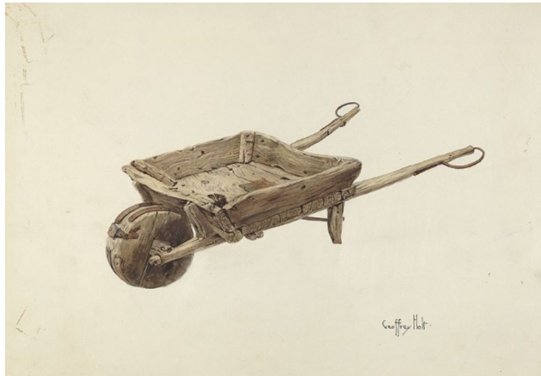
Picture 7: See-Saw (Lever and Fulcrum)

Force applied for lever is called the *effort*. The object that is being moved is called the *load*. Depending on the position of the effort, load or fulcrum, we have three classes of levers.

We will now discuss the three classes of levers in the section below.

i. First Class Levers

In first class levers the fulcrum is in the middle. examples of first-class levers include: see saw, scissors e



Picture 8: Very Old Wheel Barrow

ii. Second Class Levers

In second class levers the fulcrum is at the end with the load in the middle. Examples of second-class levers include: wheelbarrow, stapler, nutcracker etc.

iii. Third Class Levers

Picture 9: Tweezers (third class levers)

In third class levers the fulcrum is at the end and the effort is in the middle. Examples of third-class levers include: fishing pole, tongs, broom, tweezers etc.

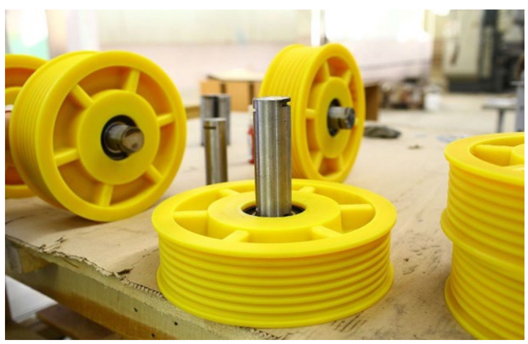
Question 4

Explain the difference between first class levers and third-class levers?

Picture 10: Bicycle Wheel (example of wheel and axel)

5. Wheel and axle

A wheel and axle consist of two circular objects all connected to a pole (axle). A wheel and axle make work easier because it applies more force or lifts the load with less effort. Examples of a wheel and axle include: door knob, steering wheel, wrench and bolt etc.



Picture 11: Belt Pulley

6. Pulley

A pulley is a wheel and axle with a Groove around the outside. A pulley has a rope, chain or belt around the groove to make it work. A pulley system consists of one or more fixed pulleys. The pulleys can be moveable or fixed. Pulleys make work easier changing the direction of force or multiplying the effort used. Examples of pulleys include: ski lift, flagpole, cranes etc.

Activities on Simple Machines for Elementary Students

1. Simple Machines Scavenger Hunt

In this activity you have students list down examples of simple machines that they see outside school. They will then categorize them according to what type of simple machines they are.

2. Building a Simple Machine

In this activity students will build a simple machine.

- Materials
- Card board box
- Straws
- String
- Scissors

Using the materials above have students design and build an example of a simple machine.

3. Big Machines

In this activity the students will watch the following video on big machines and then write down the various simple machines they could identify in the big machines.

https://www.youtube.com/watch?v=_BPZ0mPukyA Video1: Big machines

Citations

1. Picture1: Photo courtesy of Ricardo Liberato via Wikimedia commons under public domain.
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11. Picture 11: Photo courtesy of ООО ТД "Век" via Wikimedia commons under public domain.
12. Video1: Big machines, Youtube video courtesy of OscarFilmApS

Chapter 10: Earth and Space Science

This chapter will explore the concepts that elementary students should understand about space. It begins with a very general overview of the universe, then galaxies, and finally our solar system.

The universe is made of many extremely large structures. In order of size and complexity, these include superclusters, then clusters, then galaxy groups, and then singular galaxies.

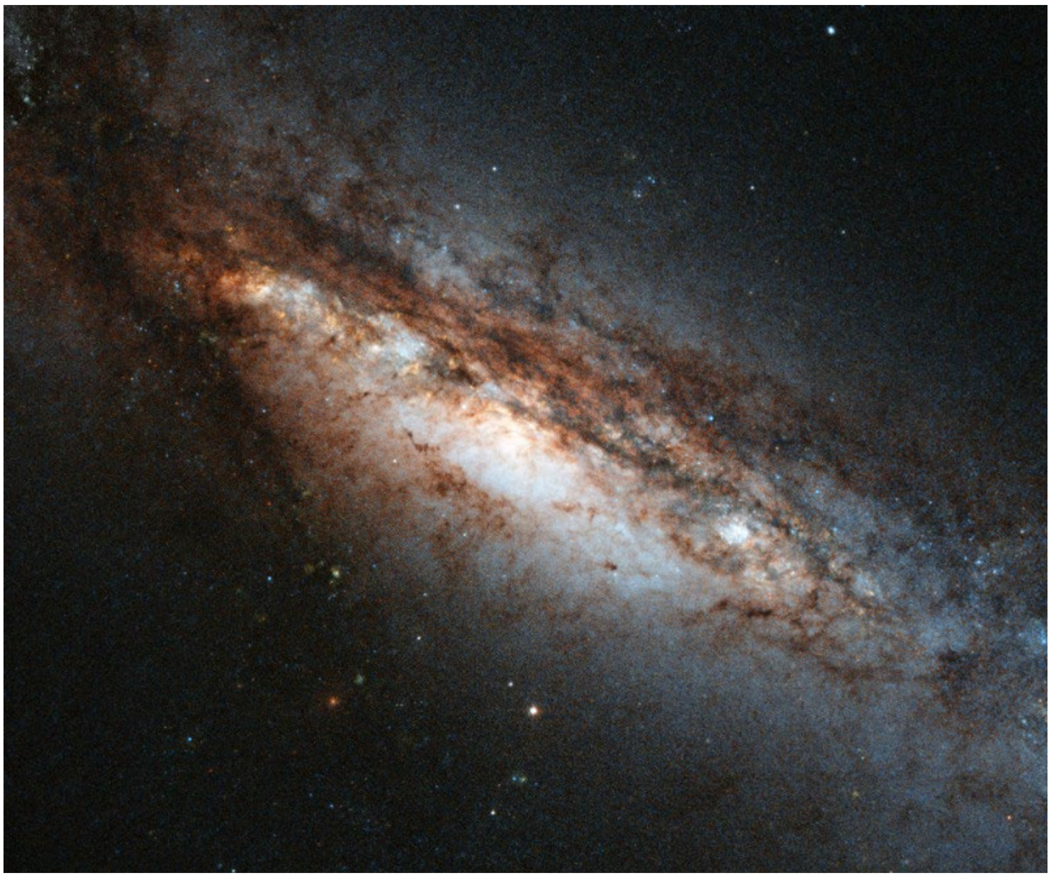


Image 1: A Galaxy

Galaxies

Galaxies are giant groups of stars and the bodies that surround them. We are a part of the Milky Way galaxy. Estimates of how many stars there are in the Milky Way ranges from several hundred million stars all the way up to four hundred billion. It is really difficult to know how many galaxies there are in the universe, but many astronomers estimate the number to be between one hundred and two hundred billion galaxies. (Some, however, claim that there are around two trillion galaxies in the universe.)

Clearly, it is difficult to count such an extremely large number of objects, even objects as large as stars and galaxies. Galaxies are often found in **clusters** of between one hundred and one thousand galaxies. There are even **super clusters** which are clusters of several galaxy clusters.

Our Solar System

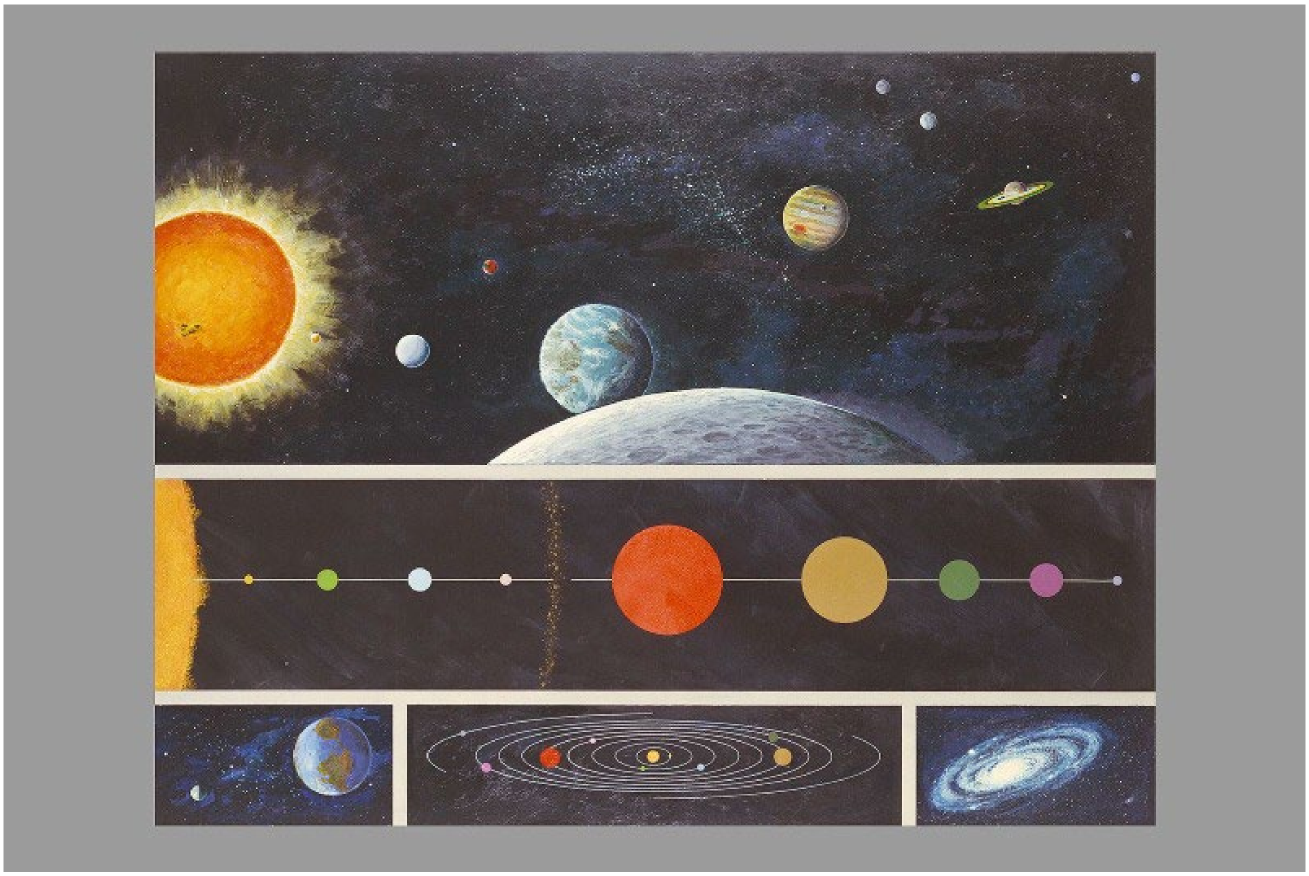


Image 2 Our Solar System Artwork by Rick Guidice . Copyright NASA

It seems that our solar system was formed sometime around 4.6 billion years ago when gravity caused a giant interstellar molecular cloud to collapse. When this happened, most of the mass ended up in the Sun. Of the remaining mass, most is in the planet Jupiter. The rest is distributed among the other planets. They will be discussed later in this planet.

Sun

Our star, the Sun, is not a spectacular star. It is not very big in comparison to others. Astronomers would call it a yellow dwarf or a G2-type main-sequence star. Yellow dwarfs fall somewhere between the hottest stars and the coolest stars. In terms of size, the sun is also in the middle. The smallest stars, neutron stars may only be 25 miles in diameter. While Super Giants like Betelgeuse which is a part of the constellation Orion, has a diameter 1,000 time that of the sun.

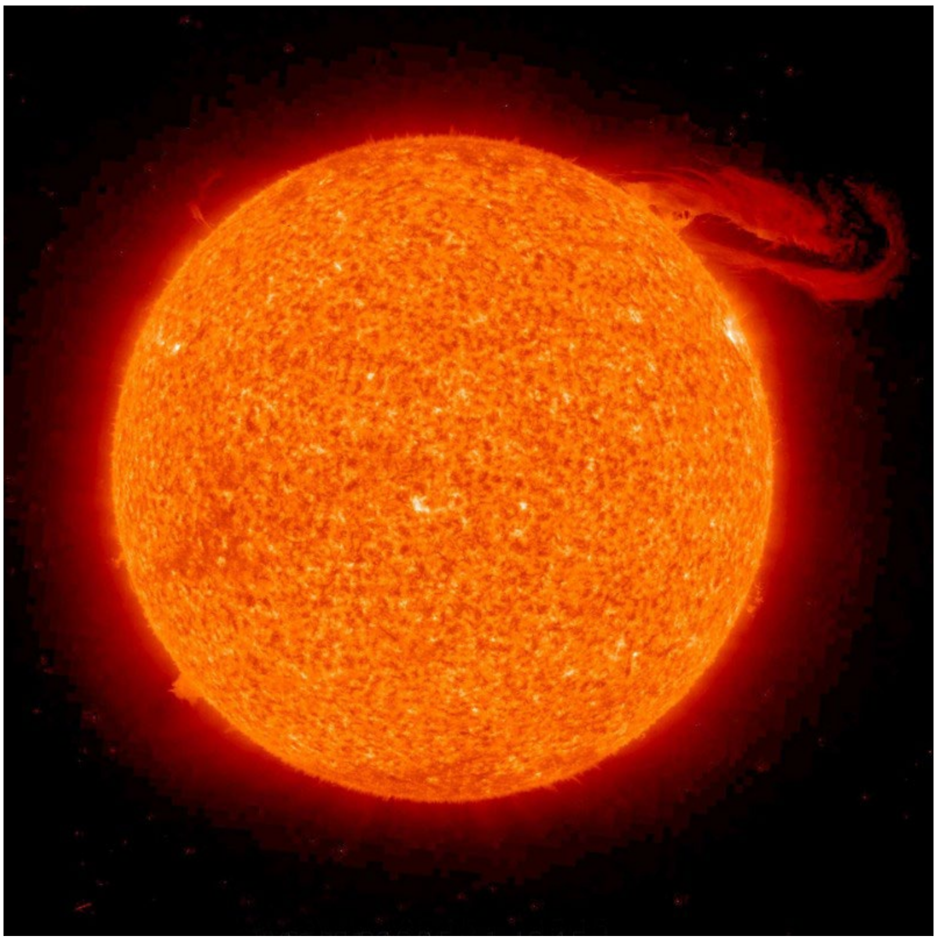


Image 3 Solar prominence from STEREO spacecraft September 29, 2008

Fusion

The sun is made up of mostly of the elements, hydrogen and helium. There is so much of these elements in the sun that it (the Sun) accounts for around 99.8% of the matter in our solar system. Hydrogen is the lightest of all atoms, and helium is the second lightest.

Because the sun is so gigantic, its gravity is extremely powerful. It is so powerful that in the Sun's core, the hydrogen atoms are pressed together with enough pressure that the hydrogen atoms fuse together to create helium. This process is called nuclear fusion. Fusion is occurring in the center of every star. Nuclear fusion produces a great deal of energy. There is a continuous combination of **gravity** pulling the hydrogen and helium toward the center of the Sun, and **nuclear fusion reactions** pushing the material out. In this way, the size of the Sun remains constant. However, in time the nuclear fuel will begin to run out and the sun will first collapse and then expand into a red giant star. This general process is true of all stars.

Orbits, Gravity and Inertia

As stated earlier, the sun makes up more than 99% of the mass of our solar system. Because of its great mass, the Sun has a very strong gravitational field. The sun's gravity is part of what holds all of the planets in their orbits. The forces involved in maintaining an orbit are gravity and inertia. Gravity is an attraction between two masses. The amount of attraction is a function of the amount of mass in the bodies, and the distance between them. In general, the more mass, the stronger the gravity. In general, the closer the objects are, the stronger the pull of gravity. We, on Earth, experience the Earth's gravity in a way that all things are drawn to the Earth's core. Yet, the Earth is also influenced by the Sun's gravity.

The second force needed to maintain an orbit is inertia. A simplified explanation of inertia in orbits would be that **any moving mass tends to stay moving at the same speed and in the same direction unless it is acted upon by an outside force**. In the case of the planets' orbits: each planet's motion around the sun is at the exact right speed and the exact right distance from the sun to keep it in place. If a planet's orbital speed were any faster, that planet would continue on its's current path leaving the solar system. If that same planet's orbital speed were any slower, that planet would eventually spiral into the sun, overtaken by the sun's gravity. **In general, the closer an object is to the Sun the faster it must travel to stay in orbit.** This is because the effects of gravity increase the closer together the bodies are.

Please click here to view (Simulation 1) of the orbits of the Earth and Moon around the Sun. As you view this model, please experiment with the sliders in the box to the right to change variables impacting orbits. You can change the mass of the Sun and the mass of the Earth. You can include the Moon, or look at the orbit of the International Space Station.

Inner Solar System

The inner solar system is made of the planets Mercury, Venus, Earth, and Mars, along with the Asteroid Belt. These are all terrestrial planets, meaning that they have rocky, solid surfaces. Some of these planets have moons, some don't. The asteroid belt is an area between Mars and Jupiter where rocky fragments are orbiting the sun. Let's look at the inner solar system.

Mercury

Image 4 Mercury Transit of the Sun (The fuzzy dot is Mercury as it passes in front of the Sun.)

Mercury is the closest planet to the sun. It is a relatively small planet that orbits the sun every three months. Mercury's surface is rocky and pocked with craters. Mercury has no moons and little atmosphere. The lack of significant atmosphere allows heat to radiate off the surface of the planet. Mercury rotates very slowly on its axis. (A "day" on Mercury is similar in length to its "year".) Because of this, and its lack of atmosphere, the dark side of Mercury is extremely cold while the lit side is extremely hot. It is very unlikely that life could survive on Mercury.


Image 5: Venus

Venus

Venus is the second planet from the sun. It is similar to the Earth in size, but has no moons. Venus is covered in a dense layer of clouds, which causes the surface to be extremely hot. Because of this, Venus is studied as an example of the effects of greenhouse gasses. An interesting fact about Venus is that it rotates backward on its axis (as compared to the other planets). It also seems unlikely that Venus could harbor life, because of the extreme high temperature on its surface.

Earth

Earth is our home. It is the only planet we know of where water is found in its solid, liquid, and gaseous forms. This is possible because Earth is just the right distance from the sun. Some astronomers have described this as the “Goldilocks” distance because it is not too hot or too cold to support life. They use this analogy as they search for planets that could support life. The Earth's atmosphere helps regulate temperature and screen the surface from harmful forms of solar radiation. The Earth has one moon, which is the only body, aside from Earth, that has been visited by humans. The Earth has solid ground, liquid water and frozen water on its surface. It also has a substantial atmosphere that produces weather and protects life from dangerous solar radiation.

Image 6: Earth's Rotation

Image 7: Image of Earth and Moon, taken by the Mars Orbiter Camera of Mars Global Surveyor on May 8 2003

The Moon orbits the Earth at a distance of about 28,000 miles. It makes one orbit every twenty-seven and a third days. Because of a slight bulge in the Moon's interior, gravity keeps one side of the. Moon pointing toward the Earth. Because of this, the side of the Moon we never see from Earth is littered with impact craters, while the side facing the Earth has many less, because of the Earth's "protection" against meteorites. The moon has little to no atmosphere, but does appear to have frozen water at its poles.

The Moon's gravity has an important impact of the Earth's oceans. As the Earth rotates on its axis, the oceans turn toward and away from the Moon. The moon's gravity acting on the ocean's water pulls it, creating tides. The moon has also had an important part of human culture. Every culture has stories and legends that involve the Moon.

