The Design of Theory

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The course I teach is *Biology: A Human Approach.* The curriculum for the course is centered around the 6 unifying principles of life; Evolution, Homeostasis, Energy/Matter & Organization, Continuity, Development and Ecology. Introducing the *String Theory* to the classroom would be best interwoven with the material covered at the beginning of the first semester when the objective to be met by the student is to understand what a *Scientific Theory* really is and the *Scientific Method* followed by scientists to test theories.

The first unifying principle covered is *Evolution* and this is a practical place at which to incorporate how everything began. Biology is centered on the beginning of "Life" and how it changed over time, all of which is *Theory.*

In order to engage the students into thinking like scientists, define how ideas are developed and theories unfold. In the textbook used for this curriculum, theory is defined as a well-tested hypothesis that organizes knowledge, fits existing data, explains how events or processes occur, and successfully predicts future observations.

In order to engage the students in this type of thinking begin with a simple question and the students will discuss and brainstorm for possible answers. For example: have the students observe a mechanical pencil. The students will form hypotheses of how it works, what makes the lead move in and out of its container. After brainstorming a unified theory, break open the pencil and reveal the answer. This activity and objective meets *Science and Technology Standard #6; all students develop and apply skills of observation, data collection, analysis, pattern recognition, prediction and scientific reasoning in designing and conducting an experiment.*

In chapter one of the textbook the students look at the human animal and compare and contrast human characteristics with those of other organisms in our biosphere. The students compare our brain, hands, intellect, the fact that we can create ideas, traditions, cultures, the way in which we learn and think, our long childhood and parenting behaviors, the characteristics that separate us form other organisms. As I mentioned in my prospectus, the things that make us special and separate from other organisms in our world. Next, the chapter covers *Evolution*, described as changes that take place over long periods of time. Students understand that evolution produces many diverse organisms that are all united by these same 6 principles.

Chapter two continues to discuss the evidence for the *Theory of Evolution.* Students create a timeline of the major events that occurred in Earth's geological history (deep time). They are introduced to fossil evidence such as "Lucy" a 3 million year old hominid found in Ethiopia in 1973. Students will be able to understand how, according to Darwin's Theory of Evolution, nature selects the best suited for a particular environment to succeed and reproduce therefore passing on the preferred characteristics.

Students read and take notes on the essay *Just a Theory* in their class journal and write an explanation of the theory of evolution's importance in modern biology. This is the point at which I will introduce the unit that I will create for my Biology course. The course is taught to a population of primarily tenth graders along with a small percentage of advanced ninth graders.

The class will discuss their own ideas about theory, ideas, and beliefs. We will begin with the theories that they are already familiar with, the Atomic Theory, the Theory of Evolution, The Big Bang. Then we will explore other theories with which they may not be acquainted. The students will discuss and take notes on other theories that have been introduced but not necessarily in the text book. These theories will, include The Big Bounce or "Spring Theory", "Branes" that slice through the higher dimensional world, Creation along with various other religious beliefs, and finally **String Theory.**

The beginning of this unit will consist of the understanding of evolution itself. The students will learn about the scientific community, the tasks and investigations that are coordinated by paleogeologists, evolutionary biologists, developmental biologists and physical anthropologists to shape the overwhelming evidence for the theory of evolution. The students will read, discuss and write the processes of evolution by means of *Natural Selection.*
This method of study addresses Science & Technology Standard #1 and Communication Standards #2 & #3.

Natural Selection was the central concept of Charles Darwin's Theory of Evolution. It investigates the origin of adaptation and the diversity among Earth's living organisms. Covering this theory the students will take a look at the observations and experiments that experts accept as fact. The main concept of this theory is that small, random, inheritable differences among individuals result in the different chances of survival and reproduction in a particular location. Those less suited for the environment have fewer surviving offspring so the useless or incompatible variations tend to disappear and the useful traits tend to be gradually magnified throughout a population. At a certain point these differences become irreversibly distinct so that the members can't interbreed with the rest. Darwin called this phenomenon "The Principle of Divergence". (National Geographic 11/04 4-9).

Darwin continued to believe in a distant, greater entity that had set the universe and its laws into motion, but not in a personal God who had chosen humanity as a special and favored species.

My past experience at teaching this concept reveals that the students can grasp the small variations and adaptations of species but they do have a hard time understanding large anatomical changes. The information provided by physical anthropologists and examples like the evolution of the horse over millions of years, from *Hyracotherium* to *Equis* helps them to grasp the changes within a particular group of organisms, but animals becoming terrestrial when they were once aquatic and mammals living in the

oceans is just unimaginable to them. I found some wonderful research *Rodhocetus balochistanensis,* which was a sea creature, its legs like flippers, its nostrils shifted backwards on its snout halfway to the blowhole position on a modern whale done by Philip D. Gingerich, a paleontologist at the University of Michigan in the 1970's. Working with colleagues in Egypt and Pakistan he also discovered *Pakicetus,* a terrestrial mammal dating from 50 million years ago whose ear bones reflect its membership in whale lineage but whose skull looks almost doglike. One of Gingerich's students found a slightly more recent form with webbed feet, legs suitable for either walking or swimming, and a long toothy snout called *Ambulocetus nantans,* or the walking-and-swimming whale. (National Geographic 11/04 31). Gingerich leaned toward believing that whales had descended from a group of carnivorous Eocene mammals known as Mesonychids with teeth to tear flesh and bone, but as technology developed as it continues to, molecular biologists were able to look at the DNA due to the tremendous accomplishments of the *Human Genome Project* in the late 1990's, and realized that there was no match to those carnivorous mammals. The DNA hybridization and other tests suggested that whales had descended from Artiodactyls, even toed herbivores like antelopes and hippos. To further support this theory, in 2000 an anklebone from a four legged whale dating back 47 million years closely resembled the homologous anklebone in Artiodactyl. Gingerich realized how closely related whales were to antelopes. This research fits very well into the present curriculum for the students will cover *The Human Genome Project* in Chapter 11 of their textbook during the third grading period.

