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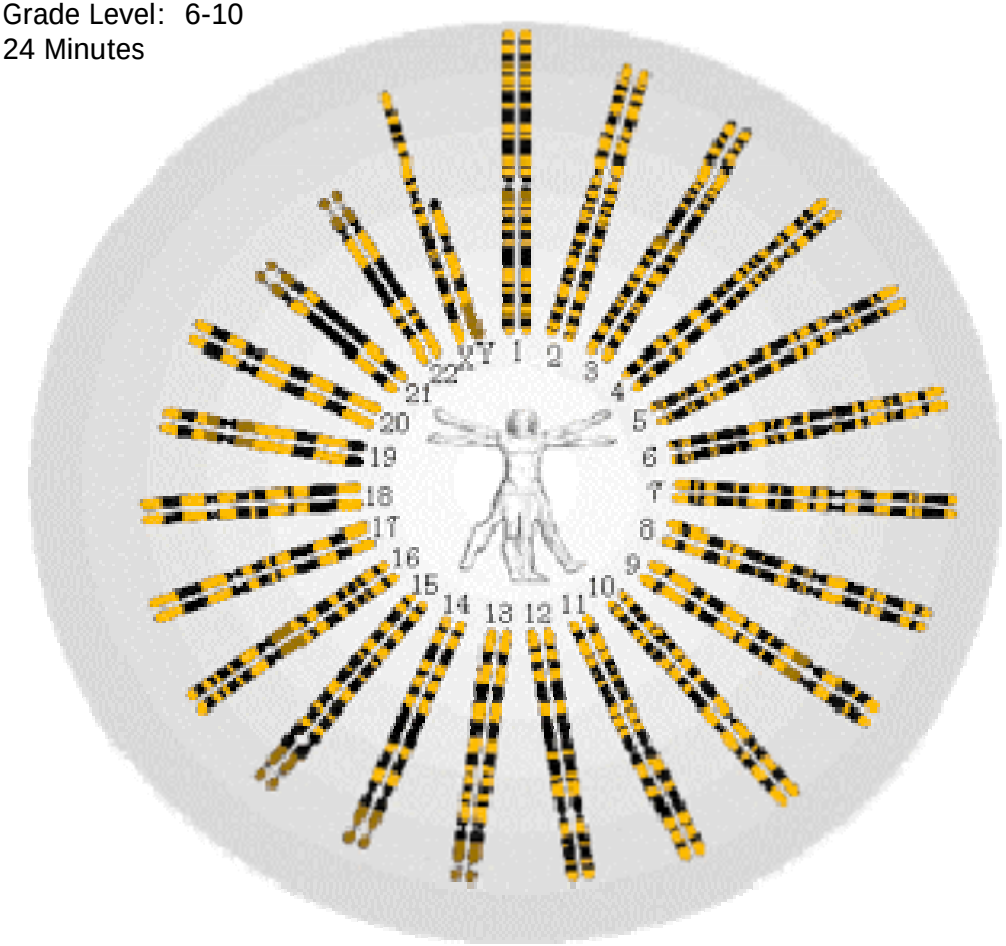
#10395
GENES, GENETICS & DNA

RAINBOW EDUCATIONAL MEDIA, 2003
Grade Level: 6-10
24 Minutes



CAPTIONED MEDIA PROGRAM RELATED RESOURCES

#3389 PATTERNS OF INHERITANCE: UNDERSTANDING GENETICS
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PRINCIPLE CREDITS

Producer, Writer & Director:	Peter Matulavich
Consultants:	Roger V. Skibbens, Ph.D Dept. of Biological Sciences, Lehigh University
	Stuart Schwartz, Ph.D Christine Curtis, Ph.D Center for Human Genetics Laboratory University Hospitals of Cleveland
	Michael Worosz, M.A. Curriculum Consultant
Videography, Animation & Editing:	Peter Matulavich
Special Thanks To:	Center for Human Genetics Laboratory, University Hospitals of Cleveland, Dr. Stuart Schwartz, Director
	Miller South School for the Visual and Performing Arts, Margo Snider, Principal

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Peter Matulavich Productions
Akron, Ohio

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SUMMARY

Each of us is a combination of traits passed down to us from our parents. To find out how this occurs, we can look to the first life forms to appear on earth -- organisms consisting of a single cell that resemble modern day bacteria. While bacteria are relatively simple, they are able to make exact copies of themselves. The instructions to do this are found on their single chromosome. There are hundreds of separate bits of information on the chromosome which are referred to as genes.