Mars

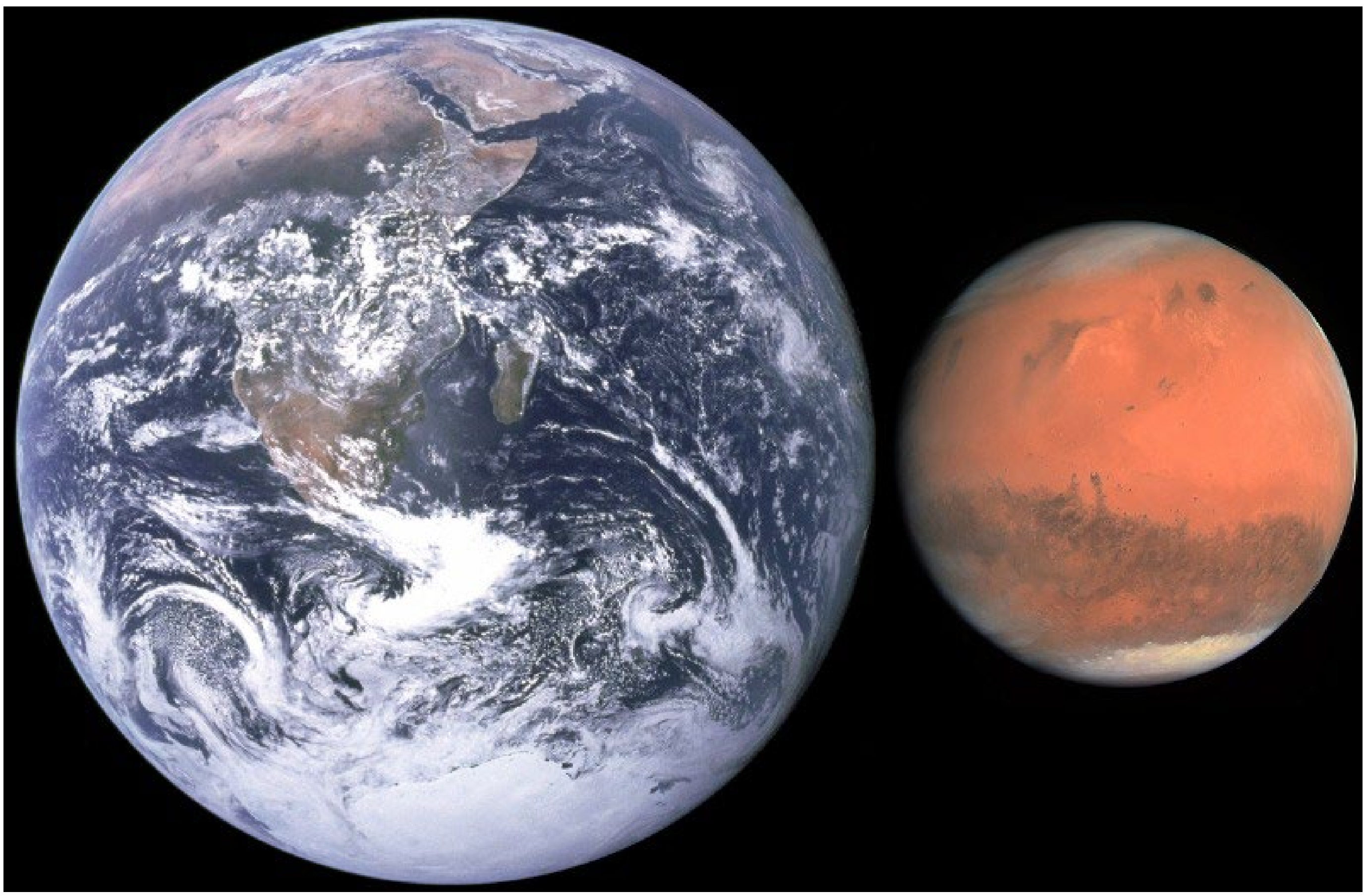


Image 8: Size Comparison of Earth and Mars

Mars is the outermost terrestrial planet. Is has two moons Deimos and Phobos. Mars has been extensively "explored" by satellites photographing its surface and by robotic devices which have landed on the surface. Some of these robots are wheeled and can travel short distances. The exploration of Mars has shown evidence that water once flowed on Mars. It also appears that there may be water in the form of ice just below the surface of Mars and on the surface in the polar regions. It is also clear that Mars has an active atmosphere. Great sand storms blast away at the Martian surface. Evidence of wind erosion is found all across the planet.

Image 9: Evidence of water on Mars.

Mars has been the object of human imagination for a long time. Because of the iron oxide on its surface, Mars has a reddish/orange color that can be observed with the naked eye.

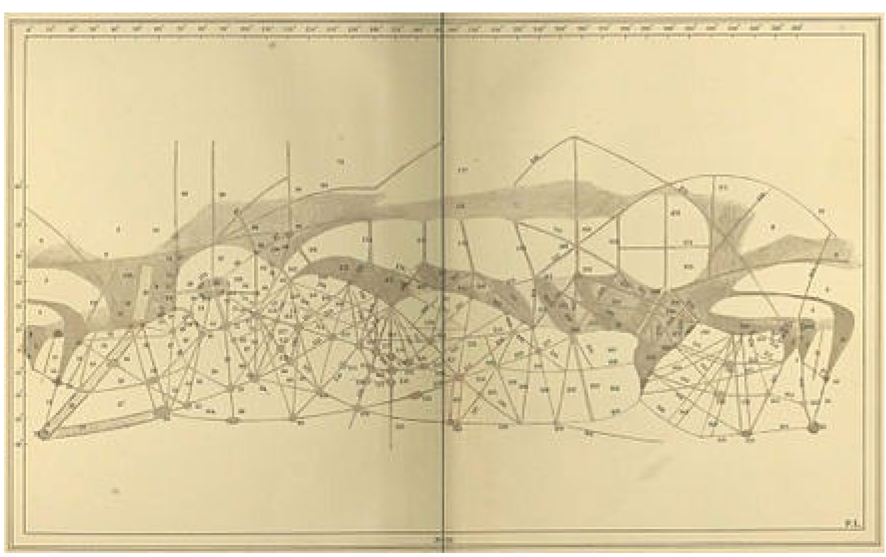


Image 10: Percival Lowell (1855-1906) made observations of Mars, showing "canals"

Additionally, when telescopes were first trained on Mars, straight line markings on its surface seemed to imply “canals” to imaginative minds of writers who published stories of “little green men” populating Mars. Because of its occasional proximity to Earth, Mars is the planet most likely to be explored by humans. There are several groups planning to establish human outposts on Mars.

Asteroid Belt

The Asteroid Belt, between the orbits of Mars and Jupiter is a disk of rock and ice fragments orbiting the sun. There are many theories about what caused the Asteroid Belt.

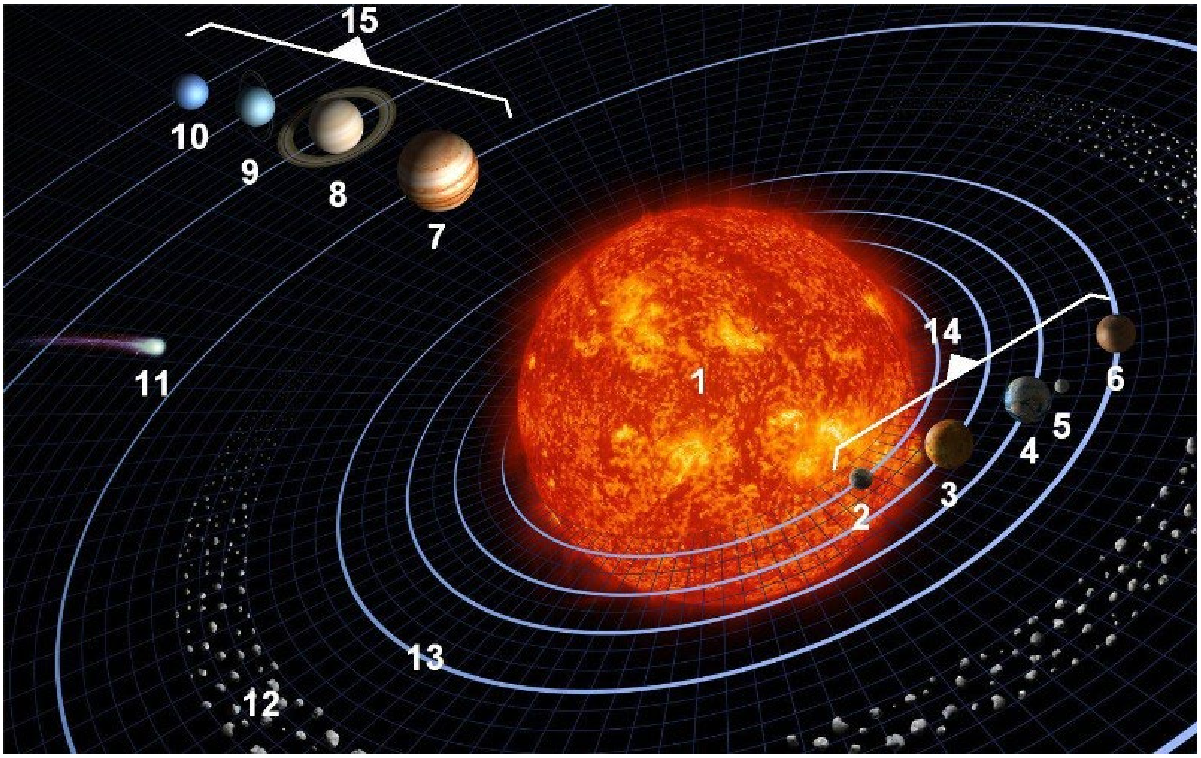


Image 11: Artist's rendition of the Solar System, showing the Asteroid Belt

One is there was another terrestrial planet between Mars and Jupiter that collided with some kind of space debris creating a gigantic explosion tearing the planet apart. Another theory is that this same planet was torn apart by extreme gravitational forces, when all of the planets lined up as they orbited the Sun.

Outer Planets

Jupiter (Gas Giant)

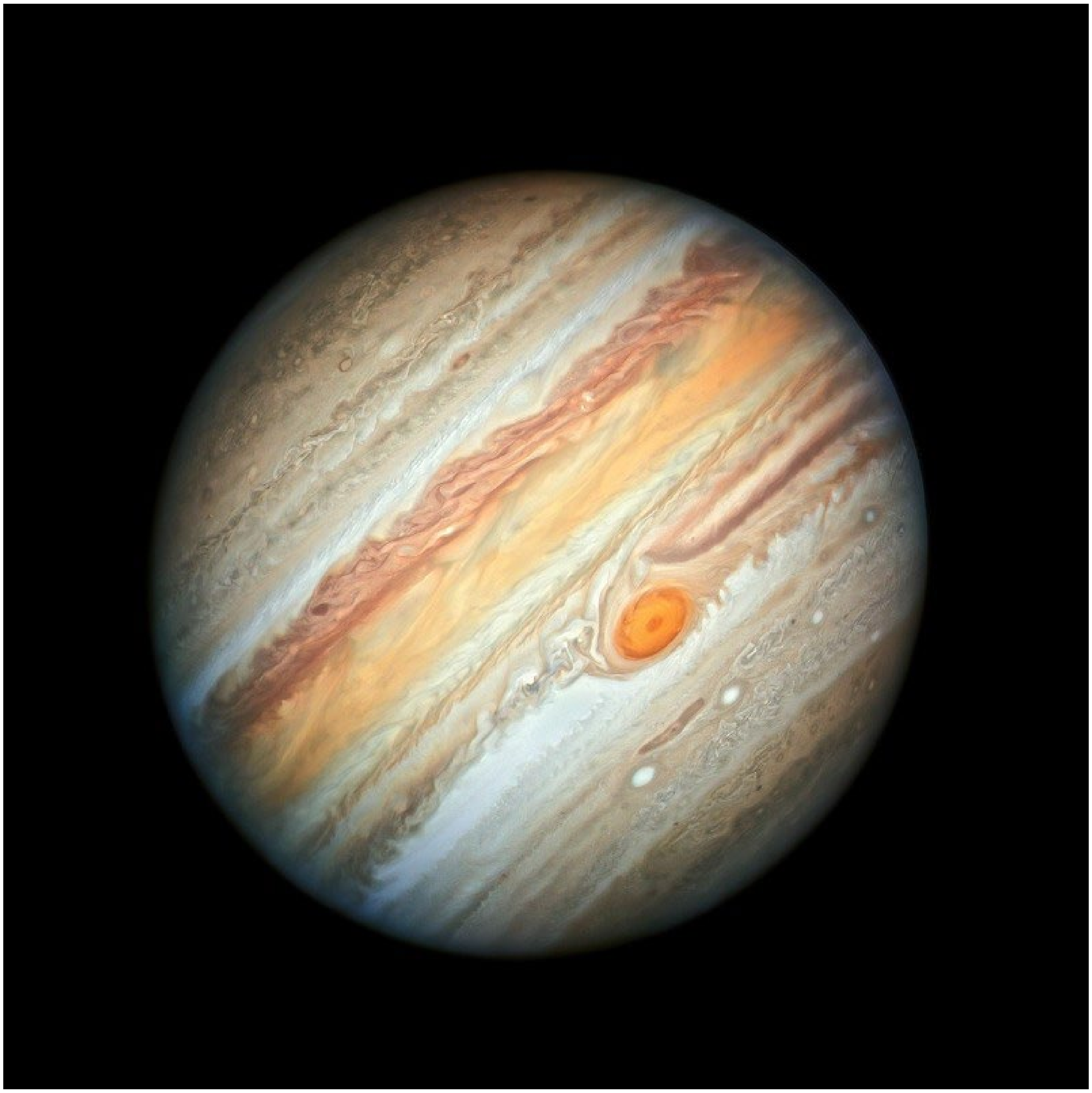


Image 12: Jupiter a Beautiful Gas Giant!!

Jupiter is the largest of all planets in our solar system. It and Saturn are classified as Gas Giant planets by astronomers. Like the Sun, they are made mostly of hydrogen and helium. Under high pressure this hydrogen and helium is in liquid form in Jupiter's interior. Because it is liquid and not solid, Jupiter's interior "swirls" in ways that make its magnetic fields extremely strong and complex. Jupiter has complex weather systems in its atmosphere. The most striking of these features is the "Great Red Spot" which appears to be a massive storm (larger than the Earth) that has been "churning" for centuries.


Image 13; Size Comparison

Jupiter has about 318 times the mass of Earth. It takes about twelve earth years to complete one orbit around the sun. Yet, it takes less than ten hours to rotate on its axis. As of recent exploration, Jupiter has 79 known moons. The first of these were discovered by Galileo in 1610, and the latest in 2003. When Galileo first saw moons orbiting Jupiter, it helped to prove the heliocentric (sun centered) model of our solar system. Prior to this the Earth was believed to be the center of the universe.


Image 14: Jupiter's moon Io

Two of Jupiter’s moons have been studied extensively. Io is the closest moon to Jupiter. It is about the size of the Earth’s moon and has an extremely active geology. The surface is covered with volcanos. This is rare, in fact Io is the only moon yet to be discovered with active volcanism.

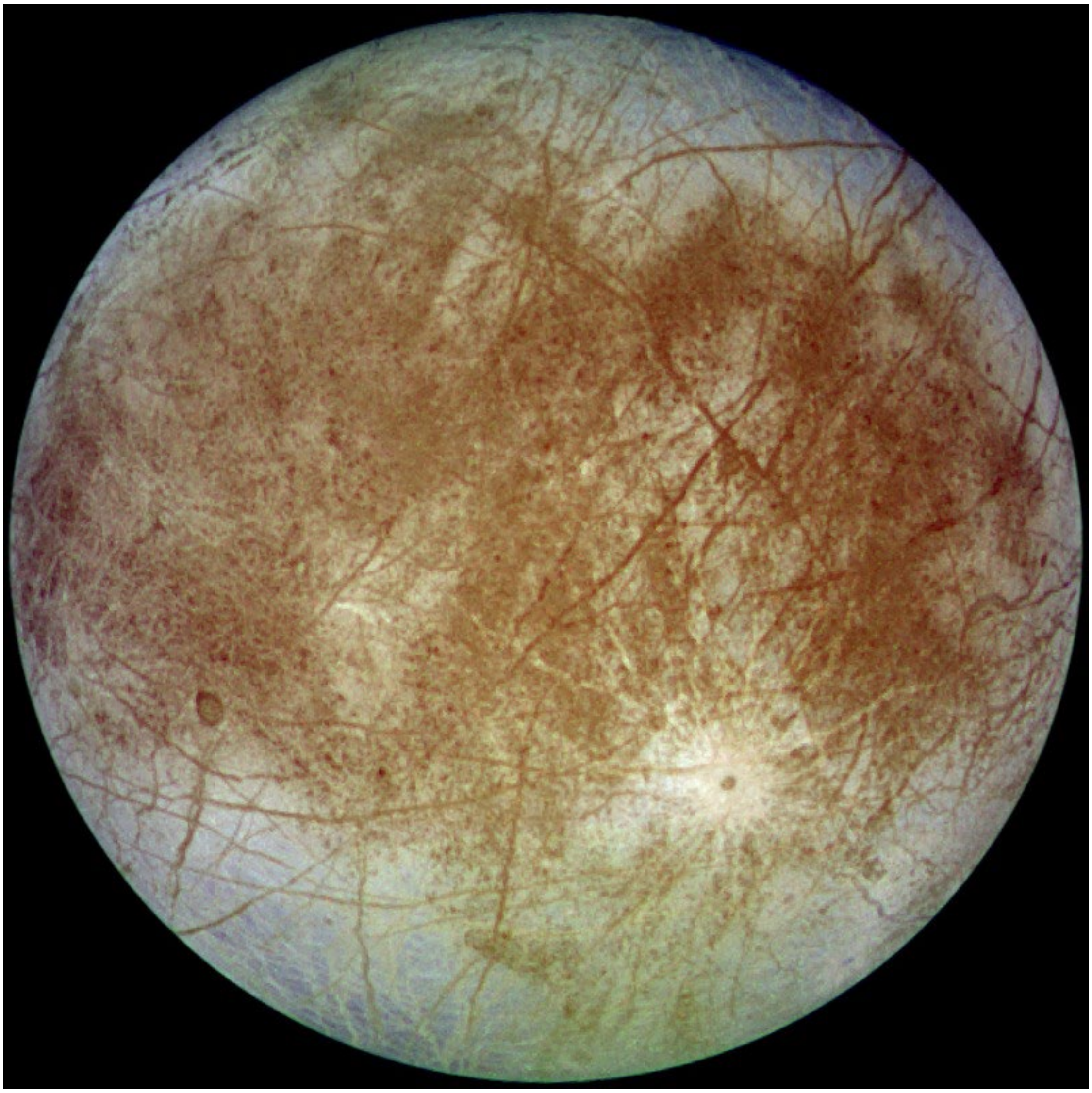


Image 15: Europa, Jupiter's moon that is thought to have liquid water.

Europa is another of Jupiter's moons that draws the attention of astronomers. It appears to have large ice covered oceans. The ice covering Europa's surface is covered with cracks and fissures. It is believed that the surface ice is constantly being reshaped because of strong gravitational "tide" due to the great mass of Jupiter. The oceans on Europa may provide an environment that is hospitable for the formation of life.

