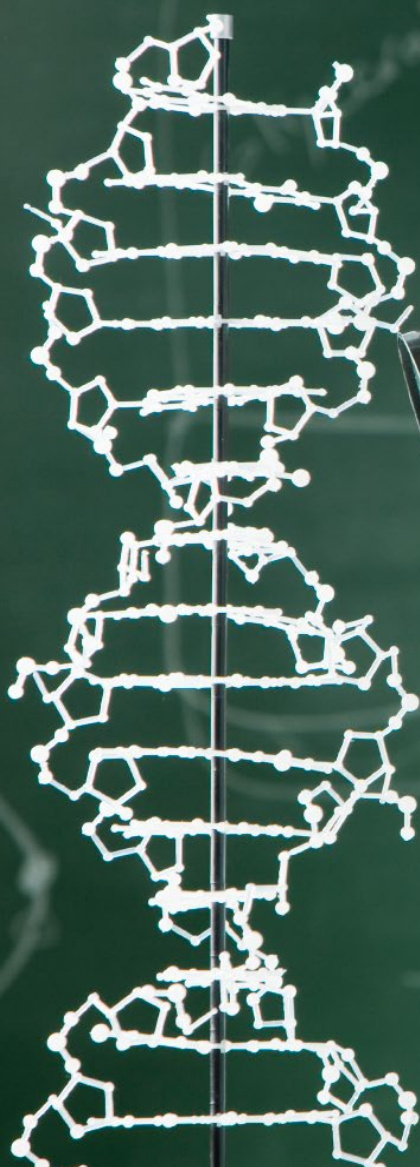




RARE TOOLKITS™

A Guide to Gene Therapy






Most likely you have a need for this toolkit: **A Guide to Gene Therapy** because you or a loved one has a rare genetic disease. As you prepare to use the tools in this kit, we want you to know that you are not alone. We are in this together. It is our hope that the personal stories, resources, tips, and suggestions for self-reflection in this guide will make the road to advocacy for your rare disease more manageable.


We know, all too well, that a lack of information and support for people living with rare diseases can lead to feelings of depression, anxiety, and isolation. This is common, but you are not alone. Fortunately, rare advocates see these challenges as opportunities to take control and many fill the void with support, knowledge, and change to proactive next steps.

While we believe you will benefit from reading all of the material in this toolkit, we don't want to overwhelm you. We've included a table of contents to make it convenient for you to find the information you are most interested in at this time. ■

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 *Paper and pen indicate an interactive exercise*