When bacteria and other single-celled organisms reproduce, they make exact copies of themselves because these organisms have only one parent. The same genes are passed down generation after generation.

Most multi-cellular organisms need two parents in order to reproduce and because of that, their offspring share the genes of both parents but are not identical to either one.

Multi-cellular organisms reproduce during a process called fertilization when a male's sperm cell joins a female's egg cell. Human sperm and egg cells each have 23 chromosomes and when they join, a new cell is created, called a zygote, with 23 pairs of chromosomes. The single zygote reproduces itself in a process called mitosis. The result is two identical cells, each with 46 chromosomes. These cells reproduce themselves and so on and so on, eventually creating a new individual with countless unique traits.

The traits individuals inherit from their parents are done so according to rules first discovered by Gregor Mendel. One rule is that an individual carries two factors, or genes, for each trait, but passes down only one. Another rule is that one of the factors, or genes, is dominant over the other.

Punnett squares, a type of diagram, can be used to help predict what traits offspring are likely to inherit from their parents.

The secret to how chromosomes carry the blueprint of life from generation to generation is found in the substance of which chromosomes are made: deoxyribonucleic acid, or DNA for short. The DNA molecule resembles a twisted ladder, the rungs of which are formed of four chemical bases: adenine, thymine, guanine, and cytosine. It is the way these bases are arranged that determine the characteristics of a life-form. Since a DNA molecule has millions of rungs, countless combinations are possible.

Knowledge of DNA has led to incredible breakthroughs in the fields of genetic engineering, agriculture, farming, medicine, and gene therapy.

OBJECTIVES

After viewing this video, students should know:

- how traits are passed down
- what genes are
- what chromosomes are
- why single-celled organisms reproduce exact copies of themselves
- why multi-cellular organisms seldom reproduce exact copies of themselves
- the importance of sperm and egg cells
- what fertilization is
- how many human chromosomes there are
- what a zygote is
- Mendel's rules of heredity
- what a Punnett square is
- what dominant and recessive traits are
- what DNA is
- what genetic engineering is

REVIEW QUESTIONS

1. What is it called when an egg cell joins a sperm cell?

Fertilization

2. How many chromosomes does a bacterium have?

One

3. How many chromosomes are found in human egg and sperm cells?

Twenty-three in each

4. How many chromosomes does a human zygote have?

Two pairs of 23 chromosomes

5. Where are chromosomes found in multi-cellular organisms?

Within the nucleus of each cell

6. How many sperm cells are permitted to penetrate an egg cell?

One

7. What is another name for cell division?

Mitosis

8. Who was the Austrian monk to discover the rules of heredity while working with pea plants?

Gregor Mendel

9. What is a dominant trait?

A trait that has more power or influence over another.

10. What do you call an organism that possesses two dominant or two recessive genes for a single trait?

Purebred

11. What do you call an organism that possesses one dominant and one recessive gene for a single trait?

Hybrid

12. What do you call the type of diagram that assists you in predicting the traits of offspring?

Punnett square

13. What are chromosomes made of?

Deoxyribonucleic acid

14. What woman, along with Francis Crick, James Watson, and Maurice Wilkins, is credited with helping to discover the structure of DNA?

Rosalind Franklin

15. What are the initials of the four chemical bases found in DNA?

A, T, G and C

16. What is it called when a DNA molecule reproduces itself?

Replication

17. What do you sometimes call the special images showing an organism's sequence of DNA bases?

A DNA fingerprint

18. How many genes do humans have?

More than 30,000

19. What do you call it when scientists change the genes that line a DNA molecule?

Genetic engineering

20. What is the process called where abnormal genes are replaced with healthy ones?

Gene therapy

ACTIVITIES

These activities are designed to encourage students to learn more about some of the things covered in the video.

1. Have students draw and color pictures of a human cell showing the nucleus and the chromosomes within it.

2. Have students create a DNA molecule by pasting strips of colored art paper together in the shape of a twisted ladder.

3. Have students research and report on one of the following important figures in the field of genetics: Gregor Mendel, Rosalind Franklin, James Watson, Francis Crick, or Maurice Wilkins.

4. Have students report to the class the traits they inherited from their parents.

GLOSSARY

adenine: one of the four chemical bases that make up DNA.

bacteria: the smallest and simplest single-celled organisms; some cause disease

cell: the basic unit of which all living things are composed.

chromosome: structures that carry the genes that pass on traits

Crick, Francis: English scientist credited with co-discovering the structure of DNA.

cytosine: one of the four chemical bases that make up DNA.

deoxyribonucleic acid: see DNA

DNA: the substance of which chromosomes are made.

dominant trait: a trait that has more influence over another.

egg cell: specialized female cell possessing all the female's chromosomes

fertilization: the process during which a male sperm cell and female egg cell are joined.