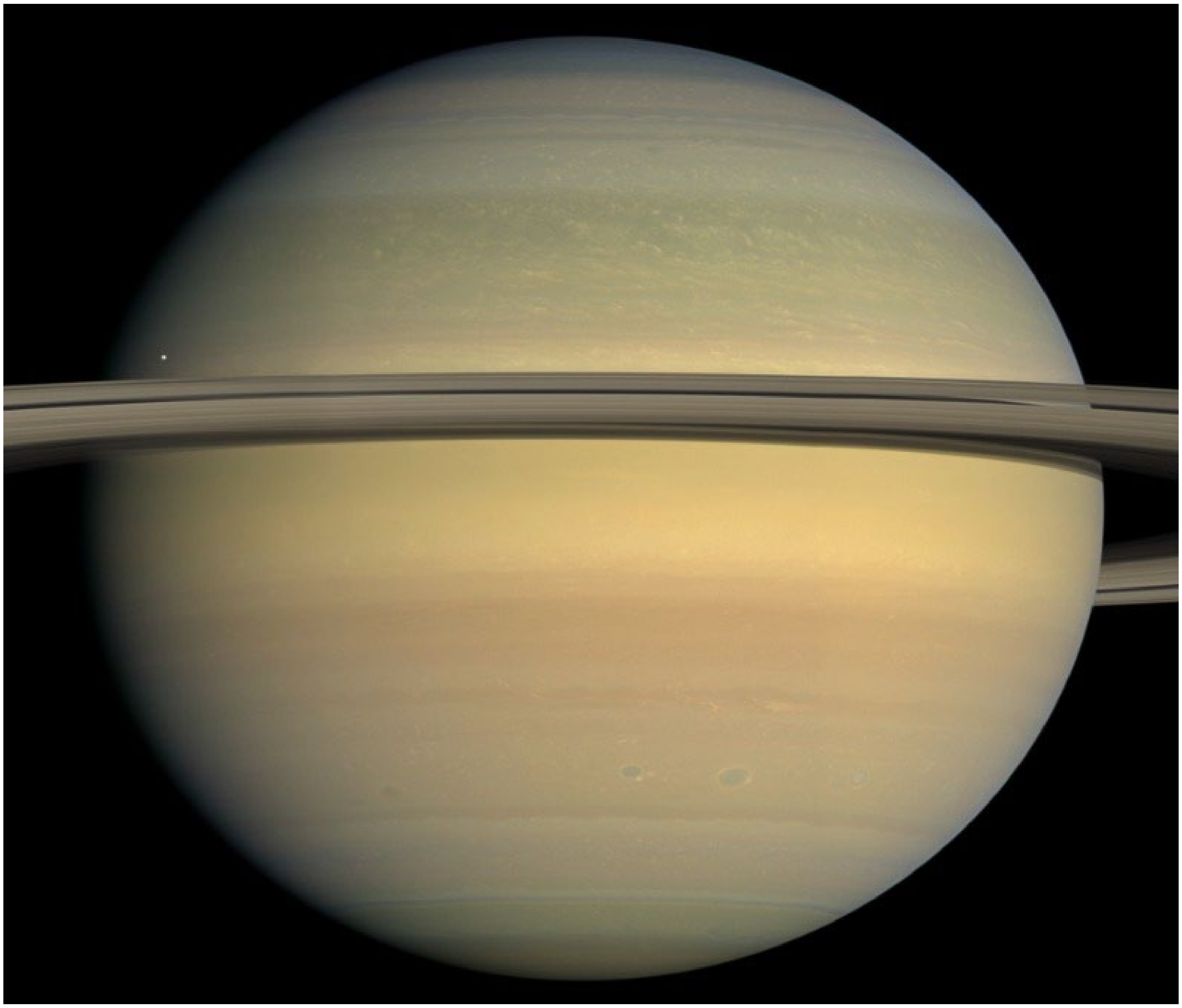


Image 16: Saturn

Saturn (Gas Giant)

The second of the gas giants is Saturn. It is the second largest planet in our solar system. Like Jupiter, Saturn is made up primarily of Hydrogen and Helium in a liquid form. Saturn is one of the most intriguing of the planets. In the mid 1600's Christian Huygens first identified Saturn's Rings.

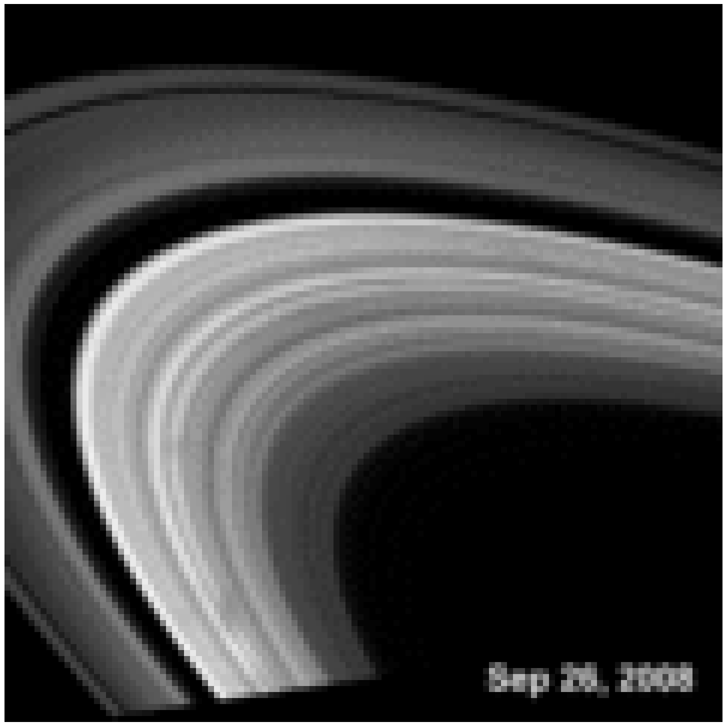


Image 17 Saturn's Rings

For a long time, the nature of these rings was not known. However, as the Voyager 1 satellite passed close to Saturn in November of 1980, and the Voyager 2 made a "flyby' in August of 1981, it was discovered that the rings were made of a multitude of small rocks and chunks of ice orbiting the planet in thin bands.

Fun Fact: Saturn's density is less than water. This means that if it were possible to have a swimming pool that was large enough, Saturn would float in it.

Uranus (Ice Giant)

Uranus is the seventh planet from the Sun. It is about four times the size of the Earth. While it is similar to Jupiter and Saturn, because of its great distance from the Sun, it does not have much internal heat. (Uranus and Neptune would be very difficult to detect with an infra-red camera.)

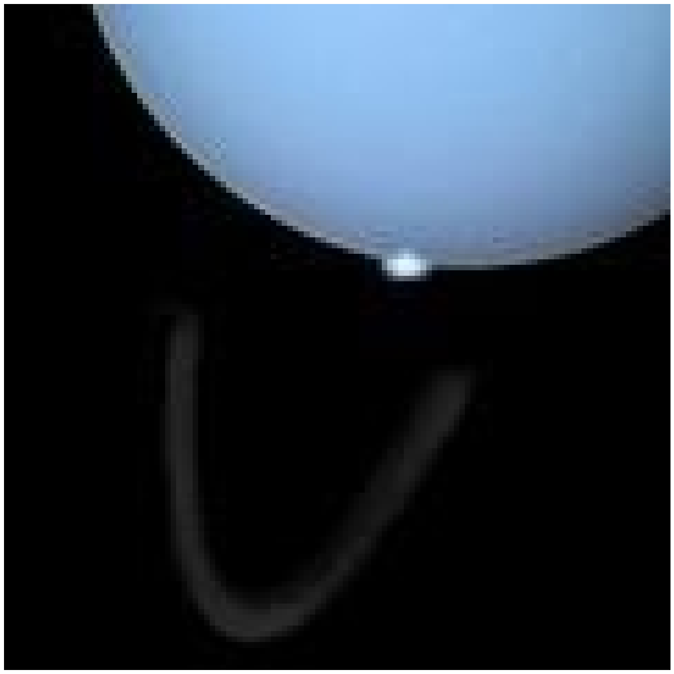


Image 18: Uranus

Because of this, both Uranus and Neptune have been labeled “Ice Giants”. Uranus to have at least twenty-seven moons, and sixteen rings that are barely visible. Perhaps the most interesting thing we know about Uranus is that its axis is tilted around 90 degrees compared to most planets. Therefore, Uranus might be thought of as “rolling on its axis as it revolves around the Sun.

Neptune (Ice Giant)

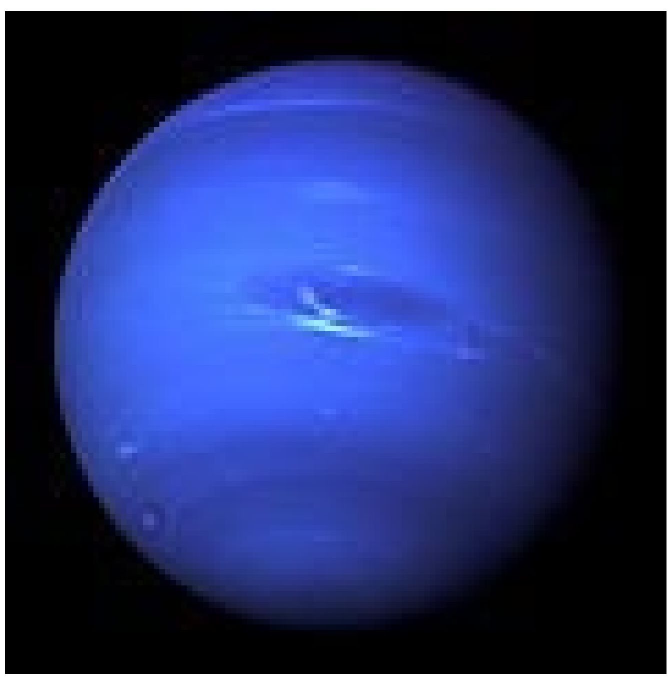


Image 19: Neptune

Neptune is the furthest of the planets from the Sun. (Pluto and others further-out are now classified as “Dwarf Planets”). Like Uranus, Neptune is an Ice Giant. It is very far from the Sun. It takes Neptune almost 165 years to orbit the Sun. Neptune has fourteen known moons. It also has six faint rings.

Trans-Neptunian Objects

Trans-Neptunian Objects are bodies that orbit the sun at a distance that is outside of Neptune's orbit. They include a variety of different objects.

Pluto and Charon

Pluto was discovered by Clyde Tombaugh, an astronomer at the Lowell Observatory in Arizona. There had been mathematical "proof" of an unknown object influencing the orbits of the outer planets. With a lot of patience, Tombaugh spent 25 years searching for what we know as Pluto. In 1930, he was able to detect Pluto's motion against fixed stars.

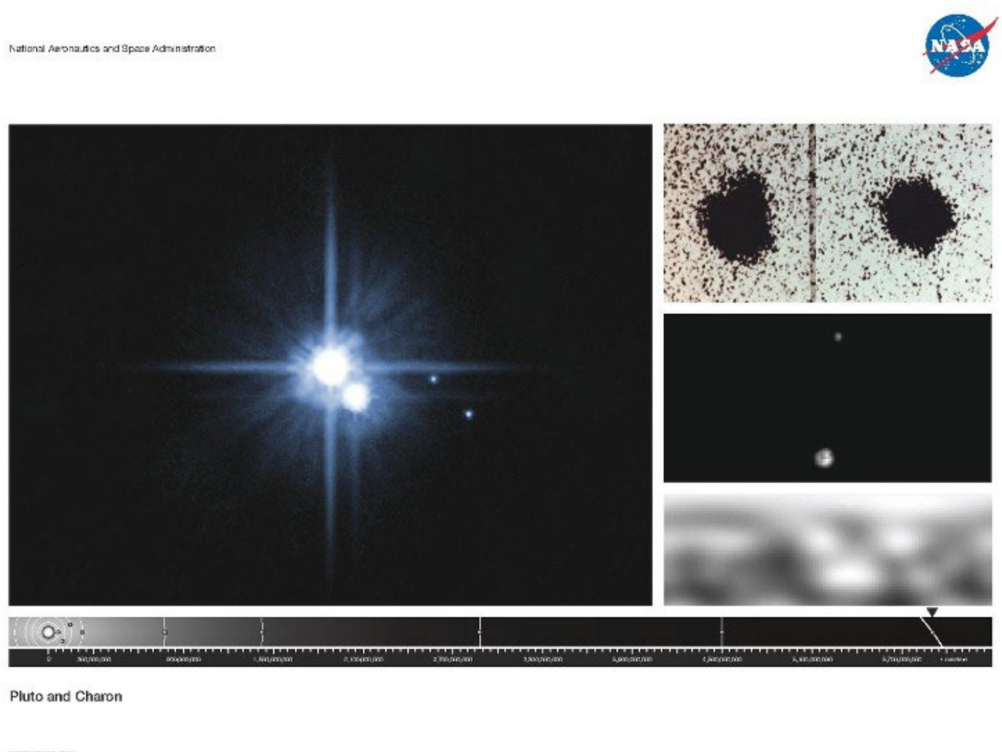


Image 20: NASA photos for Pluto and it's moon Charon

Pluto was considered a planet until 2006, when the International Astronomical Union created an official definition for what constitutes a planet. At that time, Pluto was demoted to Dwarf Planet status.

There are several things that make Pluto unusual. First, Pluto has an extremely eccentric orbit. Most of the time, Pluto is well outside Neptune's orbit, however its orbit "dips" inside of Neptune's orbit for twenty of every two hundred forty eight years.

Another unusual thing about Pluto and its moon Charon has to do with their sizes. Pluto and Caron are nearly the same size, leading some astronomers to refer to them as twin "dwarf planets".   Pluto is the only known dwarf planet with an atmosphere.

Kuiper Belt and Oort Cloud

Far from the sun past the orbits of the planets there are objects held in orbit by the sun's gravity. Simply put, the objects that orbit on or near the same plane as the planets but well beyond Neptune are in the Kuiper Belt. The term Trans-Neptunian Objects is applied to the objects that make up the Kuiper Belt.

The Oort cloud is a theoretical region a thousand times further from the sun than the Kuiper Belt. It is a "spherical shell" around the sun. The importance of the Oort Cloud is that it believed to be where long period comets "reside" when they are not in the "near sun" part of their orbits.

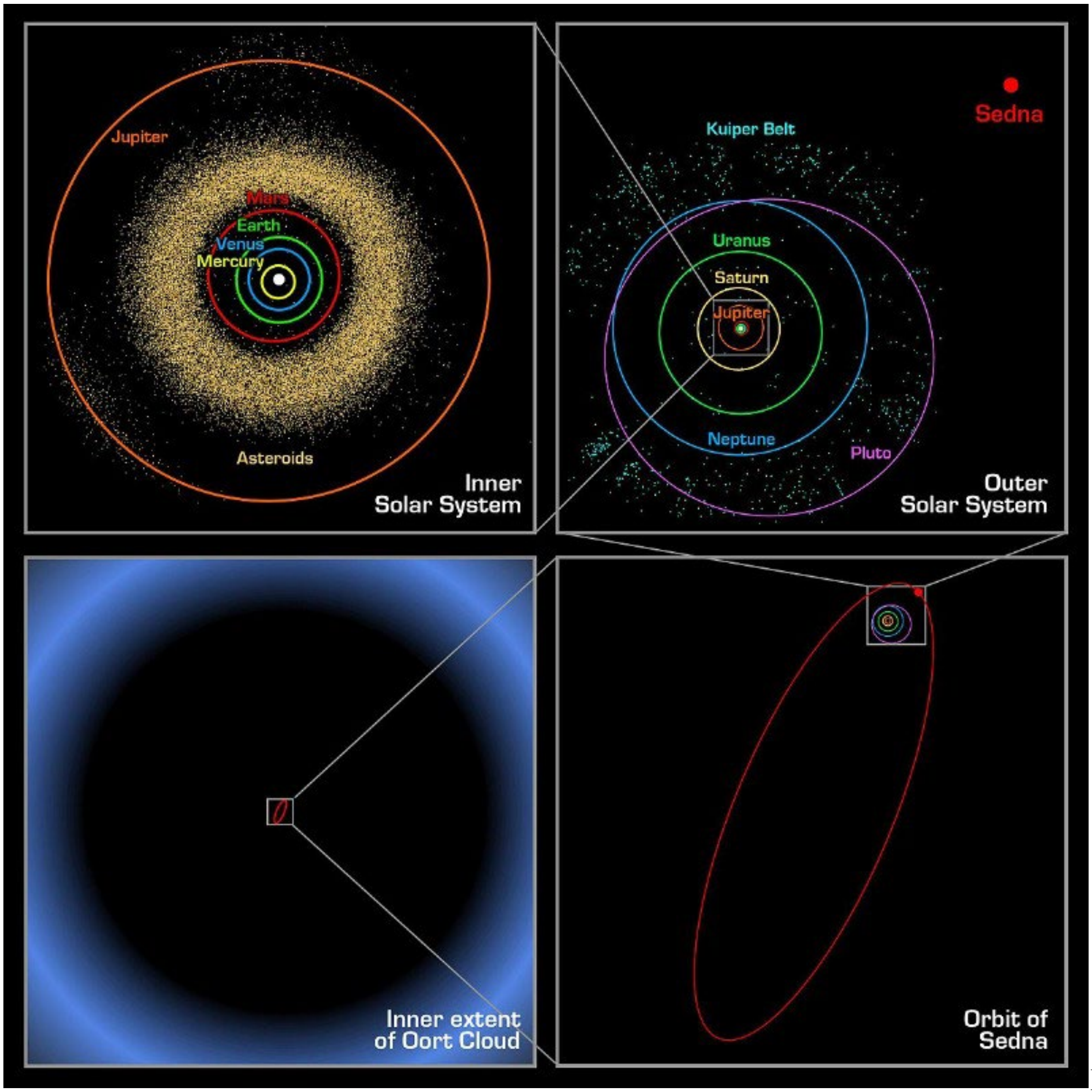


Image 21: Scale of objects in the Solar System

The image below at left shows an ever expanding view of the solar system. The upper left box shows the inner solar system and the Asteroid Belt. The orange ring is the orbit of Jupiter. Looking closely at the upper right box, you can see that same area out to Jupiter in the center of the image. This image shows the outer solar system and the Kuiper Belt. In it shows the dwarf planet, Sedna in the upper right. Sedna is a dwarf planet and one of the most distant bodies found in our solar system. Sedna's orbit, even at its closest approach to the sun, is still much farther than Pluto's furthest location in nits orbit.

The lower right image shows Sedna's orbit. Finally, the lower left box shows the theoretical location of the Oort Cloud. (Note the scale of each of the final three boxes is represented by the small box inside each of the following images.)

Comets

Comets are small bodies that have extremely elongated elliptical orbits. The distances that their orbits extend from the sun means that their orbital period can be quite long. Comets whose orbits end in or near the Kuiper belt are termed short-period comets. Their orbital periods can range from several years to a million years of more.

Comets whose orbital period is less than 200 years are called "Near Periodic Comets". Those with orbital periods between 200 and 1000 years are "Long Periodic Comets". Near Parabolic Comets are ones whose orbital period is longer than 1000 years. There are other types of comets that appear in our solar system only once. These are termed "Hyperbolic Comets".

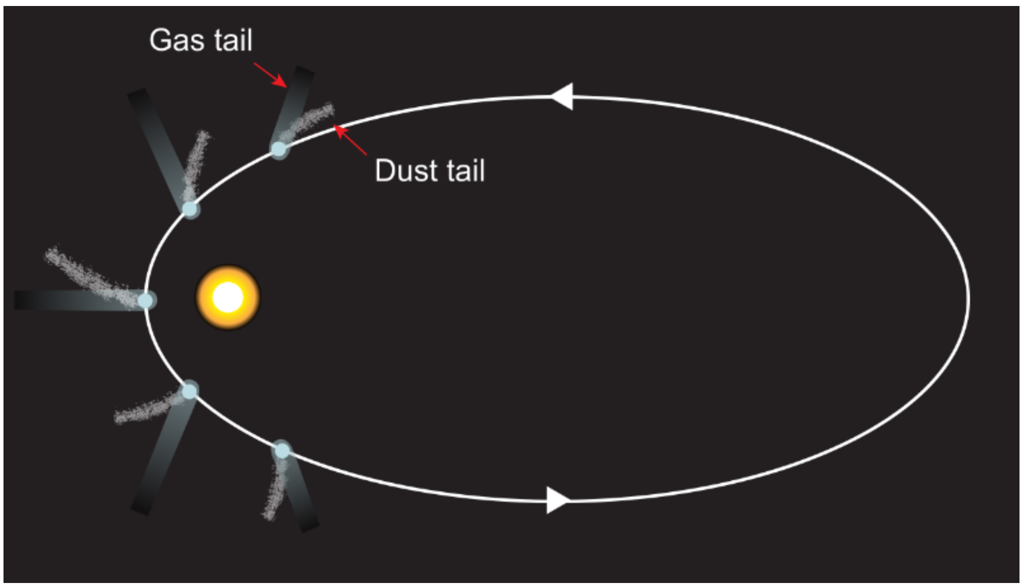


Image 22: A comet's tail is always pointed away from the sun.