Phil Gingerich is a reverent empiricist. He grew up in a conservative church in the Midwest and was not taught anything about evolution. The subject was clearly overlooked. Although he is a scientist and does recognize the evidence of ancestral connections between many species, but as far as the search for some missing link, one common ancestor or even the beginning of the universe itself, he sees these beginnings to be theory. He recognizes the Big Bang Theory up to The Superstring Theory as theory that needs to provide more evidence to satisfy him.

This is where I will initiate the theories scientists have devoted years of research toward finding the answer as to how the universe began.

In this country 64% of the public say they attend weekend worship services at least once a month. According to a Gallup poll drawn from more than a thousand telephone interviews conducted in February 2001, no less than 45% of responding U.S. adults agreed that "God created humans pretty much in our present form. Only 37% of the polled Americans were satisfied with allowing room for both God and Darwin, that is a divine initiative to get things started using evolution as the creative means. Even fewer Americans, 12% believed humans evolved purely from the primitive cell without the involvement of a God.

These statistics haven't changed in 23 years. Gallop polls taken in 1982, 1993 and 1997 posed the very same results. The view of the Creationist has never been supported by fewer than 44%. This information leads us into another discussion. Are polls and

surveys scientific? Is science to be based on a popularity contest? Is this the information used to provide funding for research in specific areas of science?

The school at which I teach contains a large population of Christians, the largest percent being Baptist. A large majority of my students also participate in Sunday school, church youth group activities (particularly basketball) and go to service regularly. The subject of God comes up every time the concept of evolution is introduced.

A colleague of mine asked her students to write a short essay on their view of how the universe was formed. An overwhelming majority of students believe that God created Adam and Eve, they had children, their children had children, and so the universe was formed. "Simple huh?" This assignment looks to be an interesting way to introduce the students to the complex theory that is new and on the horizon for both skepticism and research.

This unit will begin with the theory that dominated the public school textbooks, The Big Bang. The students will review that according to the Big Bang Theory the universe was created sometime between 10 and 20 billion years ago from a cosmic explosion that hurled matter in all directions. In 1927, a Belgian priest, George Lemaitre, was the first to propose this idea that the universe began with this explosion of particles (atoms). Years later, Edwin Hubble found experimental evidence to help justify this theory. He found that distant galaxies in every direction are going away from us. Students are reminded that experimental evidence is the scientific means to confirm or reject a theory. The strongest confirmation of this theory was received in 1964 by Arno Penzias and Robert Wilson when they discovered Background Radiation (the glow left over from the Big Bang itself). If we were to wind a cosmic film of the expansion of the universe backwards toward the Big Bang, we would get back to a single particle that has no size.

Another possibility for the birth of the universe is what you might call the Big Bounce, the idea that, previous to the Big Bang, there might have been a universe that was bigger, then got smaller, and then went through a "fiery intermediate stage" out of which came another expanding universe.

Then there are these things called "Branes" or dimensions. We see our world in three dimensions. This theory predicts that there was another "Brane "or dimension that was somewhere else in the universe and it crashed into our Brane dumping a lot of energy into it and because of this event the Big Bang occurred.

Students will bring into the discussion ideas of their own. It's been my experience in past lessons that students can be very passionate about their beliefs and traditions that they have grown up with. Students often use the term "proof" or lack of, to disregard these theories or at least make equal their beliefs. I agree with Amanda Peet, a physicist interviewed by *NOVA,* on her viewpoint on String Theory when she stated, "You can never prove that a theory in nature is correct. All you can prove is that it's the best theory you have."

I don't like to contradict the beliefs and values of my students. It tends to turn them off from the subject matter. In the past I have used the "baking a cake" analogy. Although we have evidence that the organisms on earth adapted and evolved over time, life could not have evolved if the circumstances were not absolutely perfect. If the atmosphere didn't contain exactly 21% oxygen along with other critical specific occurrences, life would have not evolved. Any more oxygen would cause outrageous fires on this planet, any less we would not be able to breathe and plants would not be able to transpire. If you bake a cake and don't have the ingredients measured properly or you don't bake it at a specific temperature for a specific amount of time, it won't be a cake. Even though the ingredients are there, someone had to put it together properly. This is the fundamental behind another theory called *Intelligent Design.* While researching these different theories, I came upon another analogy that I think explains this phenomena even better.

This story comes from *The London Observer*. A family of mice lived in a grand piano. They enjoyed listening to the music that came from the great player whom they never saw, but whom they believed in. One day one of the little mice got especially brave. He climbed deep into the bowels of the piano. He made an astonishing discovery. The music didn't come from a great player; but rather, the music came from wires that reverberated back and forth. The mouse returned to his family tremendously excited. He informed his family that there was no great player who made the piano music, but it was the wires. The family of mice abandoned the belief in a great piano player. Instead they had a totally mechanical view. The next day another one of the mice got especially brave. She climbed even further up into the bowels of the piano. To her amazement she found that indeed the music didn't come from the vibrating wires, but instead from little hammers that struck the wires. It was the hammers that made the music. The family of mice did not believe that there was a player playing the piano. Instead they believed that their mechanistic understanding of the universe explained all reality. But the fact is that there was a piano player touching the keys causing the mechanisms inside the piano to produce the music.

Students in this community seem most comfortable studying the creation of this universe when it fits with what they have been taught by those they respect, their family. So just because we understand how things work does not mean that there is not an intelligent mind behind the process which seems to provoke their interest rather that challenge their beliefs.