Franklin, Rosalind: English scientist whose work, largely uncredited until recently, helped lead to the discovery of the structure of DNA.

gene: a portion of a chromosome that carries the traits of an individual.

gene therapy: the science of replacing abnormal genes with normal ones.

genetic engineering: the science of altering the genes of organisms

guanine: one of the four chemical bases that make up DNA.

Human Genome Project: a project involved in identifying all the genes of humans.

hybrid: an organism that carries both a dominant and recessive gene for a particular trait.

mitosis: a type of cell division where a single cell separates into two.

molecule: the smallest unit of an element or compound.

nucleus: the control center of a cell.

offspring: the children of a particular parent.

Punnett square: a diagram used to help predict the traits of offspring.

purebred: an organism possessing either two dominant or two recessive genes for the same trait.

recessive trait: a trait that is hidden.

replication: the splitting and duplication of a DNA molecule.

sperm cell: specialized male cell possessing all the male's chromosomes

thymine: one of the four chemical bases that make up DNA.

trait: a specific characteristic or quality of an organism.

Watson, James: American scientist credited with co-discovering the structure of DNA.

Wilkins, Maurice: English scientist credited with co-discovering the structure of DNA.

zygote: the cell produced by the joining of a sperm and egg cell.

WEBSITES

The following list includes some of the best websites devoted to genetics.

DNA from the Beginning
http://www.dnaftb.org
Funded by the Josiah Macy, Jr. Foundation, this site is an in-depth animated primer on the basics of DNA, genes, and heredity.

Genetics Science Learning Center
http://gslc.genetics.utah.edu/
Dedicated to helping people understand how genetics affects their lives and society, this site is sponsored by the Eccles Institute of Human Genetics at the University of Utah.

Genetics Education Center
http://www.kumc.edu/gec
Sponsored by the University of Kansas Medical Center, this site is devoted to educators interested in human genetics and the human genome project.

SUGGESTED READING

The following books are recommended for younger and intermediate readers.

Evolution
by Linda Gamlin
Dorling Kindersley, 1993

Genetic Engineering
by Jenny Bryan,
Thomson Learning, 1995

How Did We Find Out About Genes?
by Isaac Asimov
Walker and Company, 1983

The History of Genetics
by Robert Snedden
Thomson Learning, 1995

They Came from DNA
by Billy Aronson
W. H. Freeman and Company, 1993

SCRIPT

Girl
Can you wiggle your ears?

Boy
Jiggle your eyes?

Girl
Do your fingers bend in strange ways?

Boy
And what about your arms?

Girl
Can you make your knuckles dance?

Narrator
Not everyone can do these things. Whether or not you can is all determined by your genes. To find out how, let's learn more about genes, genetics, and DNA.

Each of us is a unique individual, from the color of our hair and eyes, to the shape of our lips. How is it that no two of us is exactly alike? That's because each of us is a combination of traits passed down to us from our parents. How does that happen? To find out, we have to go back billions of years. . .to the first life forms to appear on earth.

Boy
Those look like bacteria.

Narrator
They are, and the first life forms were similar to modern day bacteria -- tiny microscopic organisms each consisting of a single cell.

Boy
Aren't all living things made up of cells?

Narrator
Right, and bacteria are the smallest, simplest cells. Yet as simple as they are, they are able to perform one remarkable feat. Can you guess what that is?

Girl & Boy
Multiply!

Narrator
That's right. They are able to make exact copies of themselves one after another, after another.

Girl
How do they know how to do that?

Narrator
To find out, let's split this model of a bacterium in two. The inside of a bacterium is filled with a jelly-like fluid.

Located within this fluid is a thin ribbon-like loop called a chromosome, shown here in red.

The chromosome carries information controlling all the cell's activities, including reproduction. There are hundreds of separate bits of information on the chromosome. They are referred to as genes.

Boy
So when a bacterium reproduces, it is actually following hundreds of separate instructions, or genes.

Narrator
That's right.

Girl
They all look identical.

Narrator

They are. That's because they have only one parent. The same is true for other single-celled life forms, like these microscopic pond organisms. They have only one parent. The same genes are passed down generation after generation. That's why all of these organisms are identical.