When close to the sun, comets are made of three parts: the nucleus, which is a loose collection of ice, rock and dust; the coma or "atmosphere" of the comet; and the tail which is blown off the coma by solar winds. The nucleus is always in existence, and the sun's gravity pulls it toward the inner solar system. As it is pulled closer to the sun, the sun's energy warms it and gasses are released forming the coma. The closer the comet gets to the sun, the greater the energy releasing these gasses. Solar radiation pushes the material away from the sun in two ways. Dust and gases are both carried away from the coma as separate tails.

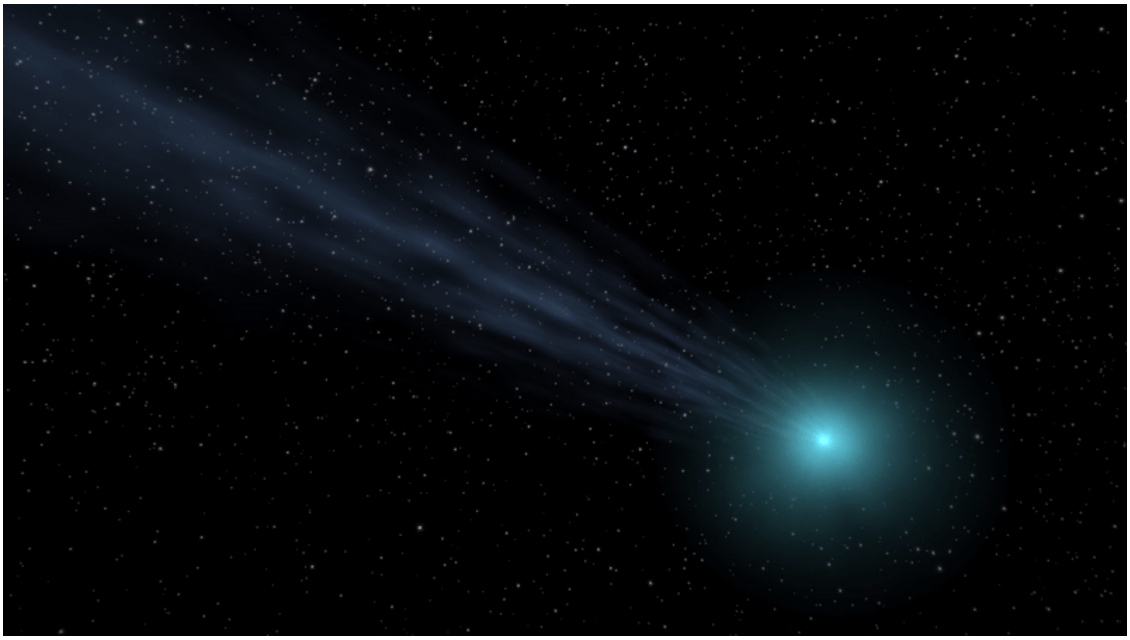


Image 23: Animation of a comet's tail.

They each can be visible through different processes; the dust reflects sunlight directly and the gases glow because of a process called ionization.. Therefore, a comet's tail is always pointing away from the sun. Hale Bopp, Haley's, and Hyakutake are among the most famous of the comets.

Meteors and Meteorites

The last of the objects discussed in this chapter are meteors and meteorites. Meteors might be described as rocky space debris that is drawn into the Earth's atmosphere by the Earth's gravitational field.

Image 24: Meteor Bolide observed in Southern Australia in 2011.

As meteors enter the atmosphere, friction with the molecules that make up the atmosphere heat the meteor as it crashes toward the Earth's surface. This causes a momentary flash across the night sky. This flash is a meteor, though sometimes people erroneously call them shooting stars. When a meteor is of sufficient size and is durable enough a portion of the original material will crash into the Earth.

Image 25: Leonid Meteor Shower 1833

A "Meteor Shower" occurs when a large collection of debris pieces are in the path of the Earth's orbit around the Sun. As the Earth approaches this this material, many pieces can be drawn into the atmosphere, causing many meteors to flash across the sky in a relatively short period of time. Meteor showers are regular events that can be counted on to provide interesting astronomical experience. The picture to the right is a drawing made in 1833 by Edmund Weib after watching the Leonid Meteor Shower.

Exploration of Space

Humans have been exploring space ever since the beginning of agriculture. Watching the night sky, people notices that specific combinations of stars appeared at specific times of the year. By studying these patterns, people found it possible to create a "calendar" describing when it was time to plant and harvest crops. Ancient astronomers appear to have influenced the architecture of Stonehenge and the Mayan Pyramids. So, studying the stars has been going on for a very long time. Among the stars, ancient astronomers noticed objects that moved slowly across the sky. These included the planets Mercury, Venus, Mars, Jupiter and Saturn.

Hans Lippershey was an eyeglass maker living in the Netherlands. In 1608, he created the first telescope. The development of the telescope allowed scientists to study the solar system in a new way. When Galileo trained his telescope on Jupiter, he noticed its four most visible moons.

Image 26: Jupiter and the Galilean Moons

This discovery led to the acceptance of the heliocentric model of space and ushered out the geocentric model which placed the Earth in the center of everything. Ever since then, optical telescopes have served as a vital tool in the exploration of space. Great optical telescopes have been built on high mountains in an effort to be above the clouds and minimize the impact of the atmosphere on the images that can be produced. The Keck Observatory in Hawaii, the Hale telescope on Mount Palomar, and the Nicholas U. Mayall Telescope at Kitt Peak in Arizona are among America's most powerful optical telescopes. Optical telescopes gather radiation in the visible portion of the electromagnetic spectrum. When properly outfitted, they can also detect infrared radiation. Space based telescopes are better equipped to detect infrared radiation. Radio telescopes are large radio antennas that gather radio waves that were produced by the processes that happened inside stars. The word happened is important here because all of our views of stars are looks back into time. (This is because of the time it takes for the light, or other parts of the electromagnetic spectrum to reach the Earth. Even at the speed of light, it takes more than four years for the light from the nearest star to reach us. The furthest objects are thought to be more that thirteen billion light years away.)

The Space Race

After the defeat of Germany in World War Two, there was a massive geopolitical contest between the Soviet Union and the United States. German scientists had developed the V2 rocket with which they bombarded London during the waning days of the war. These scientists were highly sought after by Russian and American space programs at the end of the war. The Russians got some of the German scientists and engineers and America got some. Among those who came to America was Werner Von Braun, who was widely considered the "Father of the American Space Program".

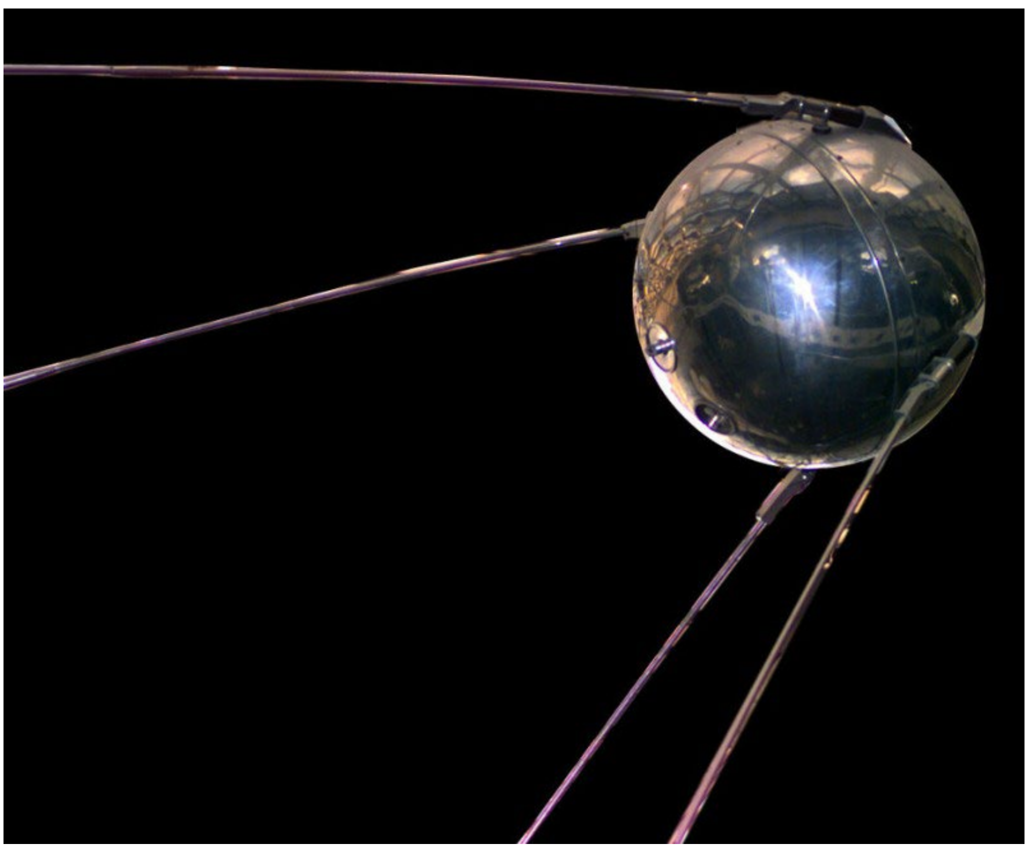


Image 27: Sputnik 1

The Soviets scored the first blows, by placing the first artificial satellite into orbit. In 1957, the soviets launched Sputnik 1, proving that they could place a payload into orbit. This shocked and frightened the scientists and engineers in America's space program.

A second major accomplishment of the Soviet's space program occurred in 1961, when Yuri Gagarian became the first human to orbit the Earth in his spacecraft Vostok 1.


Image 28: Yuri Gagarian in Vostok 1I

This achievement was followed by the first woman to orbit the Earth.

In 1963, Valentina Tereshkova became the first female to orbit the Earth. In her Vostok 6 capsule Tereshkova completed twenty two orbits and remained in orbit just under three days.

Image 29: Stamp commemorating Valentina Tereshkova and Vostok 6

As the soviets were achieving these mileposts, the American space program had a difficult time getting started. There were numerous spectacular failures of the American rockets.

Project Mercury

However, in shortly after Gagarian's first flight, American Alan Shepard became the first American in space in a Mercury spacecraft named Freedom 7.

Image 30: Alan Shepard

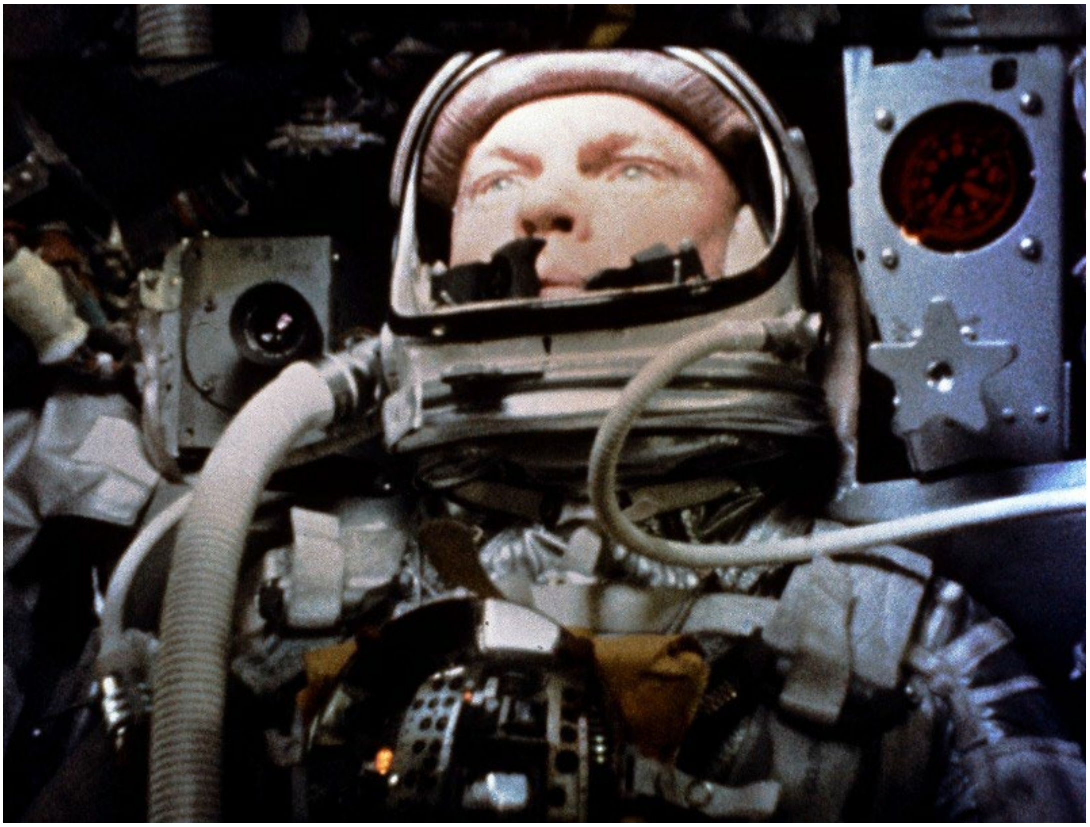


Image 31: John Glenn in Freedom 7I

Then, in early 1963, John Glenn became the first American to orbit the earth in his Friendship 7 spacecraft. During this era, there was a separate space program where the X-15 rocket plane was tested. It made two flights that crossed Kármán line, the internationally recognized altitude used to designate the edge of space.

John Glenn, shown to the right was the second American in space. His first voyage in Freedom 7 was in 1963. He later had a career as a United States Senator from Ohio. While serving in the senate, in 1998, Glenn flew in the Space Shuttle Discovery. He was 77 years old on that mission.

Project Gemini

In 1961 president Kennedy challenged America to land a man on the moon before the end of the decade. Though the planning for Project Gemini had been started before this challenge, it was a vital part of the race to land a man on the moon. Project Gemini utilized a two person space capsule.

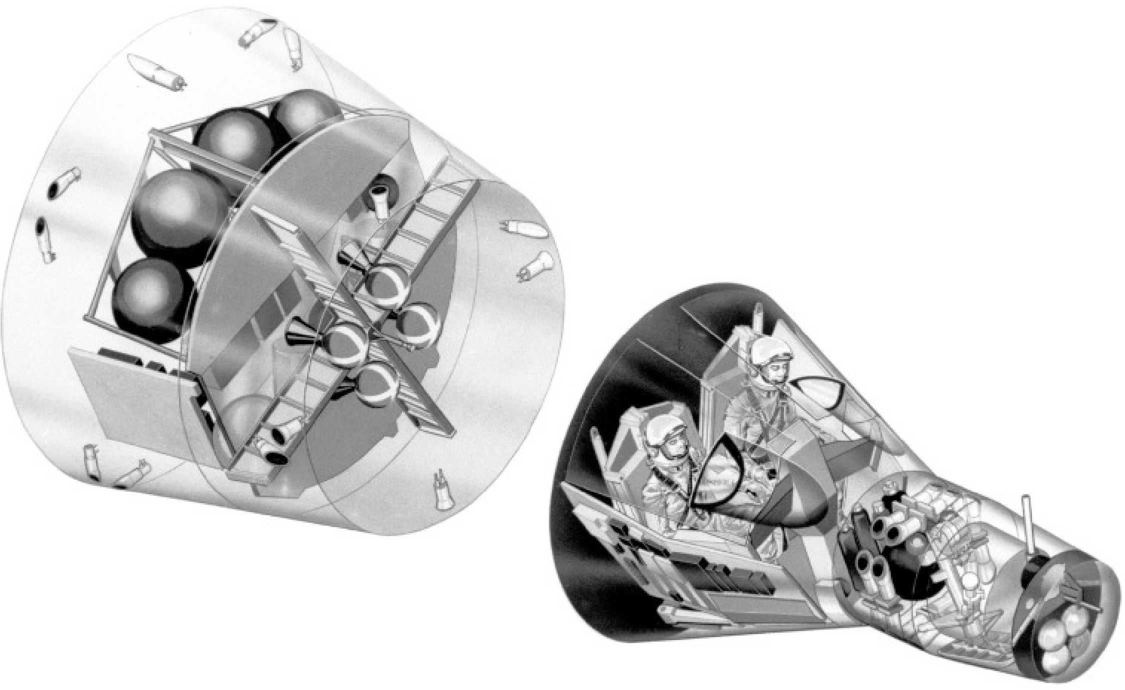


Image 32: The Gemini Spacecraft

The goals of Project Gemini included: the study of the effects of prolonged space flight on the human body; developing materials and procedures for rendezvous and docking of spacecraft; developing procedures for "space walks" and high orbit flights, and finally perfect reentry and "splashdown" procedures.

These goals were all met. They allowed NASA scientists and engineers to develop plans for the moon landing in Project Apollo.

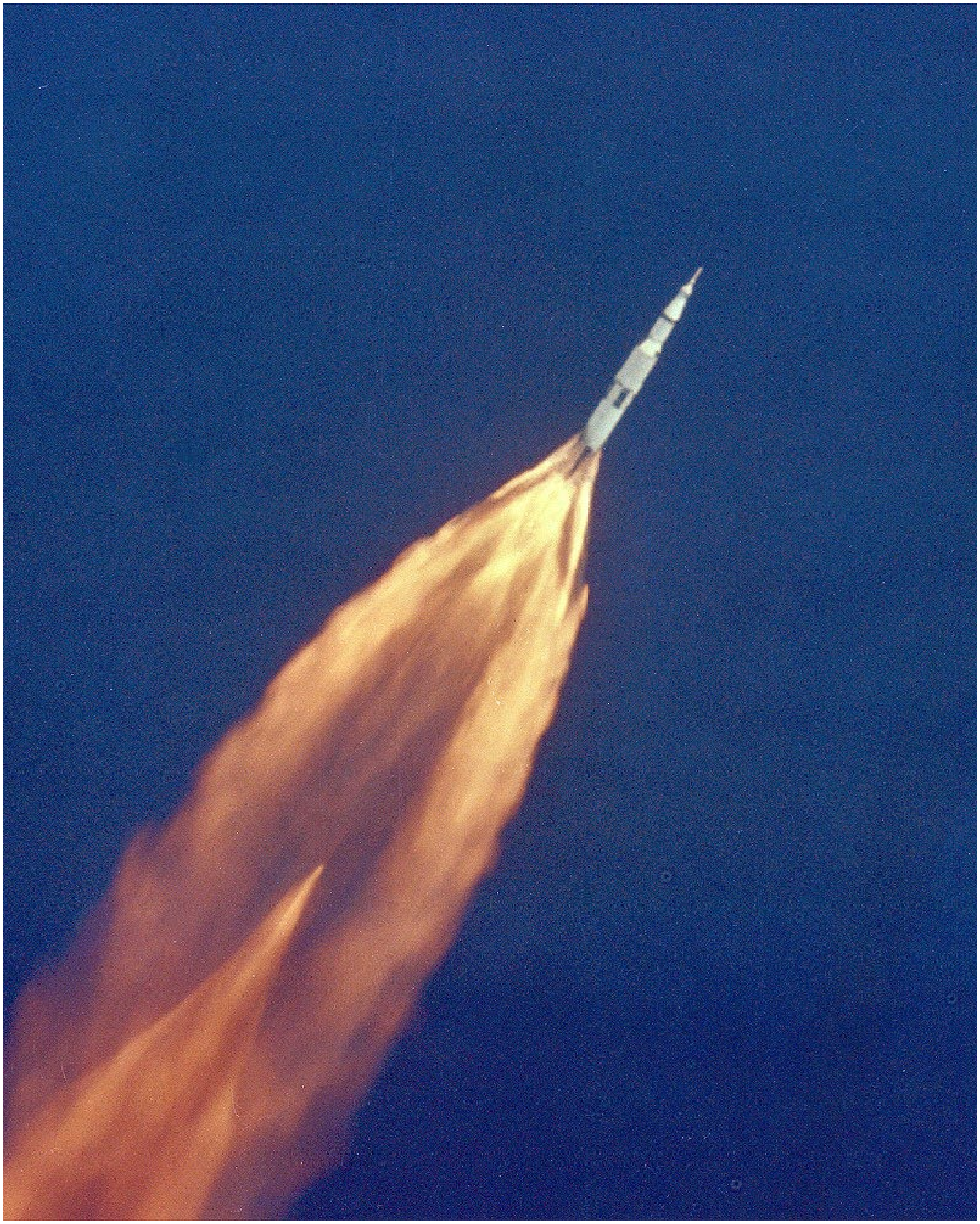
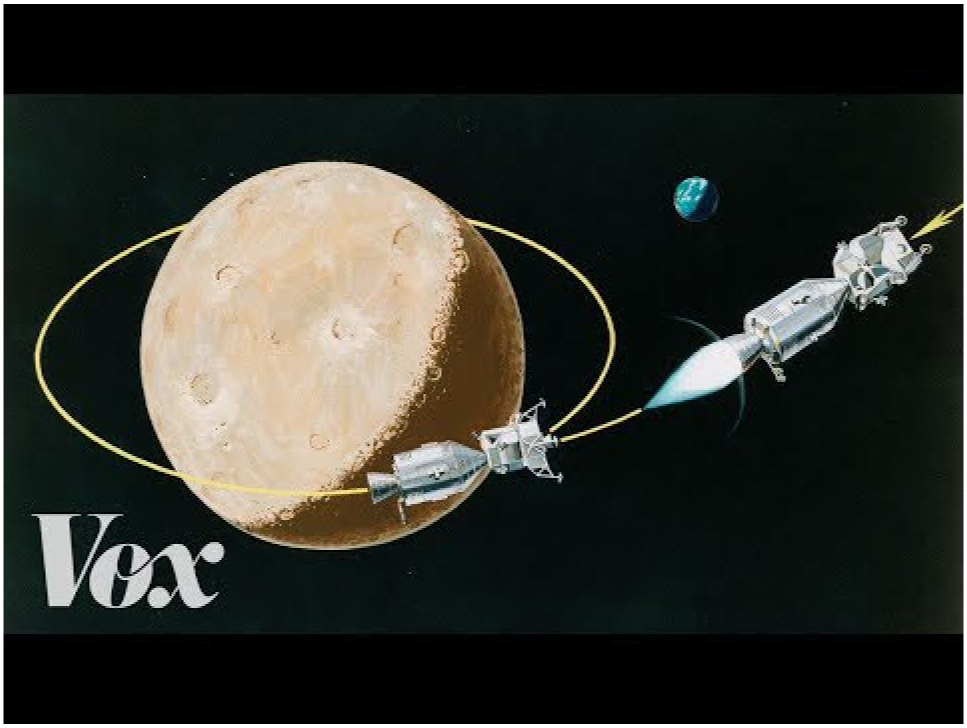


Image 33: The Saturn 5 rocket launching Apollo 11 toward the moon.