 *Exclamation point indicates a fun fact*

Intro to Gene Therapy: Gene Pool

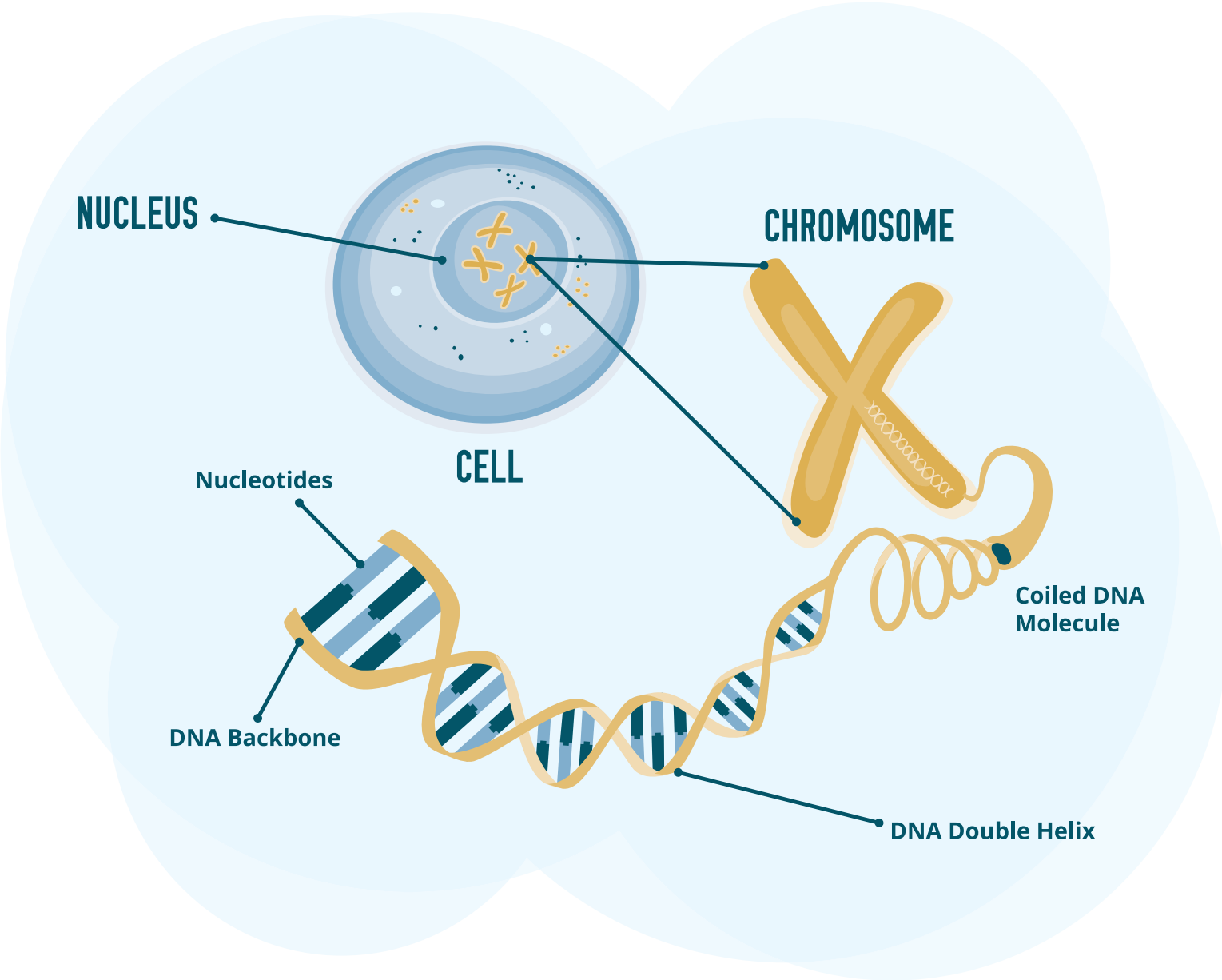
Come On In, The Water Is Fine!

Within the human body millions of molecules act together to:

- Turn food into energy for cells
- Make the nerves transmit signals from the body to the brain and back again
- Take oxygen from inhaling air and moves it to cells
- Perform all the other jobs needed for the body to develop and repair
- Make it easier to zip up tight jeans (We wish!)

Many of these molecules are proteins. Genes provide the instructions necessary for building proteins. When these instructions are incorrect the result may be proteins that do not work, too much of a protein, or too little of a protein. Each of these results can cause many problems within the body.

Many rare disorders are caused by changes in a gene or genes that change proteins in a way that makes them malfunction. So far, most treatments for diseases and disorders use chemicals or proteins to affect the protein not functioning as needed. In contrast, **gene therapy** uses a gene (or, potentially, the building blocks of a gene) to restore a functional protein. ■



Gene Therapy Interactive

List three things you have heard about gene therapy for the treatment of rare diseases.

1. _____
2. _____
3. _____

The goal of this toolkit is to provide rare patients and caregivers with an overview of gene therapy and why it is being investigated as a possible treatment for many rare diseases. To make the content easier to connect with and more engaging, there are illustrations, interactive journal prompts, and trivia about genes and jeans.

Topics covered in the toolkit include:

1. An introduction to what gene therapy is
2. A brief history of the development of gene therapies
3. An explanation of how gene therapy works
4. A summary of where gene therapy research is today, including current challenges, examples of advances with gene therapy treatments, and what the future might hold



Gene Therapy-101

Attention shoppers! Gene therapy is not a form of “retail therapy” that makes you feel better after you buy a new pair of bootcut jeans. Gene therapy is a way to treat diseases by introducing genetic material into cells that will lead to a working protein and maintaining the new genetic material in the cells over a long time. There can be different approaches to gene therapy based on what the genetic change causing the disease is.