But look at these kittens.

Boy & Girl

Aw, they're cute.

Narrator

They're from the same litter, yet they're all different. They have different colors and different markings. That's because they have two parents and share the genes of both.

Single-celled organisms need only one parent to reproduce.

But most multi-cellular organisms, that is, organisms with many cells need two parents in order to reproduce. Multi-cellular organisms include just about every plant and animal you're familiar with, including insects.

You've probably seen insects connected at their abdomens.

Boy & Girl

Sure.

Narrator

This is how many insects mate.

In this example, the male mantis inserts a special organ into the female and injects a fluid into her abdomen. The fluid contains specialized cells called sperm.

The female has specialized cells of her own. They're called eggs.

When an egg cell is joined by a sperm cell, it will develop into a new being, in a process called fertilization.

These are human sperm cells. They're extremely small and can be seen only under a powerful microscope. The cell's nucleus is found in the head of each sperm.

Girl

Nucleus? That's like the cell's control center, right?

Narrator

Right.

Since sperm cells are so small, we'll use these models to show them better. All of the male's genes are contained in each cell.

Boy

Where are they?

Narrator

They're found here in the head, on its chromosomes, inside the cell's nucleus. There are 23 chromosomes in all and all the male's genes are contained on those chromosomes.

Human egg cells also have 23 chromosomes. Males produce many sperm cells, and each seems to race to reach an egg. But only one will be permitted to penetrate an egg.

When a sperm cell is successful, the 23 chromosomes of the male sperm cell join the 23 chromosomes of the female egg cell, creating a new cell with 23 pairs of chromosomes.

Girl
For a total of 46 chromosomes.

Narrator
The fertilized egg cell is called a zygote.

Boy
So how does a single zygote become an entire organism?

Narrator
By reproducing itself, in a process called cell division. This type of cell division is called mitosis. You end up with two identical cells.

Girl
Each with 46 identical chromosomes.

Narrator
Then, these cells will reproduce themselves, and so on, and so on. These are just models of cells.

This is a real cell. It belongs to a salamander and it's about to undergo mitosis. Watch what happens to this thin line here. It's a membrane that surrounds the nucleus.

Boy
It disappeared.

Narrator
It's one of the first stages of mitosis.

Girl
What are those things that look like worms?

Narrator
Those are the chromosomes. They've recently duplicated and they're moving to the center of the cell.

Boy
They look like they're lining up.

Narrator
That's exactly what they're doing. They're getting ready for one of the most important parts of mitosis. Now watch closely. . .as the chromosomes seem to pull apart, almost like taffy, and move to opposite ends of the cell.

Girl
Neat.

Narrator
Finally, the cells separate.

Boy
And you end up with two identical cells.

Narrator
Your height, the shape of your nose, your complexion, everything that makes you a unique individual, are all passed down to you from your parents. These are all referred to as traits.

Girl
But what determines which traits will be passed down?

Narrator
That was the same question asked by Austrian monk, Gregor Mendel, more than a hundred years ago, and he decided to find the answer. Working with pea plants, Mendel learned several important rules about heredity.

One was that an individual carried two factors, or genes, for each trait, but passed down only one.

Another rule was that one of the factors, or genes, was dominant over the other.

Boy

Dominant?

Narrator

That means it has more influence or power over the other.

Let's use a simple example to explore these rules. If this black rabbit and white rabbit were to mate, what color do you suppose their offspring would be?

Girl

I don't know. Black?

Boy

Maybe white.

Girl

How about gray?

Narrator

No need to guess. To find out, we'll use a simple diagram called a Punnett square. We'll assume there will be four offspring, one for each square. One. Two. Three. And four.

Next, we'll put the black rabbit here on the left. . .and the white rabbit on top.

According to the rules discovered by Mendel, we know that each rabbit carries two genes that control color. Let's say the black one is purebred for black.

Girl

Purebred?

Narrator

That means both of its genes are black. We'll refer to them as capital f, capital f. F is for fur.

The white rabbit is also purebred. That means that both of its genes are white. We'll refer to them as small f, small f.

Boy

Which genes will the offspring inherit?

Narrator

Since the black rabbit carries only two black genes, capital f, capital f, it can only pass down a black gene to each of the four offspring.

Since the white rabbit carries only two white genes, small f, small f, it can only pass down a white gene.

Each of the four offspring end up with both a black gene and a white gene. But each will be black, because black is dominant.

They may look exactly like the black parent, but there is a big difference. These offspring are no longer purebred but are now called hybrids. They carry both a white gene and a black gene. The black trait is dominant, and the white trait is recessive.