Video 1: Apollo 11 Explained

Project Apollo

The Project Apollo mission was to land men on the moon and return them safely home. It ran from 1961 until 1972. In 1967, there was a tragic accident where three astronauts were killed by a fire while training in the Apollo capsule. The fire was caused by an electrical spark in an oxygen rich environment. This accident nearly stopped America's space program. However, by 1968 a redesigned Apollo spacecraft was launched in the mission designated Apollo 7. The subsequent missions tested materials and procedures needed to reach the moon.   Apollo 8 was the first to use the Saturn 5 rocket and to orbit the moon with astronauts aboard. Apollo 10 again orbited the moon and tested the lunar landing module taking it to within 50,000 feet of the moon's surface. Apollo 11 carrying Neal Armstrong, Buzz Aldrin, and Michael Collins was the first mission to land on the moon.

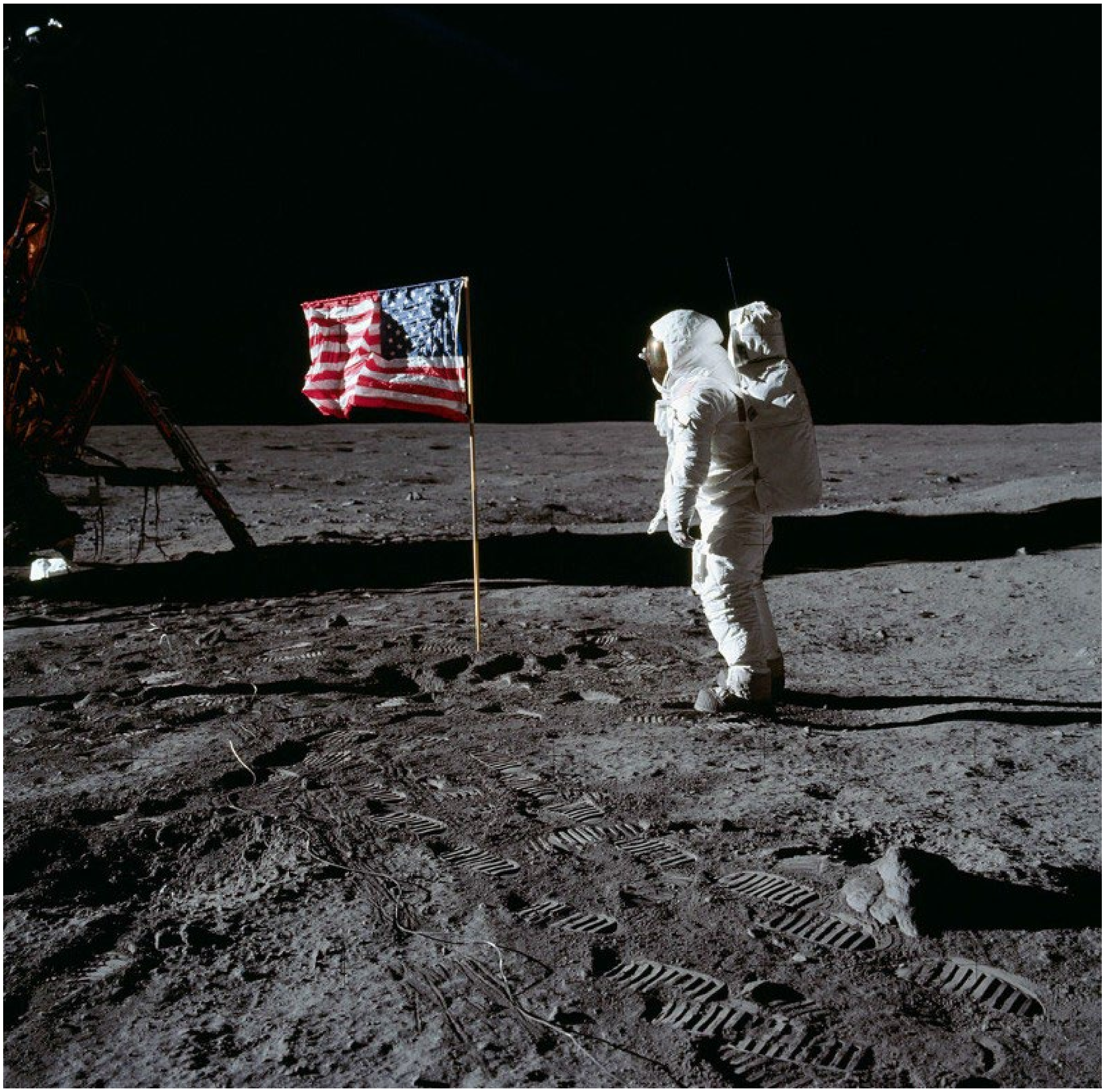
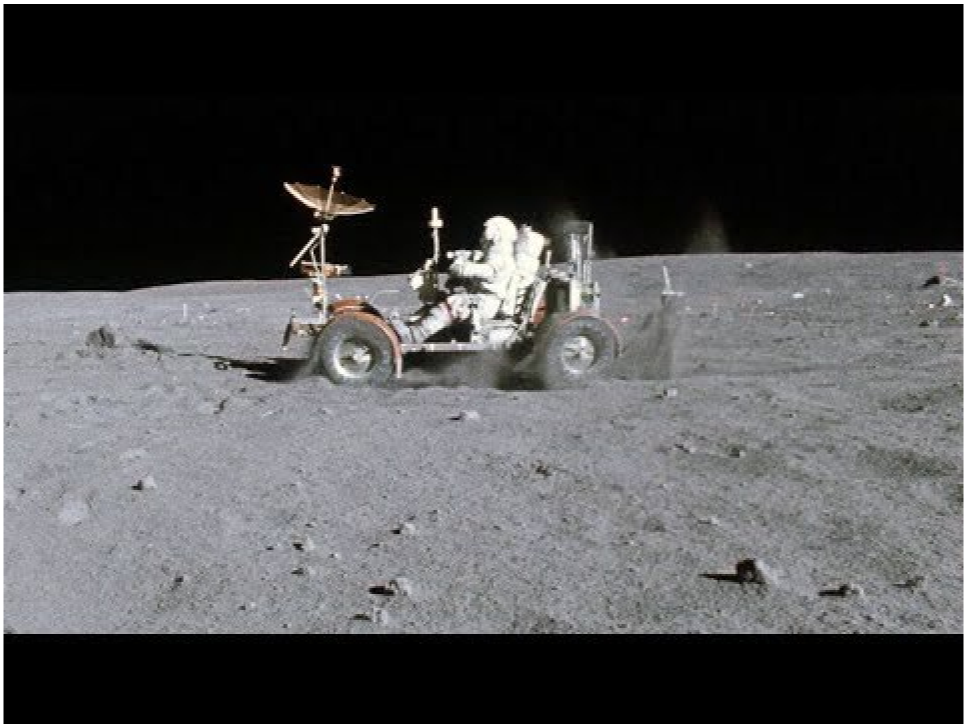


Image 34: Buzz Aldrin on the Moon's surface.

Apollo 11 proved that the American Space program could beat the Soviet Unions to the moon. There were six additional Apollo missions, including Apollo 13 which had to be aborted due to an oxygen canister explosion in the service module. The mission was completed without the loss of life and was considered a triumph of human ingenuity. Missions 15 through 17 featured excursions on the lunar rover.

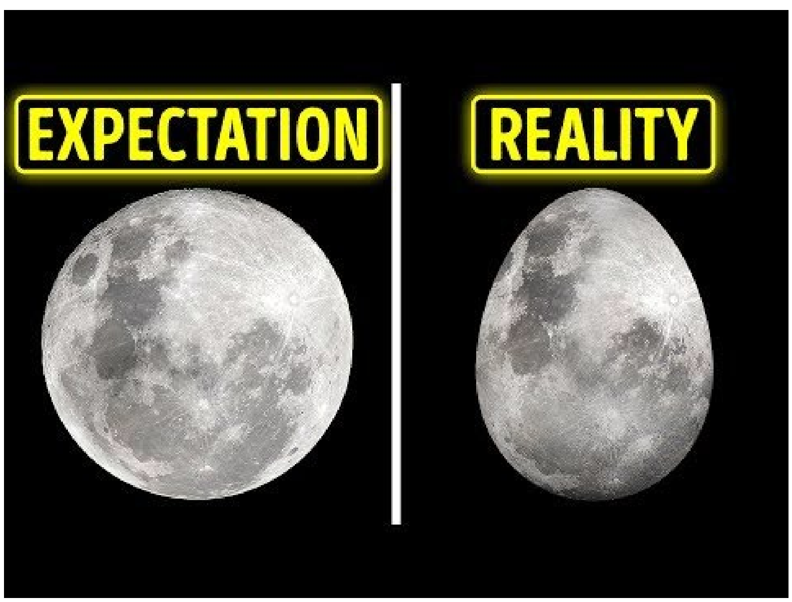


Video 2: About the Lunar Rover (Click on image or address below.)

[Apollo 16 "Grand Prix": lunar rover / buggy (LRV) footage - HD Video Stabilized - Bing video]

Bonus Video

[Apollo 16 - LRV "Grand Prix" - Rover - Bing video]



Video 3: Just for fun here are some interesting "facts" about the moon.

While through the Apollo program America won the "Moon Race", the Apollo spacecraft was a part of the first cooperation on space between the United States and the Soviet

Union. The Apollo Soyuz mission saw an American Apollo spacecraft docking with the Soviet Soyuz craft.

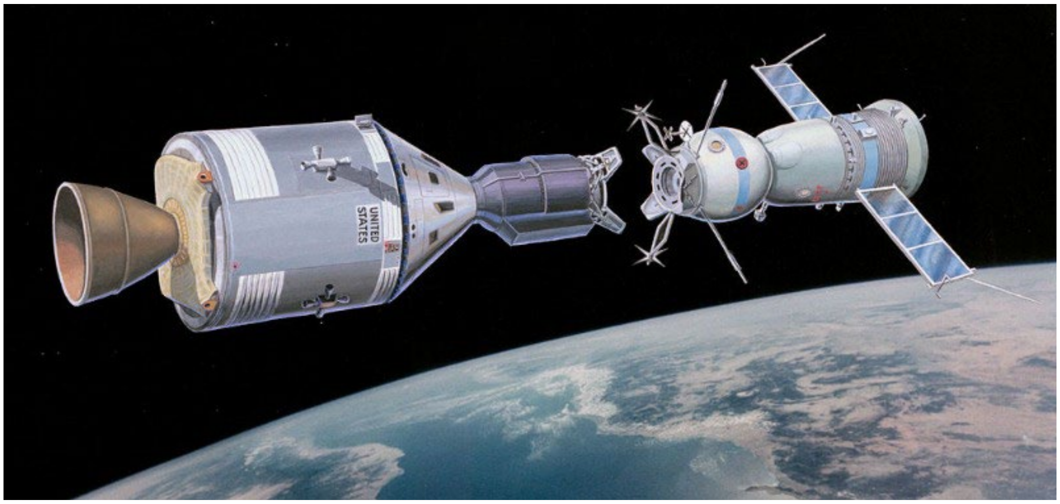


Image 35: Apollo-Soyuz

Space Shuttle

NASA ended the Apollo program in 1972. I seem as though the mission of NASA may have run its course. However the vision of developing a permanent platform in space led to the development of the Space Shuttle which would provide the delivery platform for building the International Space Station. The shuttle was designed to be a completely different kind of launch system. Previous space flight relied on one-use rockets that were expensive and inefficient.


Image 36: Space Shuttle Launch

The idea of the shuttle was to develop a platform which would launch vertically like a traditional rocket and land on a runway, like a glider. The idea was to make a reusable spacecraft that would have a short turn-around. The Space Shuttle program was successful, with 135 missions beginning in 1981 and ending in 2011.

Image 37: Space Shuttle Challenger Explosion

Yet, there were two disastrous missions where all on board perished. The first was the Shuttle Challenger which was the tenth flight of the space shuttle platform. On board was Christa McAuliffe, a teacher from New Hampshire. Seventy-three seconds into the flight there was an o-ring failure causing a massive explosion which blew the craft apart.

The second occurred in 2003 when the shuttle Columbia was lost. During launch, ice shed from the external fuel tank struck and punctured the wing. Upon re-entry hot gasses entered the wing and from there destroyed the spacecraft.

Disasters aside, the space shuttle proved to be a reliable and durable launch platform and a vital part of the International Space Station construction.

The International Space Station is a cooperative venture between many nations. The Unites States, Russia, Canada, Brazil and Japan are among the most committed partners. The station was built on the ground, but assembled in space.

Image 38: The International Space Station

The Space Shuttle and the Russian Proton rocket system provided most of the heavy lifting.

The first module was launched by the Proton rocket in 1998. Since then, over forty assembly flights were needed to assemble the International Space Station. It contains fourteen pressurized components and structural pieces to hold solar panels and communications/experimental gear. The International Space Station has allowed astronauts and scientists to live in space for prolonged periods of time. It has been continuously occupied since the year 2000. Since then, over two hundred people from nineteen countries have visited the International Space Station. There have been well over two hundred space walks from it. There are more than fifty computers onboard to run the station and manage experiments. There are six sleeping quarters for crew.

It is worth noting that the Chinese Space Agency has launched two space stations on their own.

Unmanned Space Exploration Vehicles

In addition to manned space exploration, there have been many unmanned probes to explore space. Beginning in 1958, NASA has been involved in more than 1,000 unmanned missions. On these missions more than thirty are ongoing missions that continue to collect and return data to this day. Among the most ambitious are the Pioneer Programs Probes that explored the outer solar system and have actually left the solar system. The Voyager probes were meant to explore Jupiter and Saturn. They were reprogramed mid-flight to add fly-bys of Uranus and Neptune. The New Frontiers mission Is exploring Venus, Jupiter and Pluto. The Magellan probe was the first mission launched from the space shuttle. It explored Venus. The Galileo probe explored Jupiter and its moons.

Image 39: Hubble Space Telescope

The Hubble Space Telescope was launched in 1990. Since then it has provided vast amounts of data and imagery to astronomers all over the world.

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Earth Science

Earth sciences, obviously consist of disciplines that study the Earth. In elementary curricula, the earth sciences are often lumped together with astronomy to create a group of earth and space sciences. This group is often one of three branches of science presented, the other two being physical and life sciences.

The earth sciences include several major fields that we will include in this book. These are the typical fields covered in elementary classrooms. We will look at the Earth's interior and atmosphere. We will look at Biosphere, Hydrosphere, and Lithosphere. We also include some ecological science.

Overview

Let's begin by looking at an overview of the physical structure of the Earth. The Earth is the third planet from our star, the Sun. It is a terrestrial planet, which means it has solid land masses, as opposed to the gas and ice giants like Jupiter and Neptune. The Earth is the only planet in our solar system which has water in solid, liquid and gaseous states. This fact makes Earth much more favorable for life (as we know it) than the other planets in our solar system.

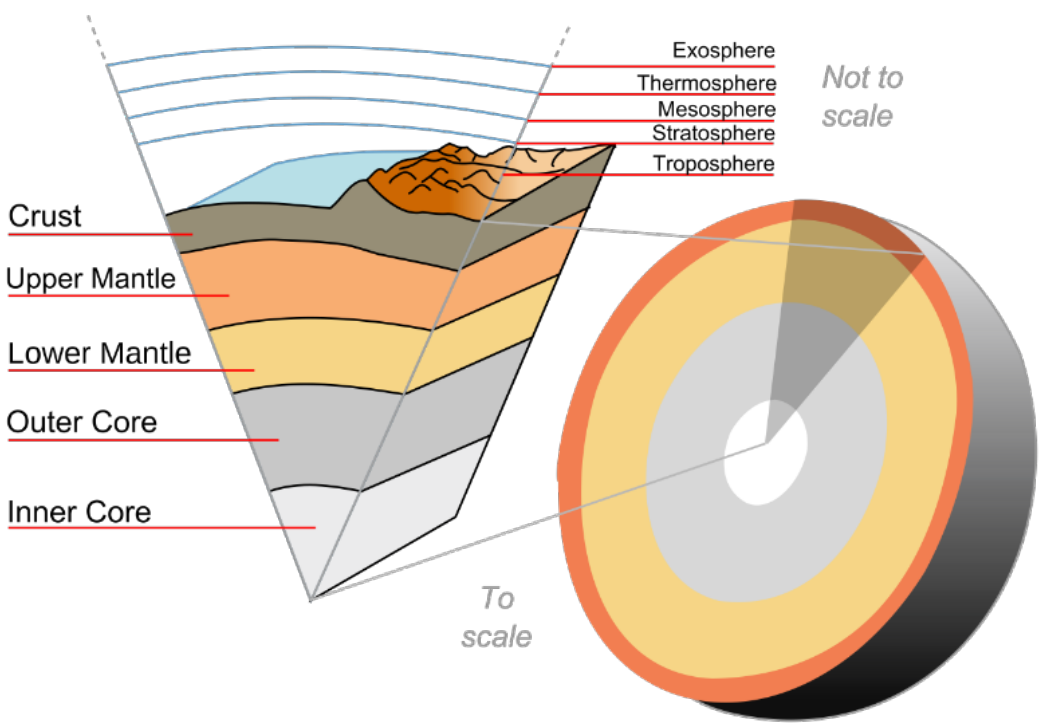


Image 1: Layers of the Earth

The Earth is a giant nearly spherical body. Something like a solid golf ball, it has different materials in different layers. These layers, which will be discussed later, include the inner core, outer core, lower mantle, upper mantle and crust. In addition there are atmospheric layers, which will also be discussed later, the troposphere, the stratosphere, the mesosphere, the thermosphere, the exosphere, and the ionosphere.

The Earth contains a lot of water. In fact, the oceans cover around seventy one percent of the Earth, surface. The oceans are large, and contain around ninety-seven percent of the Earth's water. The oceans are deep and salty. They play a major role in moderating the Earth's climate. Of the fresh water, much is locked up in glacial ice. This means that the fresh water available to support non-aquatic on earth is a small fraction of the total.