Potential approaches to gene therapy can involve:

- Delivering a functional gene
- Changing how often or when a gene turns on to make a protein or turns off to stop making a protein

Because of groundbreaking research for new methods of gene therapy, it may even one day be possible to repair a disease causing gene by correcting only the harmful change or changes in the gene.

Mother's Hips

But before we cover gene therapy, let's review how genes work. If you were paying attention in your high school biology class, the following material about cells will be familiar to you. But, if your attention was otherwise directed on your cute lab partner, here's what you missed.

DNA (deoxyribonucleic acid) holds the genetic information for development and function. In people a gene is a specific region on DNA that codes for RNA (ribonucleic acid). RNA is what often instructs the body to make proteins that it needs.

In humans, genes are located on **chromosomes**. Chromosomes are tightly wound DNA strands that are found in the nucleus of each cell.

Humans have 23 pairs of chromosomes, or a total of 46 chromosomes. One of these chromosomes pairs are the sex chromosomes, often referred to as “X” or “Y”, and determine the biological sex of a person. The other 22 pairs of chromosomes are called autosomal chromosomes and are truly pairs in that they should have the same size, shape, and number of genes.

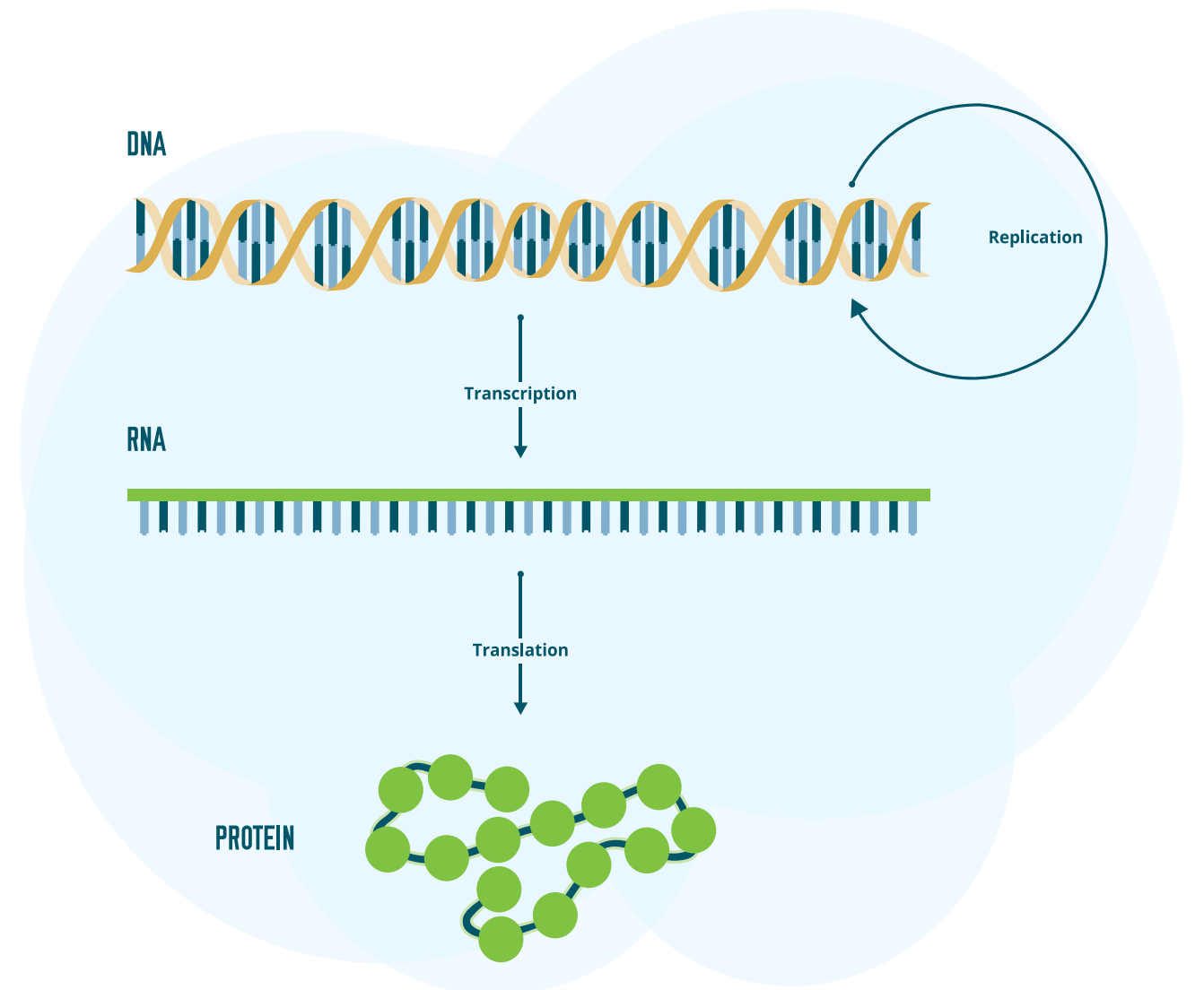
Autosomal chromosomes provide two copies of each gene. For people with “XX” chromosomes only have one copy of the genes on the “X chromosome and one copy of the gene on the Y chromosome.