This theory is also being looked at by a few states here in the U.S. including our neighbor, Ohio. On January 3, 2002, Science Excellence for all Ohioans (SEAO) and the Intelligent Design network, Inc. posted a web site that solicited comments on proposed modifications to the Tenth Grade Life Science Section of a published draft of Ohio Science Academic Content Standards. The poll collected 309 usable comments. Comments that were duplicative or incomplete were discarded. Of the 309 responses, 243 (79%) specifically "Agreed with the modifications and 66 (21%) "Disagreed". Among those that disagreed were 28 (9%) who provided comments that "where did we come from" which necessarily raise deep philosophical and religious issues, (as does the

beginning of the). It is important that the state not become an exponent of one view over the other. Here lies support for integrating *Intelligent Design* into the curriculum.

Teaching origins science also involves critical legal issues. All eight lawyers responding, including 2 professors of law, agreed with the modifications. None were opposed.

**A persistent complaint against design theory and objective origins science is that no "real scientist" or professor agrees with it (so it seems, due to the reaction to my prospectus by the instructor of this seminar series, (although I did have one supporter in the class). The biggest argument against Intelligent Design is that there is no experiment we can do to support or disprove its hypothesis. To underscore its inadequacy, at the conclusion of this paper I will provide a list of those that hold doctoral degrees and well-credentialed respondents that favor the inclusion of *Intelligent Design* as part of the science curriculum. The *Discovery Institute* web site reflects that a list of 100 highly credentialed scientist who recently signed the following statement: "I am skeptical of claims for the ability of random mutation and natural selection to account for the complexity of life. Careful examination of the evidence for Darwinian theory should be encouraged." The *NOVA* program that was based on the book *The Elegant Universe, itself* had its own skeptic. Sheldon Lee Glashow sees string to be philosophy not scientific theory which is the argument often held by physicists against the Intelligent Design Theory. Neither at this time can be tested. Physicists do have ideas which they "hope" to be able to perform sometime in the future when technology has the time to catch up. But for now String theory is "Safe". It can neither be proven true or false. Until we can develop a communication system to communicate with these other worlds or parallel universes, possibly using waves of gravity, there still exists no possibility today and no real conclusion can be drawn at this time.

Students will often need to be reminded that we are looking at these theories and ideas through the eyes of a scientist. In this case a Cosmologist. Today, from the point of view of cosmology, there are 2 distinct theories favored that describe the birth of the universe. One being the Big Bang which we have already discussed, and a somewhat new approach to the Big Bang, the *String Theory*.

The clearest and simplest explanation of string that I have found to describe to my students is that we used to think of the beginning as a tiny point particle of which everything was compressed down to and the temperature would have been infinitely hot. The trouble with "infinity" is that it is very hard to calculate. String theory tells us that the universe started in a less singular way. Instead of a point particle at the beginning physicists now imagine this energy in the form more like a string. They think that everything in the universe is made of these tiny vibrating strands of energy called strings. One characteristic of strings is that each one vibrates in a unique way, representing the mass, charge and spin of known elementary particles.

String Theory Unit

Lessons in the Biology curriculum are broken down into specific categories; **Engaging** the student, **Exploring** the history of the idea, **Explaining** its characteristics, relevance, and fundamentals of the theory or idea, **Elaborate** by giving opinions, data collected, brainstorming and class discussion and finally **Evaluate**, usually a quiz or exam is given at the end of each unit.

In order to engage the students in this unit the following activity will cover the first objective: **The students will learn about a new theoretical fundamental unit—a string—and explore how its vibrational pattern indicates the particle it is.** Please refer to the Activity attached; "A new Building Block". This activity Science and Technology Standard #1 is met.

This activity will be followed up by exploring the history of the string theory: **The students will be able to describe the String theory in a nut shell.** Refer to the class notes attached; "The String Theory". This lesson covers Communication standards #2 & 4. (This lecture and discussion may take 2 days.)

The Dimensions that are mentioned in the previous lecture is a difficult concept for students to follow. The activity "Deducting Dimensions" will satisfy both the **Explanation** task in the unit and help to facilitate understanding. The objective: **Students visualize a universe with fewer that 3 dimensions and to consider how more than 3 spiral dimensions could possibly exist in the universe.** This activity satisfies Science and Technology Standard #5.

Elaborating on this subject, the students will look at how science and evolution is taught in parochial schools. Students will be able to discuss what they have been taught at home or at their place of worship. Again we will revisit the question; "What is a theory?" all students will participate in a classroom discussion that encompasses Science & Technology Standards #1, 4 &7 and also Communication Standards #5, 6 &9.

Students will be **Evaluated** on a multiple choice exam attached where **The students demonstrate Knowledge and understanding.** Science and Technology #2.

The following tables summarize in more detail the results of this poll:

All Respondents

Group	Total	Agree	Disagree	Disagree, but For Objective OS	Total For Objective OS
All Respondents	309	243	38	28	271
Percentages		79%	12%	9%	88%

Level of Education of Respondents

Group	Total	Agree	Disagree	Disagree, but For Objective OS	Total For Objective OS
Doctoral Degrees	83	75	5	3	78 (94%)
Master's Degrees	56	48	6	2	50 (89%)
Bachelor's Degrees	114	87	13	14	101 (89%)
Other	56	33	14	9	42 (75%)
Totals	309	243	38	28	271 (88%)

Respondents Engaged in Biological and Life Sciences

Group	Total	Agree	Disagree	Disagree, but For Objective OS	Total For Objective OS
Doctoral Degrees	44	38	5	1	39 (89%)
Master's Degrees	15	10	5	0	10 (67%)
Bachelor's Degrees	21	14	3	4	18 (86%)
Other	5	3	1	1	4 (80%)
Totals	85	65	14	6	71 (84%)

Respondents Engaged in Teaching and Education

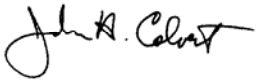
Group	Total	Agree	Disagree	Disagree, but For Objective OS	Total For Objective OS
Doctoral Degrees	48	42	3	3	45 (94%)
Master's Degrees	12	10	2	0	10 (84%)
Bachelor's Degrees	19	17	2	0	17 (89%)
Other	1	1	0	0	1 (100%)
Totals	80	70	7	3	73 (91%)

Respondents Engaged in Practicing or Teaching Law

Group	Total	Agree	Disagree	Disagree, but For Objective OS	Total For Objective OS
All Lawyers	8	8	0	0	8 (100%)

We wish to thank all of those who took the time to comment on the Modifications.