The land masses on Earth are called continents. There are seven, and all but Antarctica have supported civilizations since before recorded time. The continents appear to be static, but actually "float" on the upper mantle. Because of this, the continents are actually moving very slowly in relation to each other. Where these slowly moving plates contact each other, there are active geological structures and events. The structures include volcanos and mountains. The events include mountain-building and earthquake activities.

The content presented in this chapter is somewhat beyond what would be covered in the typical elementary science curriculum. It is presented in this way so that you, as a teacher, will have enough content background to answer questions your students might raise.

The Earth's Layers

Inner Core

In the center of the earth lies its's solid inner core. The inner core is astoundingly hot. It is estimated to be between 9,000 and 13,000 degrees Fahrenheit, making is as hot, or maybe even hotter than the surface of the Sun! It is believe to be made mostly of an iron-nickel alloy. One would think that even an iron-nickel alloys would be melted at that temperature. Normally, that would be correct, but the extreme gravitational pressure squeezing the inner core keeps it solid.

Image 2: Layers within the Earth

In addition to nickel-iron alloys, the core contains small amounts of radioactive material such as uranium and potassium, which produce heat, adding to the core's extreme temperature.

The inner core is actually quite large. It is estimated to be about 1,500 miles across and makes up nearly one fifth of the Earth's volume. Interestingly, the inner core is believed to rotate slightly faster than the surface of the earth. This is possible because the solid inner core is surrounded by the molten outer core.

The Earth's **outer core** is sandwiched between the inner core and the mantle. It is made of very hot liquid materials that are in motion. There is a theory, called the Dynamo Theory, suggesting that the currents within the iron-nickel rich outer core are what account for the

Earth's magnetic field. This is partly due to the fact that the magnetic field in the outer core is estimated to be around fifty times more powerful than it is on the surface.

Interestingly, the inner core transports heat from the inner core to the mantle. Because it removes heat energy from the inner core, the solid inner core's diameter actually grows around a millimeter each year.

The thickest portion of the Earth's internal structure is the **mantle**. The mantle extends nearly 18,000 miles into the earth. It is made of rocks high in silica, iron sand magnesium. The mantle is divided in to the upper lower sections. While the mantle is considered solid rock, the high temperatures inside the mantle make the silicate content of the rock "ductile" When a material is ductile, it can be significantly deformed before it ruptures. Because the mantle is ductile, it moves, very slowly, because of its extreme temperature and pressure it encounters.

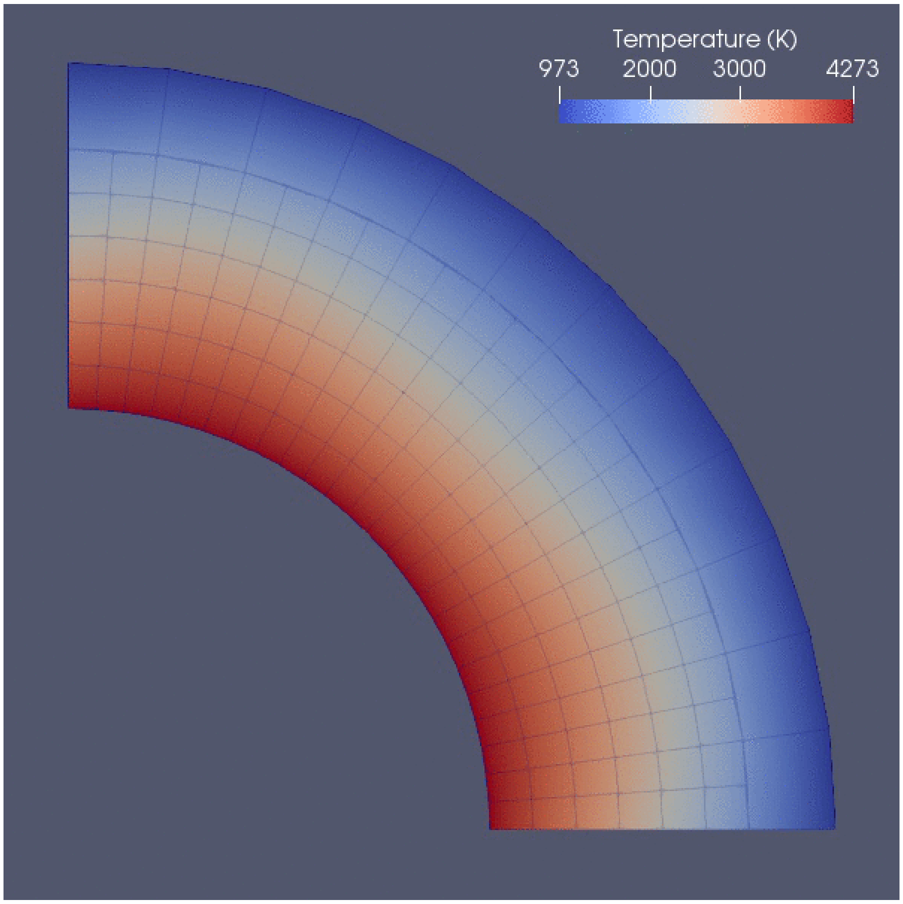


Image 3: Model showing Convection Currents in the Earth's mantle.

Described as convective motion, this very slow movement of the mantle causes the "Plate Tectonics" that move the continents on the Earth's surface. The heat that causes these convection currents comes from the heat left over from the formation of the Earth, and the radioactive decay of, potassium, thorium, and uranium, which are found in the Earth's mantle and in its crust. A way to think about these convection currents is to think of a pot of oatmeal that is bubbling. The hotter oatmeal in the bottom of the pot is carried upward because of its heat to the surface. Cooler oatmeal slowly sinks to the bottom of the pot. While this process is extremely slow in the Earth's mantle, is very a powerful force, causing earthquakes, volcanoes, and building mountains.

The Earth's crust is the outermost solid layer of the Earth.

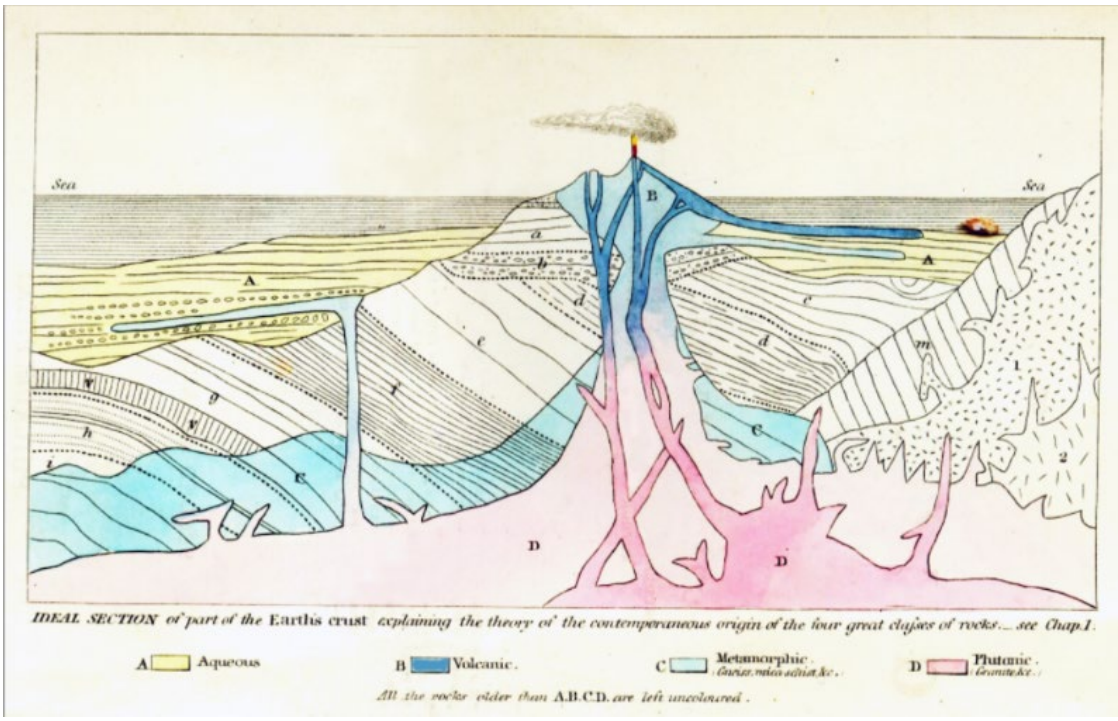


Image 4: Charles Lyell diagram of Earth's Crust (1837)

It varies in thickness from around three to almost forty-four miles. The crust is thinnest under the oceans and thickest in the mountainous regions on continents. The oceanic crust is composed of dense igneous rocks made up of iron, magnesium, and silicates. Basalt is an example of the typical rock material found in the oceanic crust.

Continental crust material is thicker but less dense. It is made up of rock high in sodium, potassium, aluminum, and silicates. An example of rock found in the continental crust is granite. More detail on the rocks that make up the crust will be discussed later as part of the rock cycle.

Earth’s Atmosphere

In addition to the solid layers that make up the Earth there are several layers that make up the **Atmosphere.** The vast majority of the mass in the atmosphere is located in the lowest layer, the Troposphere. The Troposphere varies from around ten and a half miles thick at the equator to around four and a half miles thick at the poles. The troposphere is where all of the Earth’s weather is formed.

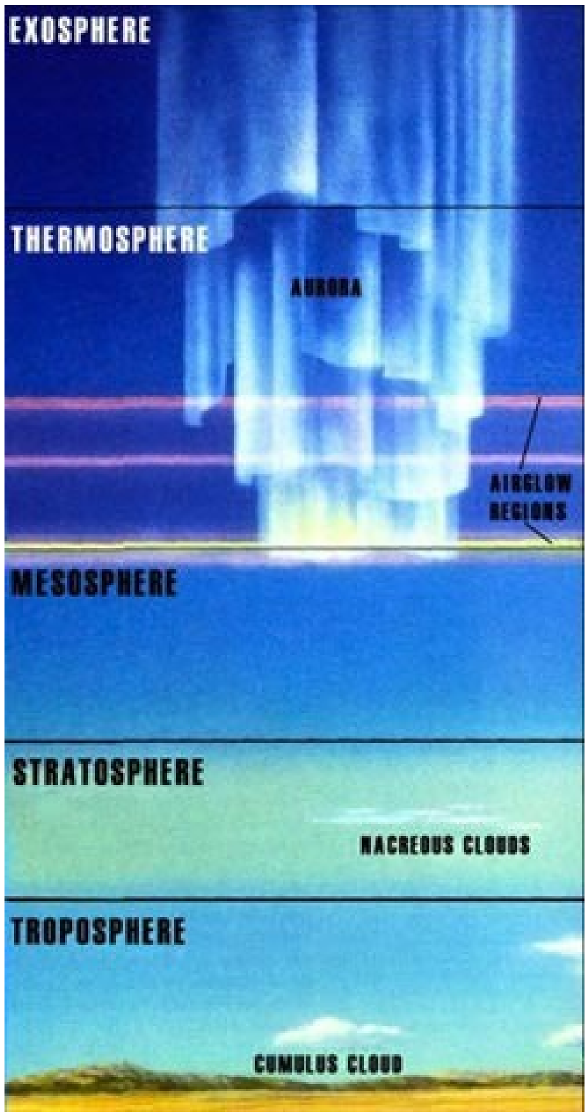


Image 5: Layers of the Atmosphere

Above the Troposphere is the **Stratosphere**. The stratosphere is actually colder closer to Earth and warmer further away. This is because the Stratosphere collects and absorbs much of the

Sun's ultraviolet radiation in the "Ozone Layer". The winds in the stratosphere can reach 130 miles per hour.

Beyond the Stratosphere lies the **Mesosphere**. When we see a meteor flash across the night sky, the material is likely burning up in the Mesosphere. The Mesosphere extends upward to about fifty -two miles above the earth.

The **Thermosphere** is the next layer and it contains the **Ionosphere**. It is the Ionosphere that is ionized by solar radiation that strikes the Earth. The ionosphere varies in thickness from day to night. It is thicker and closer to the surface of the Earth in the day. It becomes thinner, moving away from the Earth's surface at night. This is why some radio frequencies travel much further at night. The Kármán Line is the barrier between the Earth's atmosphere and "space". It is at the top of the Thermosphere around sixty-two miles up.

The "Spheres of the Earth" and Earth Sciences

Another way to look at the earth's structure is through what have been called "spheres". These "spheres" are not what we think of as globes or balls, but rather areas upon the earth where different things can be found. The **Lithosphere** is where rocks are found. The **Hydrosphere** is where water is found. The **Atmosphere** is made up of air and the **Biosphere** is where life can exist. Ice is found in the **Cryosphere**. And some lists include the **Pedosphere** where one will find soils. It is within these "Spheres" that the major Earth Sciences are organized.

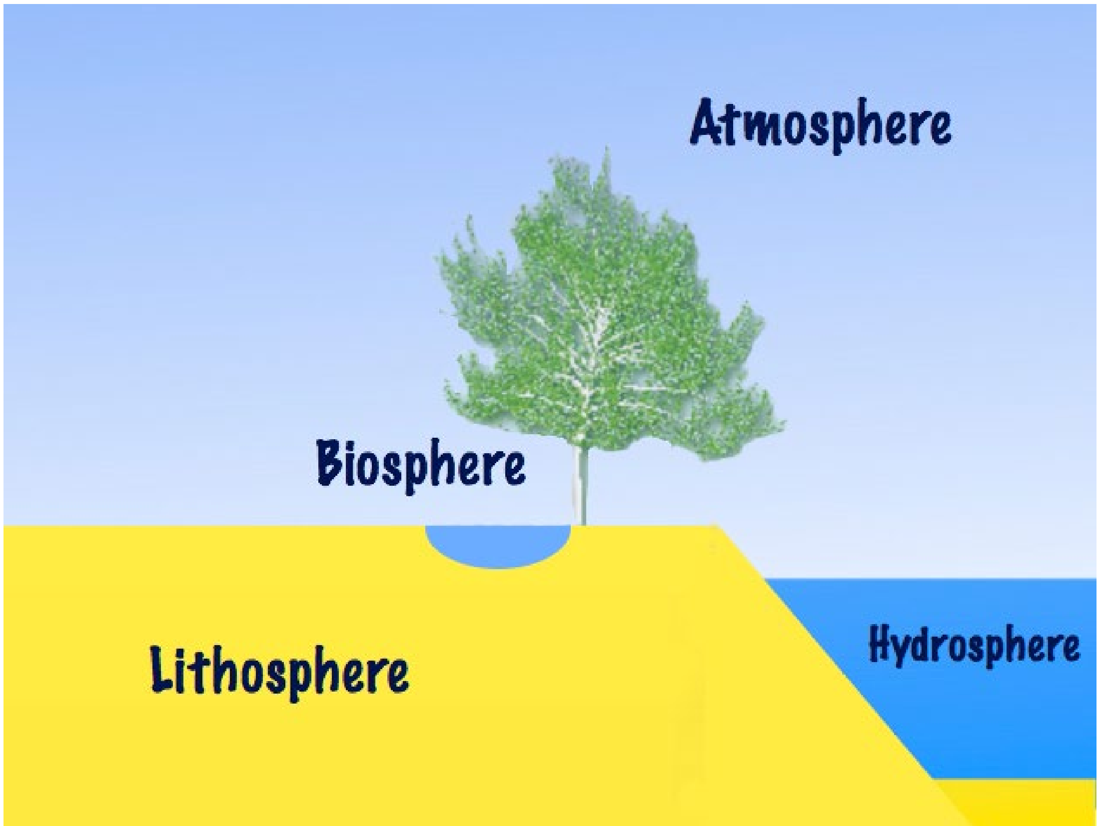


Image 6: Spheres of Earth Science

The **Lithosphere** is where all of Geology is placed. There are many disciplines that make up Geology (Environmental, Historical, Planetary, Structural). There are also disciplines such as: Glaciology; Hydrogeology; Sedimentology; Minerology; Volcanology and Speleology (the study of caves). The **Pedosphere** is where soil sciences are placed. Geography and Systems Ecology are other sciences under this umbrella. The **Hydrosphere** is the home of the following Earth Sciences: Hydrology and Limnology (the study of freshwater); and Oceanography.
The **Biosphere** sciences include: Biochemistry, Biogeography; Human Ecology; and Paleontology

The **Atmosphere** "houses" Atmospheric Chemistry Climatology, Meteorology, Paleoclimatology and Hydrometeorology. While this book will not focus on any of these specific sciences in detail, there influences will be seen in this chapter.

Different Earth Science Disciplines

Geology is the first of the Earth Sciences to be addressed. Geology has many subsets, but as a whole is the study of rock and the other solid parts of the Earth. Geology seeks to study: the properties of rocks and minerals; the structure of the Earth both above and below its's surface; the age and formation of rocks, minerals, and the structures that they make. It also looks at the history and changes in the earth's crust, movements within the Earth's crust, and changes in the Earth's climate.

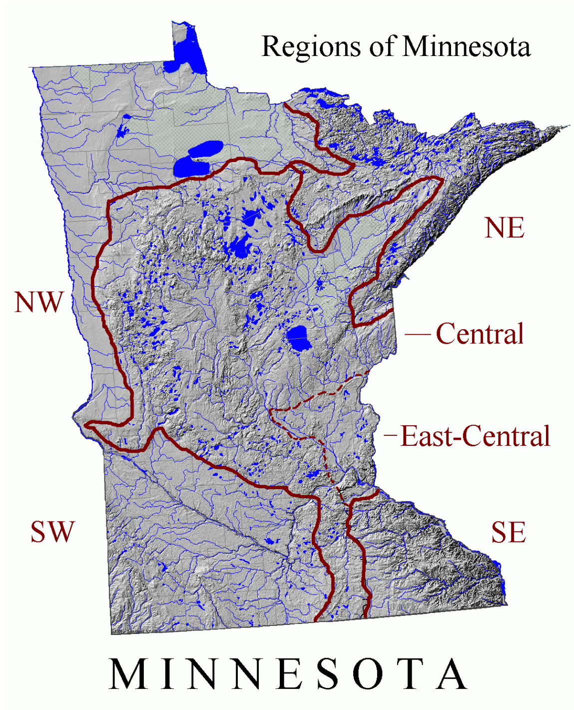


Image 7: Geologic Map of Minnesota

This covers a lot of ground. So, there are subsets of Geology that elementary students might encounter. These include **Seismology**, the study of plate tectonics and earthquakes. There is **Volcanology**, the study of volcanoes and their artifacts. Glaciology, is the study of glaciers and the ice-covered parts of the earth.

Meteorology is the study of weather and is short-termed. Climatology is the study of long-term weather patterns and their impact on the Earth. Meteorology is typically viewed as immediate and "regional" as weather patterns may vary greatly over relatively short distances.

Image 8: Meteorologists on top of Mount Washington, New Hampshire (1871)

Climatology is considered historical and/or long term and is often seen as a global study. This difference can be seen in the way a meteorologist reports on weather for an area, as opposed to the way a climatologist studies long-term patterns and projections

Ecology is considered an earth science, even though it involves plants and animals. Ecology looks at the interactions between plants, animals, and their environments. This interaction may include the geology and geography of a region, the climate and altitude and all of the living things that are a part of the area being studied.

Hydrology is the study of water. It includes the distribution of water and its movement around the Earth. Students in elementary school will study the "Water Cycle" which is a part of the study of Hydrology. They will also examine ways to protect water resources. Closely related to Hydrology is **Sedimentology**, which looks a water erosion and the movement and depositing of eroded materials. Students in elementary school might work with a simple "Stream Table" to study the effects of erosion.

Volcanology and **Seismology** are studies of the geothermal and seismic activity in the form of volcanos and earthquakes.

Image 9: Eruption of Mount Reboubt, Alaska 2009

Elementary students are fascinated by volcanos. However, the iconic vinegar and baking soda demonstration is one of the least authentic demonstrations done in elementary science classes. It would be much more realistic and meaningful to do a demonstration that used pressure to force a viscous fluid, like colored applesauce up through the volcano, since it is heat and pressure in the Earth's mantle that creates volcanos.

Typical Instructional Units in Earth Science

In the elementary curriculum, there are many Earth Science topics that are addressed. This section will address a few of the common themes.