Most cells have all 23 pairs of chromosome in the nucleus. (Some cells do not have all 23 pairs. Sperm and egg cells only have one copy of each chromosome, and red blood cells do not have a nucleus and do not have chromosomes.) Humans inherit one chromosome from each of the 23 pairs of chromosomes from each parent

Human cells also have DNA in their mitochondria. Mitochondria are small structures in the cells that are involved in making molecules for energy in cells. Each mitochondria has a small circle of mitochondrial DNA. Mitochondrial DNA is inherited only from a person's mother.

A gene can have slightly different forms, which can sometimes be seen in a person's appearance- for instance, one person may have brown hair while another person has red hair. These different forms of a gene are called **alleles**, and they result from slight differences in the DNA sequence between alleles.

Therefore, not all differences are “bad” and only sometimes do they lead to health concerns.



Cheat Sheet Summary:

- Most cells in the body contains 46 chromosomes, 22 pairs and the 1 pair of sex chromosomes, within a nucleus, which is separated from the rest of the cell.
- Each chromosome is made of DNA (deoxyribonucleic acid), and a gene is a specific region of the DNA that codes for RNA (ribonucleic acid), which in turn, often codes for a protein.
- The order of the DNA in a gene determines the order of the RNA nucleotides, which determines the order of the amino acids in the protein.
- We have two copies of each gene on the autosomal chromosome, and we inherit one copy from each of our parents. Now we know why some of us have our mother's wide hips or our dad's ample waistline; which means jeans designed for stick figures are not an option.

Change Agents

A genetic mutation means there has been a change in the sequence of the nucleotides within a gene. Often this change has no noticeable effect. But sometimes, this change in sequence can result in a protein that does not work, or too much of a protein, or not enough of a protein which causes health problems. Genetic mutations can be inherited from a parent's genes or they can be de novo, which means the change is new to a person. A mutation may be a substitution in the sequence of the DNA or it may involve sections of the DNA being deleted or repeated.