Barry Sheets
Executive Director
SCIENCE EXCELLENCE FOR ALL OHIOANS



John H. Calvert
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LESSON PLANS

NAME: K. Malone COURSE: Biology WEEK OF: ?/??/?? - ?/??/??

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
INSTRUCTIONAL MATERIALS/RESOURCES: Mechanical Pencil Journals Text pgs. 118 - 120	INSTRUCTIONAL MATERIALS/RESOURCES: "A New Building Block" activity page 15 ft. rope measuring tape stop watch calculators **Journals**	INSTRUCTIONAL MATERIALS/RESOURSES: Overhead journals	INSRUCTIONAL MATERIALS/RESOURCES: Overhead journals	INSTRUCTIONAL MATEIALS/RESOURCES: copy of the book*; Flatlands: A romance of Many Dimensions* Deducting Dimensions activity sheet journals
INSTRUCTIONAL OBJECTIVE: **Engage:** Students learn how to think like a scientist and develop a theory. **Science & Technology #1** **Communication standard #3**	INSTRUCTIONAL OBJECTIVE: **Explore:** Students are introduced to the fundamentals of **String theory** and explore how its vibrational pattern indicates the particle it is. **Science and Technology #1**	INSTRUCTIONAL OBJECTIVE: **Explain:** Students will understand the basic history and concepts of the **String Theory**. **Communication Standards #2 & 4**	INSTRUCTIONAL OBJECTIVE: **Explain:** Students will understand the basic history and concepts of the **String Theory**. **Communication Standards #2 & 4**	INSTRUCTIONAL OBJECTIVE: **Explain:** Students visualize a universe with fewer than 3 dimensions and to consider how more than 3 spiral dimensions could possibly exist in the universe. **Science & Technology #5**
METHODS OF INSTRUCTION: Students will discuss and brainstorm theories about how a mechanical pencil works. They will discuss how to test their theory and come to a conclusion. The students will the read the essay: **Just a theory on pages 118 – 120 of the text and take notes on the class discussion that follows.** **Teachers notes attached**	METHODS OF INSTRUCTION: Students will follow the procedures on the activity page and create a Rope Resonance Chart in their journals on which they will record their data. The class will share and discuss their results.	METHODS OF INSTRUCTION: Students will take notes from the lecture and participate in a discussion on the history and fundamentals of this theory. Teachers notes attached (this activity may take 2 days)	METHODS OF INSTRUCTION; Students will take notes from the lecture and participate in a discussion on the history and fundamentals of this theory. Teachers notes attached (this activity may take 2 days)	METHODS OF INSTRUCTION: Students will work in cooperative learning groups and follow the procedure on the Deducting Dimension activity sheet. They will answer the questions in their journals. The class will exchange and compare answers between groups.

LESSON PLANS

NAME: K. Malone COURSE: Biology WEEK OF: ?/??/?? - ?/??/??

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
INSTRUCTIONAL MATERIALS/RESOURCES: Journals rulers	INSTRUCTIONAL MATERIALS/RESOURCES: TV/DVD Payer The Elegant Universe (DVD) Video Observation Sheet	INSTRUCTIONAL MATERIALS/RESOURSES: Continue video	INSRUCTIONAL MATERIALS/RESOURCES: Complete video	INSTRUCTIONAL MATEIALS/RESOURCES: Scantrons String exam pencils
INSTRUCTIONAL OBJECTIVE: **Elaborate;** Students will discuss how cultural and religious differences influence what people believe. Is this considered **Theory?** **Science and technology #1, 4 & 7** **Communication Standards #5, 6&9**	INSTRUCTIONAL OBJECTIVE: **Elaborate:** Students will review the concepts of String theory and view the models scientist have proposed as they watch the video narrated by Brian Green. **Science and Technology #1 & 5**	INSTRUCTIONAL OBJECTIVE:	INSTRUCTIONAL OBJECTIVE:	INSTRUCTIONAL OBJECTIVE: **Evaluate:** Students demonstrate Knowledge. **Science & Technology #2**
METHODS OF INSTRUCTION: Students will discuss the beliefs and ideas they grew up with along with comparing other religious stories, legends and folklore about the beginning of the universe. **Extra credit: Students may research and bring in to share any folklore or legends concerning the beginning of the universe.**	METHODS OF INSTRUCTION: Students will complete a modified summary sheet during the video including the main idea of the movie, alist of concepts they already knew prior to watching the video, and a list of interesting facts they learned while watching the video. This exercise may be placed in the science portfolio.	METHODS OF INSTRUCTION:	METHODS OF INSTRUCTION; Students turn in video observation sheet for evaluation.	METHODS OF INSTRUCTION: Students will complete a multiple choice exam to be evaluated on their understanding of the unit material.

Just A Theory?

When we say we have a **Theory**, usually it means that we have an idea about how to explain something.

A **"Theory"** is a clever idea and we may not have enough evidence and others may disagree.

Scientists use this term in a different way…….

Scientific Theory:

These are explanations that are extremely well accepted by the scientific community because a variety of strong evidence supports them.

Examples of Scientific Theories:

1. Atomic Theory
2. Cell Theory
3. Theory of Evolution
4.
5. (students brainstorm)
6.

We have discussed the beginning of life, now let's talk about the creation of the Universe.

Write a 5 sentence summary to explain your theory of how the universe began:

(Discuss the students various ideas and discuss if they can be considered **Scientific Theories**, why and why not.)

A New Building Block?

Activity Setup

Objective

To learn about a new theoretical fundamental unit—a string—and explore how its vibrational pattern indicates the particle it is.