Rocks and Minerals

Typically, students learn to identify the three main rock groups. They learn that **Igneous** rocks are ones that are ones formed through volcanic activity. The word igneous is derived from the Latin phrase, made from fire. There are igneous rocks that form when molten magma comes into contact with much cooler air.

Image 10: Pumice floating in water.

Image 11: Obsidian

Pumice is an igneous rock that forms when magma is forcefully ejected from volcanos. It cools very rapidly in the air, forming tiny air pockets. Pumice is so light that it actually floats on water.

Chemically similar to pumice is obsidian, another igneous rock. It comes from the same magma, but cools very slowly, forming a dense, hard, glass like rock.

The second type of rock students learn about is **Sedimentary.** Sedimentary rocks are rocks that are first eroded by wind, water, or chemical processes. This breaks the rock into very small pieces that can be carries by wind and water. When these "sediments" are deposited in water, or even on land, layer upon layer of these sediments can be compressed together to form a new Sedimentary rock. Sandstone is an example of a soft sedimentary rock that is formed when particles of sand are compressed together. A second type of sedimentary rock in limestone.

Image 12: Fossilized Shrimp in limestone.

Limestone is formed in water when microscopic shells of the diatom organisms are deposited on the sea floor. This material "cements" organisms that drop to the bottom into the limestone it forms.

Metamorphic Rock is rock whose initial material was sedimentary, but was changed over time through heat and pressure in ways that the sediments are crystalized into a new rock form. Marble is an example.

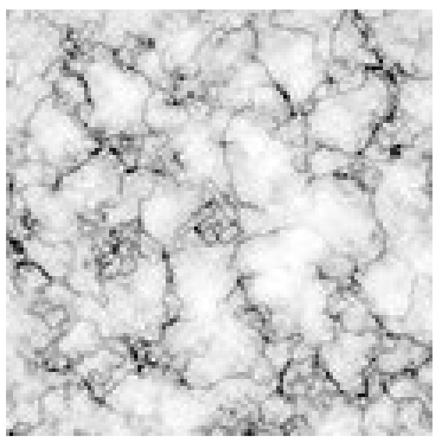


Image 13: Marble, a metamorphic rock.

It started as limestone, but eons of heat and pressure turn it into marble.

Children learn to identify types of rocks by doing simple tests. Typically, rock samples are tested for magnetism, electrical conduction, hardness, reactivity to acid, cleavage and luster.

The Water Cycle

Children learn about the water cycle through activities that demonstrate evaporation, condensation, and run off.

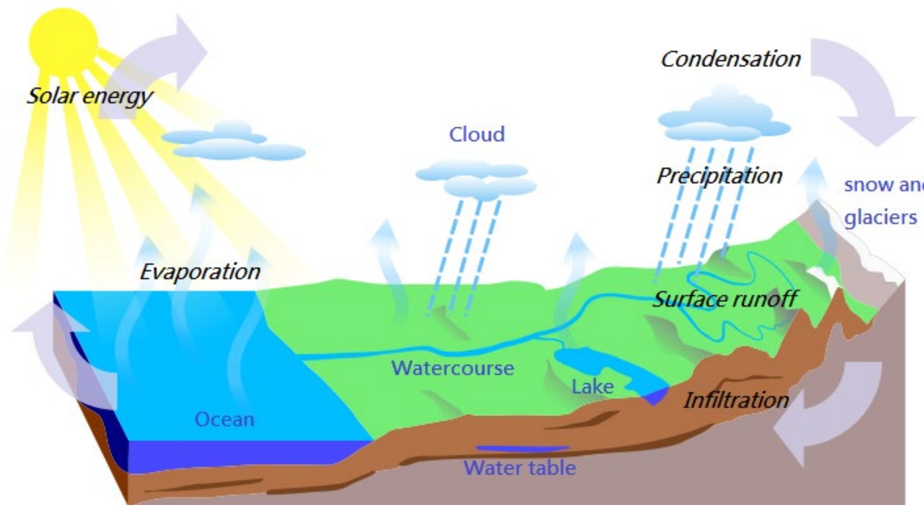
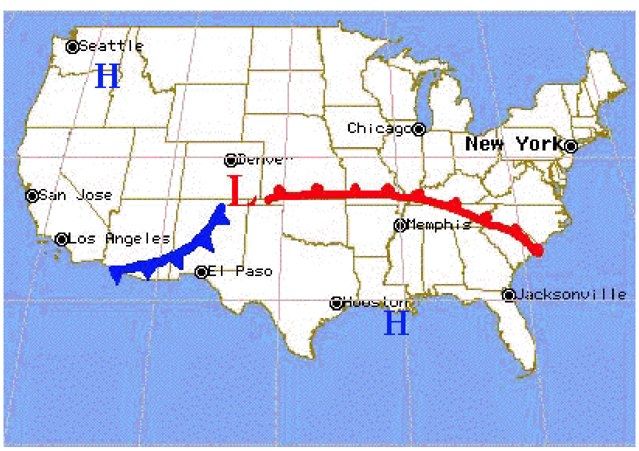


Image 14: The Water Cycle

It is easy to set up a demonstration where water containing food coloring is evaporated using a hot plate. As the water evaporated, the concentration of color in the water increases. If there is a pan containing ice suspended above the evaporating water, clear, pure water can be collected. In this way, students can see how evaporation leads to condensation, which leads to precipitation, and runs off into streams and rivers to collect into ponds and lakes. Models and posters are the common product students construct when studying the water cycle.

Weather



Closely related to the water cycle is the study of weather. Primary students can gain observation and record keeping skills as they observe the weather every day. Students can record temperature, general ideas of cloud cover, precipitation and relative wind speeds each morning. These observations can be recorded on the daily calendars and used to look for patterns.

Older students learn about high- and low-pressure systems and how they are the engines of the weather patterns we see. They also learn to identify different types of clouds, such as cumulous, stratus and cirrus and what weather each brings. Additionally, students of all ages love to learn about weather phenomenon, such as tornados, hurricanes, blizzards and hailstorms.

Plate Tectonics

Elementary children are fascinated by the "Ring of Fire". They love the idea of the power of volcanos and earthquakes, even if they can't understand the power and devastation that they cause. This leads to the study of tectonics.

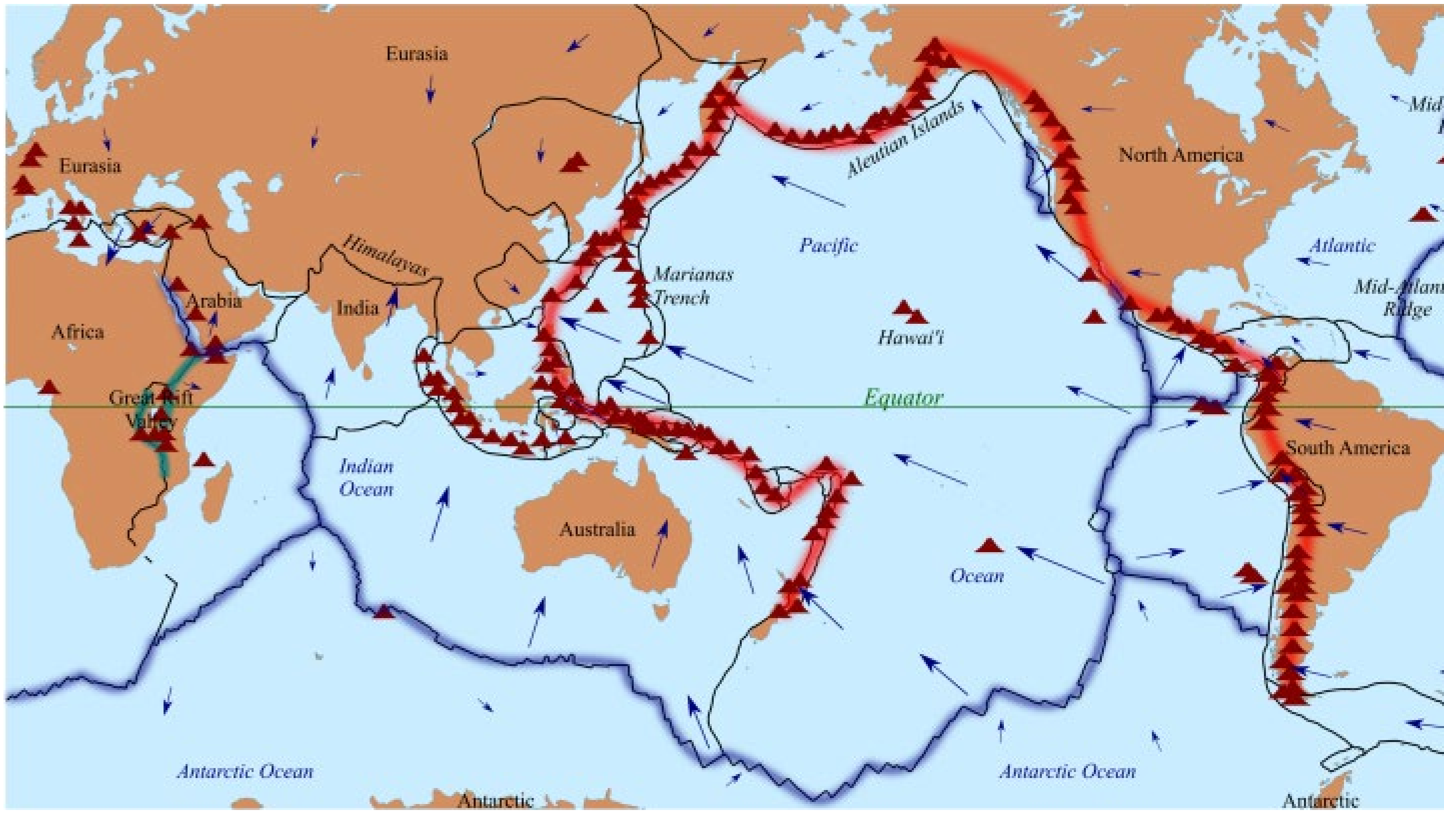


Image 16: Plate Tectonics Map

Upper elementary students will begin the study of "Continental Drift". They can begin to understand that the continents are very slow moving, sometimes colliding into each other, sometimes pulling apart, and sometimes sliding along each other. They can begin to see how this can cause mountain ranges to form, and how earthquakes can lead to cracks in the Earth's surface.

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Chapter 11: Planning and Teaching Elementary Science

This chapter focuses on the special ways in which science is taught. It will undoubtedly differ from what you are learning about teaching reading and language. It will also differ from what you learn about mathematics and social studies. We will begin with a brief history.

Brief History

American education has an interesting history. Even before we became a nation our founders were legislating about education. In 1647, the **Old deluder Satan Act** was passed in Massachusetts. This law provided that when a town grew to more than fifty people it was required to hire a teacher to teach children reading and basic math. If the town grew to more than one hundred, the town was required to provide a grammar school which offered Latin and Greek. The idea was that children needed to learn to read, so that they could read the Bible and therefore avoid being deceived by Satan. While this reasoning seems very odd to us now, this was the first law that provided for funding for public education.

Original Size

Image 1: Old one room schoolhouse

Science was not a part of the curriculum in the very early American public school. Reading Writing and Math were all that was considered essential. Science was something learned at home. Girls learned about making soap and butter. Boys followed their fathers to the family business and learned how to make candles or wheels or copper pots. The science they needed was learned by doing what children's parents did. (We know that this was a sexist system. We are not endorsing it, just giving a simplified picture of what the schools did.)   This model lasted to some degree until the industrial revolution, when fathers could no longer take their sons to work to learn the trade. At this point, schools began to be more comprehensive.

As Americans moved westward, the same model (one room school houses focusing on reading, writing, and mathematics.). However, there were books with pictures of birds and trees. Science was taught through reading.

Now, let's skip all the way to 1950s. America and Russia were in the middle of the Cold War.   On October 4th 1957, Russia shocked the world by launching Sputnik1, a tiny artificial satellite which orbited for three weeks, sending a radio signal back as it circled the globe.

Original Size

Image 2: Sputnik 1

The American leadership was shocked and terrified. They had been trying to develop rockets that could reach space, but were falling behind in spectacular ways.

Original Size

Video 1: Rocket Failure (Click the blue link.)

So, in 1958, in reaction to the American's lack of success compared to the Russians, congress passed the National Defense Education Act. This act was the first time Washington had provided funds for science education in American schools. The act provide funds for universities to offer scholarships and provide salaries for academics to develop new science curriculum materials that engaged students in doing science. The product of this legislation included several curriculum "kits" that were to replace reading based textbooks. **Elementary Science Study** (ESS), **Full Option Science Study** (FOSS) **Science Curriculum Improvement Study** (SCIS) were but a few of the "Hands-On" kits that were published for use in elementary schools.

These kits were a great departure from traditional science teaching. They offered a richer experience for students if properly implemented. Unfortunately, this was a top-down curriculum process and most teachers were not ready for the change. There was a need for teachers to change their role from giver of science knowledge to guide as student learned by doing science. In addition, the kits needed to be resupplied and prepared for each class. Sadly, the impact of these kits on elementary science education gradually withered away.

In the 1970s and 80s the next major curriculum initiative occurred. It was the **Science Technology and Society** initiative. This initiative was an interdisciplinary approach to science education where science was connected with mathematics and social studies so that science was not taught in a vacuum. This initiative was also short lived, but served as the foundation for **Science Technology Engineering and Mathematics** (STEM) programs that are popular today.

This short history is truncated. There are many other factors that have led us to where we are today.

Standards, Standards, Standards!

We live in an "age of standards". Teachers are often feeling pressure to teach to the standards that the students on which their students will be tested. There are National Standards which include the **National Science Education Standards** (NSES) and the **Next Generation Science Standards** (NGSS). These standards will be explored in class, along with the **Minnesota Science Education Standards**. They are brought up here because when we plan for teaching science we need to be aware of the standards that you are required to meet. This means that in Minnesota, educators should be following the Minnesota Standards first, and then looking to the NSES and/or NGSS.

Next Generation Science Standards

The final draft of the Next Generation Science Standards was first published in 2013. This document was developed by educators and administrators representing twenty-six states, representatives from the National Science Teachers Association, the American Association for the Advancement of Science, and the National Research Council. These agencies had worked together to produce the National Science Education Standards in which were first published in 1996, and the Benchmarks for Science Literacy in 1990. The series of documents is listed to indicate how dedicated these organizations have been to improving science teaching and learning in science.

The Next Generation Science Standards do not supersede State Standards. Each state has the right, even obligation, to develop and monitor their own standards. While this is true, Arkansas, California, Connecticut, Delaware, Hawaii, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Nevada, New Hampshire, New Jersey, New Mexico, Oregon, Rhode Island, Vermont, and Washington are states that have adopted the Next Generation Standards as their state standards. Other states have adapted the Next Generation Standards to meet their needs. These states include: Alabama, Arizona, Colorado, Georgia, Idaho, Indiana, Louisiana, Massachusetts, Mississippi, Missouri, Montana, Nebraska, New York, Oklahoma, South Carolina, South Dakota, Tennessee, Utah, West Virginia, Wisconsin, and Wyoming. So, in all, forty states have based their standards on the Next Generation Science Standards. Minnesota, where we live, has not yet adopted the Next Generation standards. However, while we, in Minnesota, need to be concerned about the Minnesota Standards, the Next Generation standards are still very useful. **This is because the Next Generation Science Standards is more than a listing of concepts to address.**

Minnesota Standards

Where would you look for Minnesota Science Education Standards?

Three-Dimensional Learning

The Next Generation Science Standards approach science from a position that students need to have deep understanding of core science concepts. Students also need to develop meaningful understandings of science processes and become able to evaluate the evidence presented as science. The Next Generation Standards do these things through three “dimensions” of science learning. These three dimensions include: **Practices**- are behaviors that scientists engage in as they investigate and explore. Scientists create models and theories about world. In addition, engineering practices are introduced and developed through the standards. **Cross Cutting Concepts.** These are concepts that can be applied in many ways in different parts of science. These concepts, which connect different “domains” of science, include: Patterns, Cause and Effect, Scale, Systems and Models, Energy and Matter and Structures and Functions. The final dimension is **Disciplinary Core Ideas**. These “Core Ideas” all include at least two of the following criteria: 1) they have broad importance in multiple science disciplines. 2) They provide a “Key Tool” for understanding or investigating complex problems. 3) They connect to the interests and life experiences of students and to the societal or individual concerns student perceive. 4) They are both teachable and learnable across multiple grade levels.

The entirety of the Next Generation Science Standards is based on these three ideals: When one reads the standards, it is easy to see that the term Performance Expectation is used to describe what students should be able to do after instruction. The Three-Dimensional Learning concept is highlighted in the explanation of the expectation. The **Science and Engineering Practices** are underlined in blue, the **Disciplinary Core Ideas** are underlined in orange, and the **Cross-Cutting Concepts** are underlined in green. This makes it easy to see these dimensions in every Performance Expectation.

This is a brief overview of the Next Generation Science Standards. You will be working with them and the state standards in class.

Process versus Product

Teaching science is not just about teaching facts. We all know four year olds who can describe every type of dinosaur without really understanding what they are saying. Reciting facts is not what we want form our students. We want understandings that come from doing what scientists do (in a simplified form).

So we teach both process and product. Teaching science processes involves teaching students to do what scientists do as they explore our world. **In the science education literature, there are slightly differing lists of science processes that elementary students should practice and master.**

We are using a simplified list:

Classification: Placing objects or ideas into meaningful groups.

Observation: Using all of our senses to gather information.

Measurement: Adding precision to our observation by comparing things to a standard.

Inferences: Being able to use available data to draw a valid conclusion. (Also differentiate between inference and observation.)

Communication: Being able to use various methods to "tell" about what you learned. (creating accurate sketches, writing, acting, singing...)

Experimenting: This is a complex skill which involves researching a topic, forming a hypothesis, developing an experiment to test the hypothesis, controlling variables, and collecting and analyzing data.

These are all process skills.

The **product side of science teaching** is the knowledge about the world that we need to pass on to our students. This might include: identifying parts of plants, naming moon phases and describing their cause, describing the role of carbohydrates in a healthy diet, building a model or poster of an ecosystem. The product side of science teaching is the content we teach.

Objectives

Objectives are the way we measure the effectiveness of our teaching. We measure effectiveness by looking at what students can do or demonstrate after completing a lesson. Objectives are meant to be a measure of what each student has gained form the lesson. It is not a glimpse at what the majority of the students can do, but a look at each individual student has mastered.

We (Dr. Kimori, Professor Sanderson, and Dr. Browne) believe that clear objectives are vital for planning good lessons. We are teaching a simple model for writing clear objectives. It is called the ABCD method.

A stands for Audience. This is the part of the lesson where *the teacher* ***identifies the students to be taught*****.** An example might be: Each second grade student, or “Each fifth grade student”. The objective begins with the audience” Each second grade student” to remind the teacher that each and every student is expected to master this objective, thought there may be accommodations. Objectives start "Each" to help us be sure that all students are learning.

B stands for Behavior. This is not about student conduct. Instead Behavior refers to ***the thing that the lesson is designed to help the student do***. Each fifth grade student **will light a bulb** ... The bold segment of the previous partial objective is the behavior portion.

C stands for Conditions. This portion of the objective ***sets the parameters for the lesson.*** Adding to our example: Each fifth grade student will light a bulb **given one bulb, one wire, and one dry cell.** In this example the Conditions are about the materials that students can use. In mathematics, there might be "given paper and pencil only" or "without the use of a calculator". Another condition might be **"Given twenty problems."** The conditions portion of an ABCD objective tells the parameters, whether they be materials to be used or disallowed, time allowed, or even whether the activity is done individually or in groups.

D stands for Degree. The degree tells ***how well the student must do to master the objective.*** The degree might be "with 80% accuracy", or four out of five times. Each fifth grade student will light a bulb **four different ways**, given one bulb, one wire, and one dry cell. (Note: the order of the ABCD is not essential.) Some things require a greater degree mastery than others. There can also be a difference in degree of an objective when the students are first learning a new skill or process, as opposed to when they are experienced with the skill or process. The degree allows the teacher to differentiate. There may be some student in a class for whom 60% might me an appropriate degree, while others might need a degree of 95% for the same lesson.