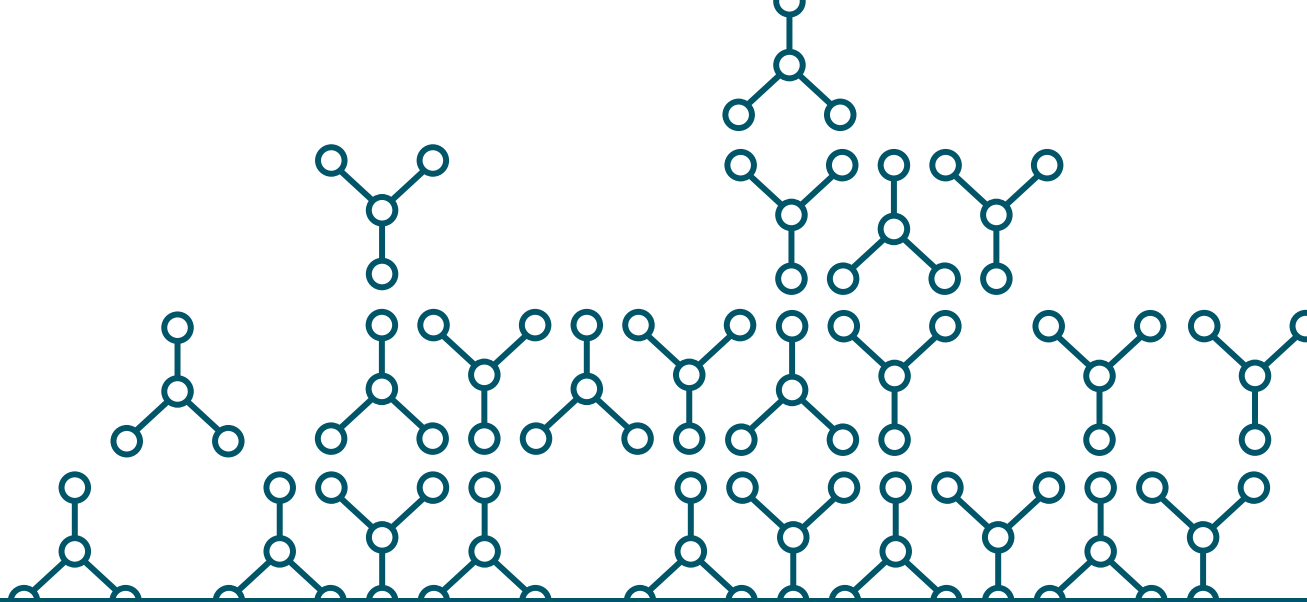
Many times, these changes in the DNA do not lead to a malfunctioning protein; but there are times when the change causes a problem. If a change in only one copy of the gene causes a disease, the disease is referred to as a dominant disorder. If a disease only results when there are changes in both copies of a gene, the disease is referred to as a recessive disorder. For men, if the change is in a gene on the X chromosome, there is no second copy of the gene, so the disease will be noticed whether it is a dominant or recessive disorder.

! FACTOID:

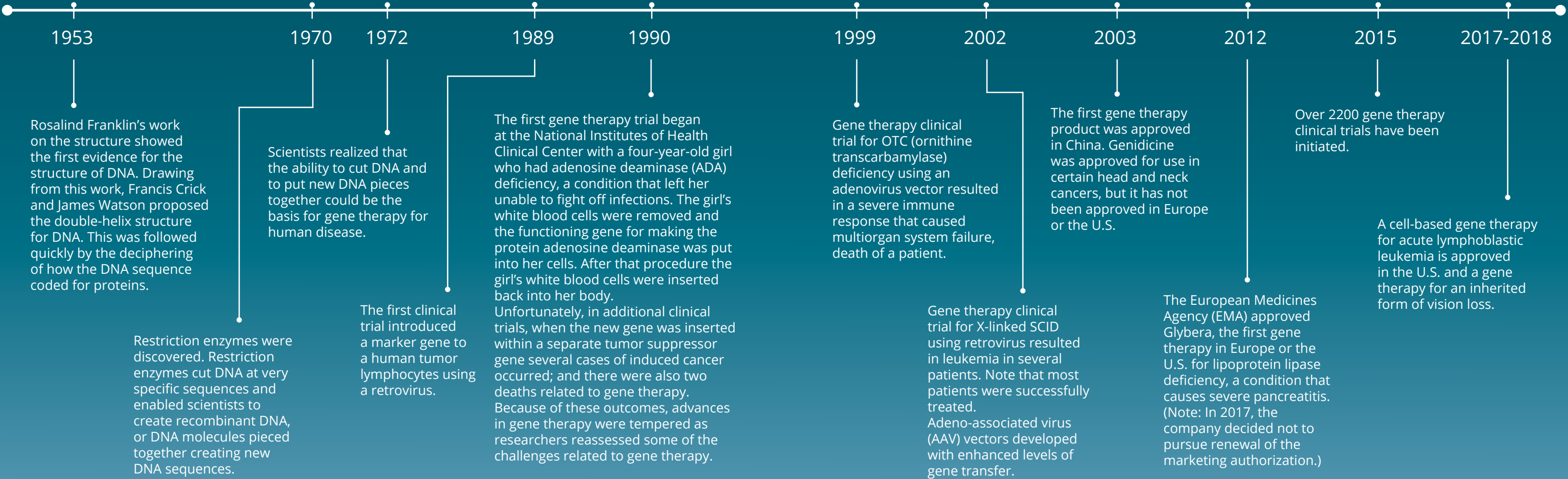
Dogs have 39 pairs of chromosomes and cats have 38 pairs.