Materials for each group

- copy of the *A New Building Block?* activity sheet on page 18
- 15-foot-long rope (4.6 meters), 1/4- to 3/8-inch in diameter (6.3- to 9.5-millimeters)
- measuring tape, at least 15 feet (4.6 meters)
- clock or watch with a second hand
- calculator

Procedure

1. Share with students the idea that there may exist a subdivision of matter more fundamental than the currently confirmed quarks and leptons. This unit is called a string, and is thought by some to be the single building block of nature. Tell students that in this activity they will be exploring one feature of strings—that different patterns of string vibration correspond to the different matter and force particles that make up the universe they see around them.
2. Organize students into groups of four and distribute the *A New Building Block?* activity sheet and set of materials to each group.
3. Illustrate the process outlined on the activity sheet for finding the fundamental frequency. For the fundamental frequency, the rope twirler's arm motion will be circular, as if the twirler were playing jump rope. For the first overtone, a very small, rapid rotary hand motion will need to be applied, using just the wrist while keeping the twirling loop moving smoothly. It takes a bit of practice to achieve this.
4. Demonstrate the fundamental frequency using the circular motion. Then demonstrate the first overtone by speeding up the rotation. Do this by shifting to a rapid small hand motion, until the twisting loop splits into two twirling loops with a pinch point in the middle. (This pinch point is known as a *node*.) Explain that by using ever-faster hand motions, additional overtones of the fundamental frequency can be formed.
5. Have students do the trials and record their results through the second overtone. After this point it will be likely that students will not be able to twirl the rope fast enough to create a third overtone (up to a point, creating a third overtone is somewhat easier with a longer rope).
6. To close, point out that Einstein's famous equation, $E=mc^2$, indicates that mass can be viewed as a form of energy. Have students report which overtone required the most energy. Ask them to suggest which "strings," or overtones, might be more massive.

A 5/16-inch (8 millimeter) right-hand laid rope works well for this activity.

Choosing a Rope

When choosing a rope for this activity, look for one that will drape over your hand, not stick out stiffly. Thick, soft ropes like nylon tend to be easier to twirl than thin, stiff ropes like cotton clothesline.

Background

Some physicists think there is a unit of matter more fundamental than what has been experimentally confirmed to date. They think that everything in the universe is made of tiny vibrating strands of energy called strings. One feature of strings is that each one vibrates in a unique way, representing the mass, charge, and spin of known elementary particles. In this activity, students will use a rope to simulate a string's vibrational pattern and deduce the relationship between the mass of an elementary particle and the vibrational energy of its representative string.

In Conclusion

Although string vibration patterns give rise to the distinct elementary particles, strings are different from point particles in many ways. One of the most important differences is that strings are one-dimensional (unlike point particles, which have zero dimensions), which allows strings to behave in a way that permits the unification of the four forces. In addition, string theory offers a conceptual framework for answering questions such as why matter and force particles exhibit their observed properties. Present theories currently do not provide this information.

www.pbs.org/nova/elegant/

A New Building Block?

NOVA Activity **The Elegant Universe**

Some physicists think there is a unit of matter more fundamental than the particles that have so far been detected. They call this new building block a string (named for its string-like appearance). One of the key features of strings is that they generate different vibrational patterns that may give rise to the properties of currently known elementary particles. But how is it possible that elementary particles like electrons and top and bottom quarks—which have different masses—can be made out of the same thing? Do this activity to find out.

Procedure

① Organize your group into the following roles:
- rope holder
- rope measurer
- rope twirler
- timekeeper

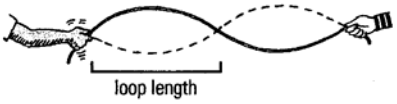
② Have the rope holder grip the rope in a fixed position. For the first trial to determine the fundamental frequency, have the rope twirler use the type of arm action used to twirl a jump rope.

③ Once the rope is twirling smoothly, the measurer should measure and record the loop length. Then the twirler should call, "start," and the timekeeper should use a watch to time 30 twirls. The timekeeper should record this time. The frequency of the rope is defined as the number of twirls per second. Use your calculator to determine this number.

④ Repeat the above procedure and average the times for the two trials. This is the Fundamental Frequency. Record the loop length, time for 30 twirls, and frequency per second in the *Rope Resonance Chart*.

⑤ Now twirl the rope again, but this time the rope twirler should twirl the rope using his or her wrist only. The twirler should increase the speed of twirling until the large single loop breaks into two opposing loops turning around a mid-point, called a *node*. Once the two loops are twirling smoothly, measure the loop length and time 30 twirls as before. Do this twice and average the times. Record this result and the loop length under the First Overtone column.

arm motion for the fundamental frequency



wrist motion for the first overtone

⑥ Repeat this process for a rope that generates three equal loops and record your results in the chart.

Questions

Write your answers on a separate sheet of paper.

① What happened to the length of a single loop as you twirled faster?

② Review your data. What happened to the frequency as you twirled faster?

③ How did the change in loop length compare to the change in frequency as you twirled faster?

④ How did your effort change as you twirled faster?

⑤ Is there more energy in a higher overtone or a lower overtone? If a fundamental string was like your rope, would there be more energy in a rapidly vibrating string or a slowly vibrating string?

⑥ How might a string represent an elementary particle like an electron differently than a more massive elementary particle like a top quark?

Rope Resonance Chart

	Loop Length (Feet or Meters)	Time for 30 Twirls (Sec)	Frequency (Twirls/Second)
Fundamental Frequency			
First Overtone			
Second Overtone			

Activity Answer

As students twirl the rope faster and faster, the original loop breaks into first two, then three, smaller loops. These loops are separated by steady nodes.

Students may notice that as the loop length decreases, the frequency increases. As students twirl the rope faster, the frequency increases roughly proportionally to the overtone number. You may wish to have students pursue the reciprocal relationship between loop length and frequency.