Audience, Behavior, Conditions, Degree.

Original Size

Image 3: Seeds for the exercise below.

Five E Lesson Plans

We have looked at standards, and objectives. Both are included in the lesson plan. In this section we examine the parts of a Four E or Five E Lesson Plan. The Five E design is the latest version of a planning tool that came about as a result of the National Defense Education Act described above. (So are ABCD objectives.)   In its earliest iteration, it was called the "Learning Cycle". The idea is that one lesson should lead into the next. We will see this in the Five E format we use today. We will describe the format, but first we want to identify "Boilerplate" portions of a science lesson plan.

Generic Information included in start of the Lesson Plan:

Date (When the lesson is to be taught).

Class/Grade (Tell who the students are).

Standards (Use the standards that apply, such as the Minnesota Science Standards.)

Objectives (Use ABCD format to inform what your students should be able to do as a result of the lesson.).

Materials (List everything you will need to have ready and available.)
Safety (List any safety precautions or concerns.)

Components of the 5-E Format

First E: Engage

The first E is called the engage segment. This is where the teacher works to prepare the students to be active participants in the lesson. This will be different from what you do in language or reading lessons. In those classes, the teacher is asked to clearly state the objectives of the lesson. **In science, we want the students to learn through the inquiry process where they are not told the outcome in advance.**

The engage portion may be as simple as asking the students to recall a previous lesson. (Who can tell me what we worked on yesterday? Who remembers when we worked with our bean seeds last week?) It could also be question about something new. (Does anyone think it would be a good idea to chew on aluminum foil?). Another approach is to show students a discrepant event. A discrepant event is often a demonstration where the outcome is not what the student will expect to happen. (An example might be to float a paper clip in a cup of water.)

The idea of the engage portion of a lesson is to cause the students to want to be engaged in the lesson. In this portion of the lesson the teacher's role is to create an inviting situation to draw the students in so that will want to participate.

Second E: Explore or Exploration

The second part of a Five E lesson is the exploration part or phase. In this part for phase, the teacher presents a task that is just beyond the abilities of most of the students in class. This task should be something that a small groups can work on independently. This task should be interesting and clear, but not a recipe book, step by step activity. The idea is that if the students have time to try a task, but are not initially successful, they will have a desire to learn what then need in order to complete the task.

One way we show this is with **Batteries and Bulbs**. The explore phase gives student groups one dry cell, one flashlight bulb, and one short wire and asks them to draw diagrams of four ways they can make the bulb light. IN the process, the teacher takes on a sometimes uncomfortable role. During the explore phase, the teacher should not answer student questions about how to do the task. The teacher should monitor the classroom for safety and engagement of the groups. The student’s role is to be actively engaged in trying to complete the task.

Third E: Explain or Explanation

The Explain portion of a Five E Lesson is **when the teacher gathers the students (or gathers their attention) and does some direct instruction of the content necessary to complete the task**. In the **Batteries and Bulbs** scenario, the teacher describes and diagrams the way an electrolyte paste transfers electrons from a carbon rod to the Zinc can of a heavy duty dry cell. She/he also "Dissects" a light bulb to show the path that electrons flow in order to complete the circuit and make the filament glow. The teacher can even have the students act out the circuit, by holding hands and passing electrons (plastic chips) from person to person. (The point here is that the explanation phase does not have to be lecture...).

The teacher's role in the explain phase is to provide the instruction necessary for the student to successfully complete the task. The students' roles are to remain engaged and ask questions if something is not clear.

Fourth E: Elaborate

In the fourth phase of a Five E lesson, the students take the content they have just learned and apply it to the original task they were given for the exploration phase. The idea is that the new content they have been given will help the students to complete the task. This phase seems much like the explore phase, but the teacher role is different. **In the Elaborate phase, the teacher circulates among the groups and answers any questions the students have, guiding them toward the completion of the by reminding them of the content that was just presented.** If a group has successfully completed the task, they are given a slightly more advanced task to work on for the remainder of the class time.

Original Size

Image 4: Pre-service teachers engaged in the Elaboration phase.

Fifth E: Evaluation

Throughout the entire Five E Lesson the teacher is evaluating. In the Engage portion, the teacher is evaluating the effectiveness of the introduction to the lesson. She/he may need to adjust if the students do not seem to be engaging. In the exploration phase, the teacher is evaluating the students' success or lack of success with the task, and watching for signs of frustration. This is necessary for him/her to know when to move on to the explanation phase. In the explanation phase, the teacher is evaluating students" engagement and attempting to evaluate learning. And in the elaborate phase the teacher can evaluate which students have successfully completed the task. So, Evaluation is an ongoing, continuous process throughout the lesson.

However, it is important to look back to the lesson's objective(s). In the Elaborate phase, the teacher should be noting which students/groups had mastered the objective as part of an informal evaluation of the lesson.

Summary

This chapter is an outline of teaching science as inquiry. It is designed to prepare you for activities in class that will help you learn to plan for and carry excellent science lessons. Dr. Kimori, Professor Sanderson, and Dr. Browne both believe that students need to be actively involved with the science they are studying. The lessons should be **inquiry based** and as hands-on as possible. Both **process and product** will be addressed in science lessons. We believe that the Five E lesson plan format works well for elementary classroom science lessons, though it may need modification for the classrooms in which you teach.

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Chapter 12: Teaching Science to Diverse Learners

Culturally and linguistically diverse students including those who are multilingual and learning English as an additional language, constitute a substantial and growing demographic in the United States (McFarland et al., 2017) But these groups of students tend to receive unequal access to and inadequate instruction in science with their cultural and linguistic assets going largely unacknowledged and underutilized (National Science Teachers Association, 2017). The need for more information about quality science education for culturally and linguistically diverse students is pressing. This chapter seeks to address this need by exploring the effective strategies to teach in a diverse classroom in a K-6 education setting and beyond.

Teachers who understand culturally different behaviors respond in ways that appropriately and proactively accept or redirect students' behaviors when necessary (Cartledge & Kourea, 2008). The value of quality science, technology, engineering, art, and mathematics (STEAM) education for all students is an equity issue, a civics issue, and an economic issue (Pamela & Erin,2019) and there is a need for it to be addressed to both pre-service and in-service teachers. Teachers need to be equipped with skills to implement culturally sustaining, intellectually rich, relevant, and engaging science teaching and learning to ensure that all classrooms are supportive, inclusive, and inspiring to all students. Moreover, current national science standards recognize that students must understand that science is a process of thinking and reasoning rather than defining a set of technical terms. *Next Generation Science Standards* describe students engaging in science practices as a means by which to make sense and develop understandings of natural phenomena with their peers.

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TEACHER'S POWER CAN PUT CHILDREN AT RISK, OR IT CAN SUPPORT CHILDREN TO FLOURISH IN SCIENCE

Each day as students walk into your classroom they see, hear, and observe every event differently. The differences among learners in terms of race, gender, religion, sexual orientation, etc. at times drive how the learners perceive and observe classroom events differently. As a science educator on more than one occasion in social places, I have had conversations with people that believe that I teach a subject that plagued their own schooling experience. This more often reminds me of the power that teachers have either to flourish or harm children's learning experiences in science. I recently had such a conversation with a sixth-grade student (Meneja) whose school experience was adversely impacted in a social studies class. Meneja is a student of color in a suburban school district, unlike most underrepresented students Meneja chose to stand up and call out his teacher. The following is an email that Meneja sent out to his superintendent and his teacher to air his sentiments:

(Please note that these are not their real names, Pseudonyms have been used for confidentiality)

Dear Superintendent and Mrs. Simona,

Today I felt disrespected because today celebrates a very important person in Black history. I believe this day should be more recognized by the school and should also be respected. I believe that this day is important because of the changes Martin Luther King made in many people's lives by fighting for African Americans' civil rights.
This day was disrespected in my opinion because we did not recognize the day or have the opportunity to celebrate it by attending community events. Also, in our social studies class, we did not cover chapter 18 which talked about Martin Luther King. I believe that we should cover this for educational purposes and for the students who do not understand the importance of this day. I also believe that through broadcasting this to the whole school through cooperative activities students will better understand how to stand up for other students who are being discriminated against for racial, religious, or political issues.
I hope that in the future the school district will be more aware of the significance and importance of this day.
Sincerely,
Meneja

"Dr. Martin Luther King" by Selma best videos is licensed under CC BY-SA 2.0

The email by Meneja is one example of how decisions by a teacher can harm the students who are invisible in the teacher's eyes. From Meneja's email the following aspects can be deduced as teaching that has the potential to harm:

▪ Teaching that slows or harms children's academic, social, and emotional development

▪ Teaching that reproduces common patterns that marginalize, exclude, and reinforce bias and bigotry

▪ Teaching that does not connect with or lacks respect for children's families and communities

On the flipside teaching that has the potential to help diverse learners will be described as:

▪ Teaching that supports and increases children's academic, social, and emotional development

▪ Teaching that deliberately breaks with common patterns of practice that marginalize, exclude, reinforce bias and bigotry

▪ Teaching that takes advantage of families and communities to support children's development

To achieve the features of teaching that will help diverse learners, teachers, need to carefully make decisions when planning and selecting curriculum materials. We recommend a decision-making process called INCLUDE was developed by Marilyn Friend of Indiana University. This seven-step approach helps teachers plan how to accommodate the diverse learning needs in their classroom:

1. **I**dentify classroom environmental, curricular, and instructional demands.

2. **N**ote student strengths and needs.

3. **C**heck for potential areas of student success.

4. **L**ook for potential problem areas.

5. **U**se information gathered to brainstorm instructional adaptations.

6. **D**ecide which adaptations to implement.

7. **E**valuate student progress.

While executing the INCLUDE decision-making process here are some general considerations to think about:

- Relate learning activities to personal real-life skills and experiences.
- Model assignment expectations by showing an example of the product.
- Limit expectations to two or three well-developed concepts per unit.
- Be aware of the academic levels of students so that reading, vocabulary, and other issues can be addressed.
- Use projects rather than traditional testing for evaluation.
- Concentrate on student strengths and bring those strengths into the lesson.
- Use concise written and oral directions.
- Use pictures, concept mapping, webbing, and graphic organizers.
- Require short answers as well as long essay answers; e.g., testing, oral response
- Create large and small group activities.
- Provide lecture outlines.
- Pre-teach concept vocabulary; use pre-reading clues.
- Use multiple intelligences approaches to teach the same lessons.

Some recommendations about typical successful science teaching in inclusive classes include:

- Create a classroom culture that is nurturing and supportive and that fosters mutual respect, self-esteem, self-efficacy, and resilience.
- Understand and address students' needs as learners
- Use multisensory, thematic, and cross-disciplinary approaches
- Encourage collaboration rather than competition
- Use cooperative learning strategies
- Provide lessons that are developmentally appropriate and relevant to the learners.
- Employ authentic assessment methods
- Have high expectations for all students
- Encourage students to responsible for their learning.
- Actively engage students in inquiry and other constructivist approaches (Alexakos,2001; Pellino, 2008; Vaughn & Bos, 2012)

Strategies in Making Science Accessible to All Learners

In this section, we are going to explore the strategies to effectively make science to all learners. For non-mainstream students, *equitable learning opportunities* occur when school science: (a) values and respects the experiences that all students bring from their homes and communities, (b) articulates this cultural and linguistic knowledge with disciplinary knowledge, and (c) offers sufficient educational resources to support science learning (Lee & Buxton, 2010). Research has also shown that when provided with adequate time and support, nearly all students can learn and do science when they make a sustained effort (NRC, 2012) In the report, "*Preparing the Next Generation of STEM Innovators (NSF, 2010)*, the National Science Board states, "In America, it should be possible, even essential, to elevate the achievement of low-performing at-risk groups while simultaneously lifting the ceiling of achievement for our future innovators" (p. 16). Tapping into a student's own experiences is a key to making science accessible for any learner, irrespective of background and ability. Forming predictions, collecting information, processing that data, and using it to modify current understanding is something that we do instinctually from infancy and keeps on advancing with complexity as we grow older. In the learning of science making connections to students' personal experiences makes the learning process memorable, personal, and more valuable.

In 1997-1998 the El Nino phenomenon caused by unusually warm waters was characterized by heavy rainfall in Kenya with similar effects in other parts of the world like Peru and Asia. Kenya was particularly hit by flooding and rainfall surpluses making roads to schools, markets, and farmlands impassable. Accompanied by poor infrastructure and draining systems; many people lost their lives as a result of drowning including livestock to the tune of millions of dollars. The cost of damage was irrecoverable, especially in the agricultural sector.

Bridges and major roads were destroyed to the worth of millions, halting businesses and the economy in general. Ships were unable to dock and offload cargo at the port. After the bridge leading to the way to my school was washed away it presented a great moment for me to learn about resilience and problem-solving. In my physics class, we were learning about the Bernoulli's Principle and I quickly started thinking about how it can be used to build adaptive bridges; to open and close so during high waters, so as infrastructure can remain uninterrupted in such natural disasters like El Nino.

The experts predicted that the El Nino was a phenomenon that would re-occur following the changing ocean temperatures and human activity that has adversely affected the atmospheric precipitation patterns. Given the projections of the El Nino reoccurring in the future, I came with the idea of a 'Bernoulli Bridge' that would open and close by blowing wind to create pressure changes for physics talk that I would present at Science Symposium competitions that were to be from local schools to nationwide. The Bernoulli Bridge was supposed to open and close by blowing wind to create pressure changes thus when waters rise it will remain open and not be washed away. While presenting my talk at various levels I discovered that it was an interesting topic to the audience because everyone had felt the effect of El Nino and I learned more and more about the application of Bernoulli's Principle because it seemed to have a direct connection to the experiences, I had gone through with El Nino rains. Having lived through this experience I was able to understand Bernoulli's Principle and its application because it directly related to my experience. Making science have connections to learners' experiences is one powerful way to motivate all students to understand and make connections to science.

a) Teaching Science to Linguistically and Culturally Diverse Students

Many students from diverse ethnic backgrounds are in the process of acquiring the US mainstream language, culture, and discourse patterns in schools (Contant, Bass, Tweed & Carin, 2018) Some of the strategies that can be effective in science teaching and learning for English Learners (Els) include:

i. Use of structured inquiry-based science programs- programs that have a gradual shift of control from the teacher to students are vital to students who struggle with the development of new language, customs, friendships, and less advantageous community environments.

ii. Providing context of science- Context enables children to build on what they already know and to infer the meaning of new words and verbal constructs. In inquiry approaches to learning science students have opportunities to develop verbal fluency and as they engage in discourse, record their observations and communicate their findings.

iii. Sheltered Instruction-This is an approach that is designed to help English Learners to understand academic subjects while they are developing proficiency in English. Sheltered instruction focuses on concept development and nonlanguage cues and prompts.

https://www.youtube.com/watch?v=Jqe9Nx1IlQA Video courtesy of Colorin Colorado

b) Teaching Science to Students identified with Disabilities

The Individuals with Disabilities Education Act (IDEA) (1997, amended 2004) mandates that all students have the right to a full, free public education in the least restrictive environment. Therefore, schools are required to educate students with disabilities with nondisabled students to the maximum extent appropriate for the students with disabilities. In the following sections, we will explore the strategies to teach science to various groups of students with disabilities.

i. Teaching Science to Students with Intellectual Disabilities

Students with intellectual disabilities show greater cognitive discrepancies than students with learning. Research indicates that students with mild intellectual disabilities learn concepts better when they are guided to construct them through questioning than when the information is presented directly to them (Mastropieri, et al, 1993) However, there is limited research into effective science instruction but emerging research suggests that inquiry-based instructional methods can help students with intellectual disabilities learn both functional and some science content (Miller, 2012)

ii. Teaching Science to Students with Emotional Disturbance

According to IDEA students with emotional disturbance exhibit one or more of the following characteristics over some time:

- An inability to learn not due to intellectual, sensory, or health factors
- An inability to exhibit appropriate behavior under ordinary circumstances
- An inability to maintain relationships with peers or teachers
- An inappropriate effect such as depression or anxiety
- An inappropriate manifestation of physical symptoms or fears in response to school or personal difficulties (Code of Federal Regulations, Title 34, 300.8[c][4][i])

Clearly stated classroom and laboratory rules if fairly and consistently enforced will help in maintaining a safe and supportive learning environment for all students. Ask for advice from special needs teachers and counselors who also work with your students with emotional disturbances. Please note that during an activity do not put yourself or your class at risk for the sake of inclusion. If you have any concerns arrange for a co-teacher or skilled instructional aide to assist in the lab activity. Color blindness can also impact science learning since some lines on schematic diagrams or wires are color-coded and can be difficult for students with color blindness as a teacher you will need to figure out how to adapt materials to make them accessible to visually impaired students.

iii. Teaching Science to Students with Visual Impairments

Students with low vision might need special aids or instruction to read ordinally print. Those who are functionally blind typically need to use Braille for reading and writing. Those who are blind do not gain any meaningful input through visual sense but through using tactile and auditory means to learn about their environment. Color blindness can also impact science learning since some lines on schematic diagrams or wires are color-coded and can be difficult for students with color blindness as a teacher you will need to figure out how to adapt materials to make them accessible to visually impaired students.

iv. Teaching Science to Students with Hearing Impairment

Students with hearing impairment range in their hearing ability from hard of hearing to total deafness. Hands-on activities can help with students hearing impairment make connections and meaning. It is advisable, to begin with, objects that they are familiar with in their daily environment. Place the students at the front of the classroom to improve their opportunity to hear verbally provided instructions and have access to the teacher easily when needed. Minimize any background noises to improve the learning environment for students with hard of hearing, also be sure to wear microphones well-positioned to your mouth in case your student uses a hearing aid. For science videos and TV programs turn on captioning features.

c) Teaching Science to Students Identified as Gifted and Talented

These are students who have above-average intelligence and have unusual skills, interests, talents, and attitudes about learning. Make these students feel welcome in your class by incorporating challenging science content and activities to introduce rigor and encourage abstract thinking and problem-solving skills. For gifted and talented students generally, try the following strategies:

- Provide recognition for their efforts and encourage cooperative efforts.
- Challenge students to come up with questions they think are difficulty
- Encourage student-initiated projects and alternative activities
- Introduce them to research methods
- Encourage them to use a variety of media to express themselves and their work

- Help them share their projects or work with others for example in a science magazine.

Above all remember that gifted and talented students are still developing and they need your guidance and training for their social, emotional, and physical development.

In this chapter, we have covered some of the strategies that science you should apply while teaching science to diverse groups of students. Most importantly we examined the power of a teacher to either harm or nourish children's learning experience in science. And we want to end the chapter with a response to Meneja's email at the beginning of this chapter from his teacher Mrs. Simona (not real name) so as not to leave you in suspense thinking of Meneja's experience. This is Mrs. Simona's email:

Hi Meneja,

Thank you so much for the email. I have to tell you how incredibly I am impressed I am that you took the initiative to share these thoughts and also develop such a well-written persuasive letter. You are a truly talented writer and a student with a great deal of character.

I am so sorry to have disappointed you yesterday but I want to reassure you that we will not be ignoring the contributions of Martin Luther King Junior. Your teachers should have shared that each grade will be recognizing the day and his work on a different day this week. For your grade, it will be tomorrow. You will do an activity in class and have an assembly. We spread it out over the span of the week so that we could have individual grades meet together rather than a giant assembly with 600 kids in the cafeteria. Our experience is that smaller groups seem to be more effective for things like this.

In addition, I want to thank you for giving your feedback about chapter 18. I will forward this feedback to our teachers. As you probably know as sixth-grader, we *never get through an entire textbook. In Minnesota history this year we actually changed curriculum midyear and so we are only covering a few of the chapters in the new curriculum. Nevertheless, I will pass along your feedback for future years to consider.*

Thank you again for taking the time to write this letter. Feel free to stop in and chat anytime if you want to discuss it further or if you have any questions... my door is always open for you, Meneja.

Mrs. Simona (not real name)

Reflection Questions

1. In your own opinion do you think Mrs. Simona's response to Meneja's email was nourishing or harmful to his school experience?
2. How do you think student diversity in your classroom might impact science instruction?
3. How do you believe issues of diversity and equity contribution to the achievement gap between certain groups of students?
4. How is it possible to teach science to students who are not fluent in English when you do not speak their language?
5. How will you plan to teach science to students with disabilities?