Brief History of Gene Therapy

The discovery of genes came from many different scientists over many years. Each of them expanded upon the work of scientists who came before them to delve deeper into the concept of genetics. These early scientists understood that traits could be inherited, but they did not visualize genes or have evidence of their existence. It wasn't until the late 19th century and early 20th century that chromosomes and genes were first observed. Throughout the 20th century, scientists made many advances in understanding genes and how they cause many rare disorders. ■



Timeline



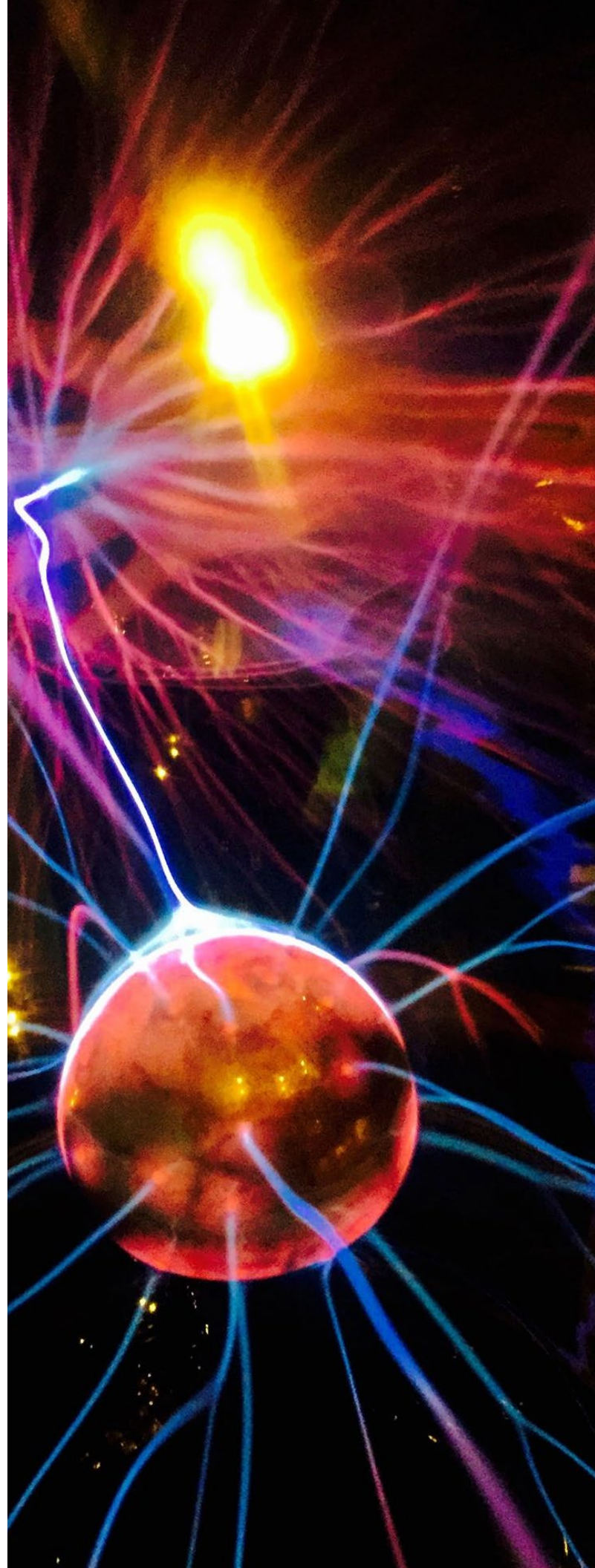
Disorderly Conduct: The Basis for Gene Therapy

Yelling too loudly at your kids soccer game or mowing the lawn before 6:00am may be considered by others disorderly conduct, but it is unlikely that either scenario is caused by a genetic disorder; and can be most likely be managed with some self-restraint. Genetic disorders, on the other hand, may be helped by gene therapy intervention.