Explain to students that the frequencies they produce in their trials are based on several factors—the length of the rope, the tension of the rope during the trial, and the mass per unit length of the rope. Different ropes will have different mass per unit length. Therefore, student results will most likely differ from the sample results in the chart on the right.

Students will find that it takes increasing effort to twirl the rope to higher overtones and from this they may surmise that rapidly vibrating strings are more energetic than more slowly vibrating strings. Einstein's famous equation $E=mc^2$ shows that mass is a form of energy. A more massive particle has more energy when sitting still than a less massive particle. This relationship explains how a single unit—a string—can account for particles of very different masses. A more massive top quark would correspond to a more energetic string (a higher overtone) than a less massive electron.

Rope Resonance Chart: Sample Results

	Loop Length (Feet or Meters)	Time for 30 Twirls (Sec)	Frequency (Twirls/Second)
Fundamental Frequency	L = 10 feet (3.0 meters)	17 seconds	30 twirls ÷ 17 sec = 1.76
First Overtone	L/2 = 5 feet (1.5 meters)	12 seconds	30 twirls ÷ 12 sec = 2.50
Second Overtone	L/3 = 3.3 feet (1.0 meters)	7 seconds	30 twirls ÷ 7 sec = 4.28

Web Connection
See how resonance affects both an everyday cotton string and the tiny strings of string theory in *Resonance in Strings* at **www.pbs.org/nova/elegant/**

Deducting Dimensions

Activity Setup

Objective

To visualize a universe with fewer than three spatial dimensions and to consider how more than three spatial dimensions could exist in the universe.

Materials for each team

- class copies of the *Deducting Dimensions* activity sheet on page 21

Materials for each student

- copy of the book *Flatland: A Romance of Many Dimensions* by Edwin A. Abbott (New York: Penguin Books, 1998); see original 1884 version at **nedwww.ipac.caltech.edu/level5/Abbott/Abbott_contents.html**

Procedure

1. Have students read parts or all of *Flatland* by Edwin Abbott, which provides an account of what life would be like in Flatland, where the inhabitants are all geometric shapes living in a two-dimensional world. This reading will give students an image of a universe with fewer dimensions. You may want to have students start at *Part 2: Other Worlds*, which describes the nature of one-, two-, and three-dimensional worlds.
2. Organize students into teams and distribute the *Deducting Dimensions* activity sheet.
3. Have teams record the answers to the five bulleted questions for the one- and two-dimensional universes they are imagining. Have teams also record any additional observations or realizations about these universes. Once they have finished, have teams answer the two questions listed on the activity sheet.
4. When students have completed the activity, have teams report their results. As students consider the perspectives of inhabitants in a world with fewer dimensions, discuss with them that these inhabitants would not likely be able to comprehend a three-dimensional world, even though one exists. Point out to students that just as the inhabitants of those universes would have difficulty picturing extra dimensions, so it could be for inhabitants of our world.
5. Discuss the idea of an additional six or seven spatial dimensions with students (different string theories assume a different number of added dimensions). Students may wonder where these extra dimensions are and why they cannot see them. Explain to students that some physicists believe these extra dimensions occur at every point in the universe but are extremely tiny and curled up. They are so tiny that they cannot be detected, even with the most sophisticated research equipment.

   To help students visualize this, you may want to have them imagine how various three-dimensional objects (such as a telephone cable or a clothesline) can seem at a distance like they are one-dimensional (a line that can be traversed back and forth). In these cases, two dimensions (side-to-side and up-down) appear hidden, just as the added six or seven dimensions in string theory appear hidden from view. (See page 3 for an illustration of this concept.)

Background

String theory is elegant in a number of ways: it accounts for both quantum mechanics and general relativity, it may have the potential to describe the elementary particles that make up matter and carry forces, and it provides a mechanism by which the four forces can be unified. For these reasons, supporters of string theory are willing to take on a daunting proposition—that the universe is not actually made up of the four commonly experienced spacetime dimensions, but may contain 10—perhaps even 11—spacetime dimensions. Without these additional spatial dimensions, the equations in string theory just don't work. This activity first calls for students to imagine a world of fewer dimensions before considering the idea of additional ones.

In Conclusion

Some physicists think that added spatial dimensions may take on incredibly complex forms known as Calabi-Yau shapes. *How* the dimensions are curled up, which physicists have not yet determined, may establish the properties of elementary particles. Taking a different tack, a few theoreticians propose that the extra dimensions may be very large, even infinite, but cannot be seen because all matter, as well as light, is trapped within the dimensions of our universe; matter from other universes would appear dark to us. In this theory, gravity is the only thing that escapes, leading some physicists to suggest that this would explain why gravity is by far the weakest of the four forces.

Deducting Dimensions

NOVA Activity **The Elegant Universe**

You experience daily life in three spatial dimensions (and one dimension of time). You move forward and backward, step left and right, and go up and down stairs as you move around your world. But string theory requires that you live in a world with an additional six or seven spatial dimensions. Without these extra dimensions, the equations in string theory don't make sense. But even physicists who think about these extra dimensions every day have a hard time picturing them. One way they improve their mental picturing ability is to work backward and imagine a world with *fewer* than three dimensions. See if you can imagine a universe with only one, and then two, dimensions.

Procedure

① To the right is a set of questions for each universe to get you started. See if you and your team members can answer the questions first for a one-dimensional universe and then for a two-dimensional universe.

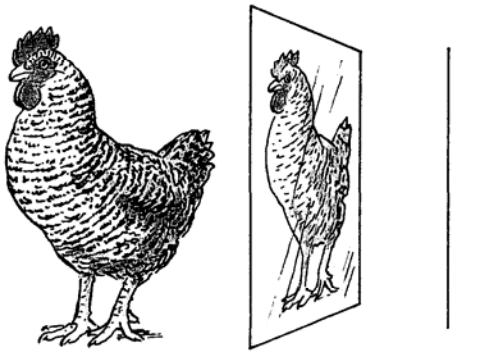
② As you explore each universe, try to imagine what life would be like in that universe.