Girl

Recessive?

Narrator

That means it's hidden.

Boy

Well, what would happen if two hybrid rabbits were to mate.

Narrator

Let's do another diagram using a Punnett square.

This offspring will receive a black gene from the parent on the left, and a black gene from the parent on

top. It will end up capital f, capital f, and will be pure-bred black.

This offspring will get a black gene from the parent on the left and a white gene from the parent on top. It will end up capital f, small f, but will be black because black is dominant.

This offspring will end up with a white gene from the parent on the left, and a black gene from the parent on top. It will end up small f, capital f, but will be black because, again, black is dominant.

Finally, this offspring will end up with a white gene from the parent on the left and a white gene from the parent on top. What color will it be?

Boy
It has only white genes, so it has to be white.

Narrator
Good. Now, which offspring gets which gene is completely up to chance. All we know for sure is that about one in four will be white.

None of the rabbits will be gray by the way, because in this example, these traits are not blended.

The same rules of inheritance apply to many of the traits of all plants and animals. If you were to cross hybrid purple corn with hybrid yellow corn, what would be the result?

Girl
That would depend on which color is dominant.

Narrator
Right! And since purple is dominant, the ears would have kernels that are about 75% purple and 25% yellow. Three to one.

So far we've only talked about a single trait, color. But all plants and animals inherit thousands of separate traits from their parents. Thousands of separate instructions that help determine what. . .and who. . .we will become, from the way we look, to our talents and natural abilities.

Boy
Talent is inherited?

Narrator
If you're good in sports, music, or art, chances are you inherited that talent from your parents.

These three girls are triplets and each is an accomplished musician, just like their mother..

But even though you inherit talent, you still have to learn how to use it, and that's why hard work, dedication and training are so important.

Mrs. Julie Hogarth is a teacher at Miller South School for the Visual and Performing Arts in Akron, Ohio.

Mrs. Hogarth
Many children inherit certain characteristics and talents, but part of what Miller South is here to do is to teach the children how to use those talents, and one of the ways we teach them is to fine tune and teach them the skills to use their talents. When you first start learning to play the piano, you learn the notes. When you first start learning to paint, you learn about color. Those are skills that are fundamental that we build from. Although often times talent is passed down, skills aren't passed down and must be developed, and that's one of the things we work on here at Miller South.

Narrator
So much is determined by our genes, even whether you

can wiggle your ears, jiggle your eyes, or bend your arms in strange ways, all of which are a result of inheriting two recessive traits, by the way.

Girl
How is it possible for so many instructions to fit inside every human cell?

Narrator
Good question! For many years, chromosomes were something of a mystery. We knew that they were made of deoxyribonucleic acid.

Boy
De-ox. . .what was that?

Narrator
Everyone calls it DNA for short.

Girl
That I can pronounce.

Narrator
We knew that DNA carried our genes from one generation to another. What we didn't know was what DNA looked like, or how it worked. That wouldn't come until the 1950s, when scientists Rosalind Franklin, Francis Crick, James Watson, and Maurice Wilkins, found the answer that unlocked the secrets of DNA.

Finally, we were able to look deep inside the cell, into the nucleus, into the chromosomes themselves, to see exactly how DNA carried the blueprint of life from generation to generation.

This is a model of a DNA molecule.

Boy
Kind of looks like a ladder.

Narrator
It does, but this ladder is twisted.

The rungs of the ladder are formed of four chemical bases that may be arranged in a wide variety of ways.

We may refer to the four bases as A, for adenine, T, for thymine, G, for guanine, and C, for cytosine.

You will only find A joined with T, and G joined with C.

It is all in the way these chemical bases are arranged that determine the characteristics of a life form.

Girl
Four bases don't seem like very many.

Narrator
No, but remember that a DNA molecule has millions of rungs, so there are nearly endless combinations possible.

And it's the way they are arranged that determines every one of our traits and make us unique individuals.

In fact, they determine whether or not organisms become. . .amoebas. . .or zebras. Lions. . .or dandelions.

DNA also holds the secret to how chromosomes are able to make exact copies of themselves in a process called replication that occurs just prior to cell division.

It is during replication that the DNA molecule splits down the center of the ladder. As it splits, additional bases are called in from the cell nucleus. The bases attach themselves to the sides of the split ladder in the same way they were in the original molecule. The result will be two identical DNA molecules. With this

knowledge, scientists are now able to do what was thought impossible just a short time ago.