To intervene, researchers need specific information about the cause of a genetic disorder before gene therapy can be explored as an experimental treatment. To develop a gene therapy, researchers must:

- First identify the target gene or genes causing the disorder.
- Understand the mechanism behind the disorder.
- Know which types of cells in the body are abnormal because of the mutation or mutations.

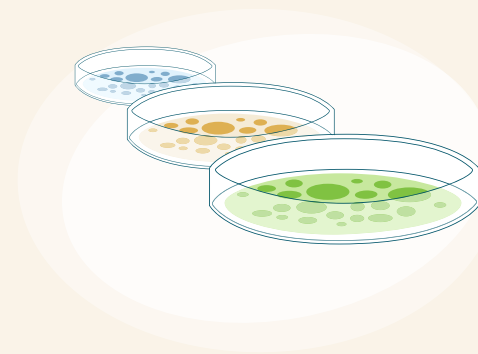
Once this information is understood about a disorder, a researcher can move forward uncovering the best way to treat the disorder. ■



GLOBAL GENES *Pharma-to-Table Café*

Seasonal veggies and fresh dairy products from Old Mc Donald's farm down the road (give or take 500 miles) are popular offerings on farm-to-table restaurant menus. Spoiler alert! Summer squash, fresh bingleberries, or double-clotted butter are not on the Global Genes' Pharma-to-Table Café menu. What you will find are, potentially, life changing "ingredients" simmering in laboratory petri dishes that are advancing medical discoveries in gene therapy.

Gene Petri Dish Menu & Delivery Options



Two large orders of cells to go!

Gene therapy can be done with somatic cells or germline cells. There are two ways to deliver gene therapy. Each delivery approach has its advantages. When the gene therapy is administered **ex vivo**, immune reactions from the delivery method are minimized. The cells can also be tested to ensure that the gene has inserted into the genome. However, ex vivo gene therapy is limited to cells that can be safely removed from the body, such as blood cells.

Entrees

Types of gene therapy

In vivo

In vivo approaches to gene therapy involve delivering the new genetic material to cells that are within the body

Ex vivo

Ex vivo approaches to gene therapy involve administering gene therapy to cells that have been isolated from the body and are reintroduced after the gene therapy occurs, ex vivo gene therapy.

Gene Therapy Delivery Options



*Phone ahead for
extra fast service!*

For gene therapy to be effective, the new genetic material must complete several steps:

1. It must be delivered into the correct, targeted cells.
2. The genetic material must be appropriately incorporated into the cell's existing genetic code or remain whole in the nucleus.
3. Finally, the new genetic material must "turn on" so that it produces a normal protein or it knocks down production of a bad protein.

There are several options to deliver genetic material into the body. Each has its own benefits and potential complications. Researchers are currently studying each delivery method in an effort to develop gene therapy.

Delivery Option 1: Viruses

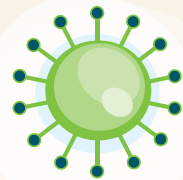
Today's lunch special includes a petri dish of fresh viruses! Researchers have borrowed a process from nature as one way to effectively achieve each of the steps of gene therapy: infections by a virus.

Viruses are very good at delivering genetic material into cells. Getting genetic material into a cell is the ultimate goal of gene therapy. For this reason and because viral delivery systems are the most effective right now, most clinical and research efforts have focused on using viruses to deliver gene therapies.

When viruses are used as a way to deliver gene therapy to cells, they are engineered so the viruses do not cause an infection. Researchers have used several different types of viruses as vehicles to deliver experimental gene therapies. Some of those viruses are listed here.



Adeno-Associated Virus



Retroviruses



Adenovirus



Herpes Simplex Virus

1. Adeno-Associated Virus
Harmless viruses that do not cause disease, in people.
2. Retroviruses
Such as human immunodeficiency virus or HIV.
3. Adenovirus
The virus that causes the common cold is a type of adenovirus.
4. Herpes Simplex Virus
Viruses that cause cold sores are herpes simplex viruses.

Delivery Option 2: Non-viral

Researchers have also experimented with other ways to deliver the DNA to cells.