One-Dimensional Universe

This universe is like a line with no ends. It has no up and down or left and right, only a forward and backward that go on forever. Remember that it is not like a wire stretched across a room within a three-dimensional space. There is no outside room; wire is all there is, just forward and backward.

Two-Dimensional Universe

This universe is like a flat sheet of paper that goes on forever. Unlike the wire, this universe has a forward and backward and a left and right. What this universe does *not* have is an up and down.



3-D Chicken **2-D Chicken** **1-D Chicken**

Questions for each universe:

- What is the shape of a creature that inhabits the universe?
- How would one creature appear to another? If the creatures are able to move around one another, how would they appear to one another if they were lines? If they were rectangles? If they were circles?
- What path would a creature take as it moved?
- How could creatures communicate?
- What kind of social structures might exist?

Questions

Write your answers on a separate sheet of paper.

① How many creatures can a given creature communicate directly with in each universe, assuming that they must be in nearly direct contact with one another to do so?

② Suppose a message needs to be passed to 64 creatures. Assuming that one creature can only communicate with one other creature at a time and that each message takes one minute to transmit, what is the shortest amount of time that a message could be passed in a one-dimensional world? How would the transmission occur? What about in a two-dimensional world?

Activity Answer

In a one-dimensional universe:

- Creatures would have the form of a very thin worm, or a point-like dot.
- These creatures could not pass each other because that would require a second dimension. So one creature could only see the dot-like end of the next creature in front of or in back of it.
- These creatures could only move forward until they bumped into the creature in front of them and backward until they bumped into the creature behind them.
- These creatures could only pass messages from one to another down the creature line (like in the game "Telephone").
- Social structures would be limited to some number of inline-communicating creatures. There might only be one large group, or any number of smaller inline groups.

In a two-dimensional universe:

- Creatures could have any shape—such as a square, triangle, or circle—that is flat like a drawing.
- Creatures would have both length and width, but not height.
- One creature seeing another would see its companion as a line and discern the other creature's shape by viewing the other creature from various angles.
- Creatures could move in any direction in their flat universe, but because there is no up and down dimension, they would have to move around each other.
- As one creature moves around another, it could see the apparent length (or size) of the creature change (unless the other creature is circular).
- Any creature could pass a message to any other that it could move to.
- Any number of social structures would be possible: singles, tribes, or larger groups. The larger the group, the longer it would take to get a message from one creature to another.

Assuming that nearly direct contact is needed to communicate, in a one-dimensional world, a creature could only communicate with another creature that is either directly in front of or in back of it. In a two-dimensional world, if a creature is long and thin, it could arrange itself with others like it in a group like the spokes of a bicycle wheel so that any creature could communicate with any other across the center (see Figure 1).

Wider—or myriad long, thin creatures—could arrange themselves in a ring, but would have to pass messages from creature to creature around the ring. This loss of group contact would always occur at some number of members within a cluster. The narrower the creature, the more creatures that can remain in direct contact within a cluster.

In a one-dimensional world, the fastest way to communicate a message to 64 creatures would be for the creature in the middle first to tell the message to a creature on one side, and then to the creature on the other side. These creatures would then relay the message to the next two outside creatures, who would relay it to the creatures outside of them, and so on, down each side of the line. The process would take 32 minutes. In a two-dimensional world, the starting creature would transmit a message to a second creature. The first and second creature, then, would transmit a message to a third and fourth creature. Then all four creatures would transmit the message to four more creatures. This exponential transmission would continue for six minutes, at which time 64 creatures would have heard the message.

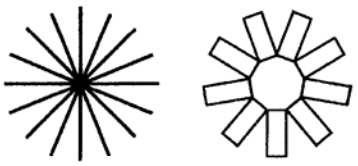


Figure 1. Narrow and wide creature clusters

Web Connection
Get some help in picturing a world of more than three dimensions in *Imagining Other Dimensions* at
www.pbs.org/nova/elegant/

Exploring the Unknown in the 21st Century

There are 20 fundamental characteristics in nature. If these characteristics were changed or different in any way our universe would not be as we know it.

In 1985 the Sting Theory became popular among physicist in the quest to find the beginning of the universe and the **Theory of Everything.** But it lost steam after 5 versions of the theory were developed and physicist abandoned the theory.

In 1995 however, a scientist named Ed Witten came up with a new perspective of looking at these 5 versions and found they were just 5 different ways of looking at the same thing so he united these 5 versions into one; **The M-Theory**.

Scientists have developed theories of how things began for centuries. Einstein developed the **Theory of Relativity** explaining how gravity worked. Newton developed **Quantum Mechanics.** These two theories tend to contradict each other so that is what motivated physicists to search for a theory that explains everything.

Taking a look at our universe through the eyes of a *String physicist.* Scientist are taking what we already know and have proven and striving to go beyond.

The speed limit of the Universe is **Light**, which is identified with the letter **c**.

The basic concepts of String Theory:

1. 11 dimensions (Parallel Universes)
2. Rather than point partials, elements are made of strings

Atom

Protons - Neutrons - Electrons

Quarks

Strings

M - Theories extra Dimensions

11 Dimensions

The 4 dimensions that we see

1. left - right
2. up - down
3. back forth
4. Time

Movies are 2 dimensional; there is no back - forth.

Dimensions are degrees of freedom.
The more dimensions, the more you can do.

M-Theory Physicists believe there are more dimensions than we can see. They think there may be Parallel dimensions.

Example: Picture your life inside a loaf of bread. Our universe is one slice of bread and we have neighbors inside the other slices. They may only be millimeters away but our atoms can not leave the slice of bread we are on and neither can those on another slice. Our atoms never collide so we are unaware of each other. These slices of the loaf of bread physicists call membranes or **"Branes".**

The structure of strings

Strings can either be open ended or closed like a rubber band.
These strings vibrate like those on a cello. Depending on where you place your fingers, you get a variety of sounds from different vibrations. Strings vibrate in various ways also. All the different vibrations are what give characteristics to all the partials of nature.