They are now able to remove a gene from a DNA molecule, and replace it with another in a process called genetic engineering.

Genetically engineered bacteria are being used to make drugs to treat disease.

Farmers are now using genetically engineered bacteria to help fertilize their fields.

Genetically engineered crops like cotton and corn grow bigger and better.

Genetically engineered salmon grow three times faster than normal ones. With more animals and crops like these, we could wipe out starvation throughout the world.

Genes and DNA molecules are difficult to see, but scientists are able to identify them by using special images. These so-called DNA fingerprints show the genes that line a DNA molecule. Researchers have already identified all the genes that make up a variety of organisms, including humans.

Boy
How many genes do we have?

Narrator
As a result of the Human Genome Project, we learned that each of us has more than 30,000 genes. We also know where they are located on each of our 46 chromosomes.

This knowledge has led to major breakthroughs in medicine, because just about every disease we know of is influenced by abnormalities in a person's genetic makeup.

At labs like this one, tests are being done on human tissue to help doctors and their patients make important medical decisions -- even about conditions that may not become apparent for months and years.

Here, human cells are being examined to determine whether there are any problems in their chromosomes or DNA.

Powerful microscopes are used to visually inspect the chromosomes themselves.

Technician
In this test we're looking at abnormal chromosomes in order to find something that might be missing, something that might be added, anything that will tell us what's wrong with our patient. For example, sometimes chromosomes switch material, so that one part of one chromosome is on the other part of the chromosome, and that can be a big problem.

Narrator
The lab also analyzes DNA for abnormalities. In order to do this, the DNA must be removed from cells, in this case from blood cells.

Technician
When we analyze your DNA, we take a blood sample and blow apart the white blood cells. We purify the DNA from that, and we might use a technique called sequencing which breaks down your DNA into the very specific base pairs or chemicals that make up the DNA ladder. After that, we'll compare that to a normal sequence and look for the little mutations or mistakes that may be in there that might explain why someone has a condition or might be at risk for a condition.

Narrator
By finding out about medical problems early on doc

tors and their patients are better equipped to make important decisions including treatment considerations. So far, labs like these are only able to identify abnormal genes. In just a few years, they hope to be able to replace bad genes with good ones.

Dr. Schwartz
What our lab does is to diagnose genetic disorders. The hope is that in the future that for the single gene defects that are diagnosed that gene therapy will be able to be used to cure them.

Narrator
Gene therapy is a type of genetic engineering and involves the removal of a problem gene and replacing it with a healthy one. This therapy may save millions of lives in the future.

Girl
Genetic engineering really sounds great.

Narrator
It can be, but we should be careful. Some people are worried that the medicines we create to fight disease might have a serious side effect of which we're not yet aware.

And others wonder whether genetically engineered food is completely safe to eat.

And others think it's just not a good idea to change a person's genes.

Boy
Should we be concerned?

Narrator
Most scientists think the benefits of genetic engineering outweigh the risks. So what have we learned?

Girl
We've seen that the traits of organisms are passed down from generation to generation through genes.

Boy
And that the genes are found on the chromosomes within every cell.

Girl
When single-celled organisms like bacteria and protozoa reproduce, they make exact copies of themselves because they have only one parent.

Boy
When multicellular organisms reproduce they hardly ever make exact copies because usually the genes of both parents are shared by the offspring.

Girl
Genes are passed down during the process of fertilization, when a male sperm cell containing the male's chromosomes, penetrates a female egg cell containing the female's chromosomes.

Boy
Human egg cells have 23 chromosomes.

Girl
Human sperm cells also have 23 chromosomes.

Boy
During fertilization, the 23 chromosomes of the male sperm cell join the 23 chromosomes of the female egg cell, creating a new cell, called a zygote, with 23 pairs of chromosomes. Forty-six in all.

Girl
This new cell will then reproduce itself during a process called cell division or mitosis, creating two identical cells, each with 46 chromosomes. Then these

cells will reproduce themselves and so on and so on.

Boy

Many traits are passed down according to rules first discovered by Gregor Mendel who learned that they are passed down in pairs and that one is dominant over the other.

Girl

It wasn't until the 1950's that scientists discovered what DNA looked like. . .and how it was able to reproduce exact copies of itself through a process called replication.

Boy

Scientists have mapped more than 30,000 genes carried by humans.

Girl

Changing the genes of organisms is called genetic engineering and it has started us on an exciting journey.

Boy

Where that journey will end, no one really knows.

Girl

That's for sure.