Stings are smaller than Protons, Neutrons, and electrons. If you look at a proton as being the size of our universe, a string would only be as big as a tree on our planet.

Strings view of the Big Bang

How does string explain the beginning of the universe?

String theory states that the Big Bang was not the beginning of everything but just the beginning of our universe.

Those parallel universes, or "Branes" drifted toward each other and collided and **BANG** our universe was created.

String theory doesn't see this as a special event, but rather an event that happens over and over again.

Would you consider String to be a scientific theory?

How will scientist test this theory?

Today research is continuing at a laboratory called **Fermilab.**
They are in search of a partial called a **Spartical**. If the String theory is correct these subatomic units should exist. Scientists estimate that it will be 10 - 20 years before we have the technology to create an **"Atom Smasher"** that can look for these sparticals.

No Sparticals = the conclusion will prove String Wrong
And the conquest for the complete story will continue.

Name _____ Period _____ Date _____

Video Observation Sheet

Directions:

1. ***Observe the Movie***, pay close attention to detail.
2. During the movie you will be ***making observations*** regarding information that you have learned throughout this chapter.
3. You are required to ***complete a modified summary sheet***, during the video.
4. After watching the video you are going to ***write a summary*** explaining the concept of the movie, at least 4 Sentences. Be Specific!

Title: _____

What is the main idea of the video? _____
_____
_____
_____

Name 2 concepts that you already knew before watching the video:
_____
_____

Name 4 *NEW* concepts that you became aware of *AFTER* watching the video:
_____
_____
_____
_____

State 2 interesting facts that you learned since observing this video: Give examples if necessary! _____
_____
_____
_____

After watching the video ***write a summary,*** on a separate sheet of paper explaining the main concepts of the movie, at least 4 Sentences. Be Specific!

Works Cited

Crick, Francis (1981), *Life Itself* (New York: Simon & Schuster).

Davies, Paul (1980), *Other Worlds* (New York: Simon & Schuster).

Dobzhansky, Theodosius, F.J. Ayala, G.L. Stebbins, and J.W. Valentine (1977), *Evolution* (S. Francisco: W.H. Freeman).

Dyson, Freeman (1979), Disturbing *the Universe* (New York: Harper & Row).

Hoyle, Fred (1978), *Lifecloud* (New York: Harper & Row).

Hoyle, Fred (1981), "Hoyle on Evolution," *Nature*, 294:148, Nov. 12

Jastrow, Robert (1997), "What are the Chances for life?," [review of The *Biological Universe*, Steven J. Dick (London, England; Cambridge University Press, 1996, 578 pp.].

Leonard, Jonathon N. (1984), "Other Worldly Life," *The Sacred Beetle*, ed. Martin Gardner (NY: Prometheus; essay originally published in 1953).

Naeye, Robert (1996), "OK, Where are They?", *Astronomy*, 24:42-43, July

Orgel, Leslie (1982), "Darwinism at the Very Beginning of Life," *New Scientist*, pp. 149-152, Nov. 15

Overbye, Dennis (1992), "Is Anybody Out There?," *Time* [special issue], Fall

Ridpath, Ian (1975), *Signs of Life* (New York: Penguin).

Rowan-Robinson, Michael (1980), "The Infrared Landscape," *New Scientist*, Jan. 31.

Schwartzman, David, and Lee J. Rickard (1988), "Being Optimistic about the Search for Extraterrestrial Intelligence," *American Scientist*, 76:364, July/Aug.

Shostak, Seth (1997), "When E.T. Calls Us," *Astronomy*, 25:37, Sept.

Sobel, Dava (1992), "Is Anybody Out There?," *Life*, 15[9]:67 Sept.

Tauber, G.E. (1979), *Man's View of the Universe* (New York: Crown)

Twain, Mark (1883), *Life on the Mississippi* (Boston, MA: J.R. Osgood

Works Cited

Doesn't science disprove Christianity.... 14 May 2002. 22 Mar. 2005 <http://www.gracecommunity.info/discus/messages/8/18.html?1106085109>.

Drum, Kevin. Political Animal. 20 Apr. 2004. 22 Mar. 2005 <http://www.washingtonmonthly.com/archives/individual/2004_04/003740.php>.

Elegant Universe, The: Einstein's Dream. Apr. 2004. NOVA. 22 Mar. 2005 <http://www.pbs.org/wgvh/nova/teachers/activities/3012_elegant_03.html>.

Glashow, Sheldon. Viewpoints on String Theory. July 2003. Boston University. 22 Mar. 2005 <http://www.pbs.org/wgbh/nova/elegant/view-glashow.html>.

Groleau, Rick. Imagining Other Dimensions. July 2003. 22 Mar. 2005 <http://www.pbs.org/wgbh/nova/elegant/dimensions.html>.

Peet, Amanda. Viewpoints on String Theory. July 2003. University of Toronto. 22 Mar. 2005 <http://www.pbs.org/wgbh/nova/elegant/view-peet.html>.

Quammen, David. "Was Darwin Wrong?" National Geographic Nov. 2004: 4-31.

Works Citied

Report on Comments on Proposed Modifications to Draft of Ohio Science Academic Content Standards Tenth Grade, Life Sciences Section. 4 Feb. 2004. Intelligent Design Network. 22 Mar. 2005 <http://www.intelligentdesignnetwork.org/OhioPoll.htm>.

Richards, Jay. Intelligent Design. 24 Dec. 2004. 22 Mar. 2005 <http://www.searchforthechurch.org/interest1.htm>.

Teaching Resources. Jan. 2005. 22 Mar. 2005 <http://www.intelligentdesignnetwork.org/TeachingResources.htm>.

The Big Bang Theory. 2 Dec. 2005. 15 Apr. 2005 <http://ligtoff.msfc.nasa.gov/academy/university/b_bang.html>.