Naked DNA

1. Naked DNA
One approach is simply injecting DNA not enclosed within anything, or naked DNA. To help the DNA get into the nucleus of the target cells, researchers may use a method called electroporation, where electricity is applied to the cell. This causes small openings to be created in the cell's membranes, including the membrane of the nucleus, allowing DNA to get in.
 - This DNA most often takes the form of a small circle and is called a plasmid.
 - Bacteria use plasmids to exchange DNA, so it also is a method borrowed from nature by researchers.
 - A plasmid is separate from the cell's chromosomes and can be activated and replicated separately.



Liposome

2. Liposome
Another approach to delivering DNA is surrounding the DNA with a small membrane of its own, which is called a liposome.
 - The liposome has a similar make-up to the cell membrane, so it can fuse with it and help the DNA enter the target cells.
3. Nanoparticle
A third non-viral approach that has been an area of intense focus by researchers is using nanoparticles to deliver DNA. A nanoparticle is something that is smaller than 1 micrometer, but many of the nanoparticles being explored for gene therapy are smaller than 400 nanometers, or very, very small.
 - These particles are so small that they can simply slip through the pores in the cell membrane to deliver the DNA. ■

Taking Aim: Benefits and Expectations of Gene Therapy

The potential benefits of gene therapy are broad reaching. Like an expert archer poised to hit a bull's-eye, researchers around the world are taking aim at treating of rare diseases via gene therapy. Gene therapy goes further than just treating some of the symptoms of the disorder. It targets the mutations in the gene(s), which in-turn treats the underlying cause of the disorder.

Because the new genetic material integrates into the cell's genome or is specifically designed to resist being destroyed, there is the potential for a one-time administration or for very infrequent administration of the treatment. ■

! FACTOID:

*On an annual basis
genealogy websites get over
108 million visits a year.*
(Source-Geanealogyintime.com)



Road Less Traveled: Current Challenges

Size Matters!

Size matters when it comes to the drug development pathway and the field of gene therapy for rare disorders. The patient populations for rare disorders are small, less than 200,000 in the United States to be classified as a rare disorder. Often, the patient populations are much smaller than that. These small populations make it difficult to find patients for clinical trials, and to therefore demonstrate that the therapy is safe and effective in the clinical trial phase.

Because of the small size of the patient populations, some pharmaceutical companies may be reluctant to invest resources in drug development. Gene therapies also face several unique challenges to what is known about the genome and current available technology. Like all rare disorder therapeutics, researchers continue to work on ways to defeat the challenges that accompany rare disorders.

High IQ: Understanding How a Rare Disorder Works

For a gene therapy to be successful, a lot of passionate and smart people, must know what changes in which gene(s) cause a particular rare disorder. Knowing this allows researchers to create a plan for addressing it through gene

therapy. It is also important for them to understand where the dysfunctional gene is causing problems within the body.

For many disorders the dysfunctional gene is active in some parts of the body and not active anywhere else; which means the gene therapy only needs to be delivered to certain cells. Gene therapy also faces the challenge of making sure the gene therapy makes it into the right cells, but not other cells where there may be unnecessary side effects.

Similarly, the timing of when the gene therapy needs to be delivered is also important. For some rare disorders, fixing the dysfunctional gene early in the patient's life may be necessary before damage to the body increases and it cannot be treated. In other rare disorders, it may be possible to deliver the gene therapy where it can reverse any damage to the body.

"Traits such as intelligence are governed by large groups of genes working together – like a football team made up of players in different positions."

-DR MICHAEL JOHNSON,
IMPERIAL COLLEGE
LONDON

Party Crashers: Disorders Caused by Many Genes

Some disorders are caused by a mutation in one gene. Like unruly party crashers, many disorders result from mutations within two or more genes. When multiple genes have damaging mutations, the amount of DNA that has to be put into the delivery mechanism gets bigger. This presents a challenge in packing the larger DNA molecules into a small virus or nanotechnology particle. There is also the possibility that some genes may get too large to fit into a virus or other delivery method.

Recessive Versus Dominant Alleles

What has been proven is how a variant of a gene or an allele acts can make the prospect of gene therapy easier or harder in the listed ways:

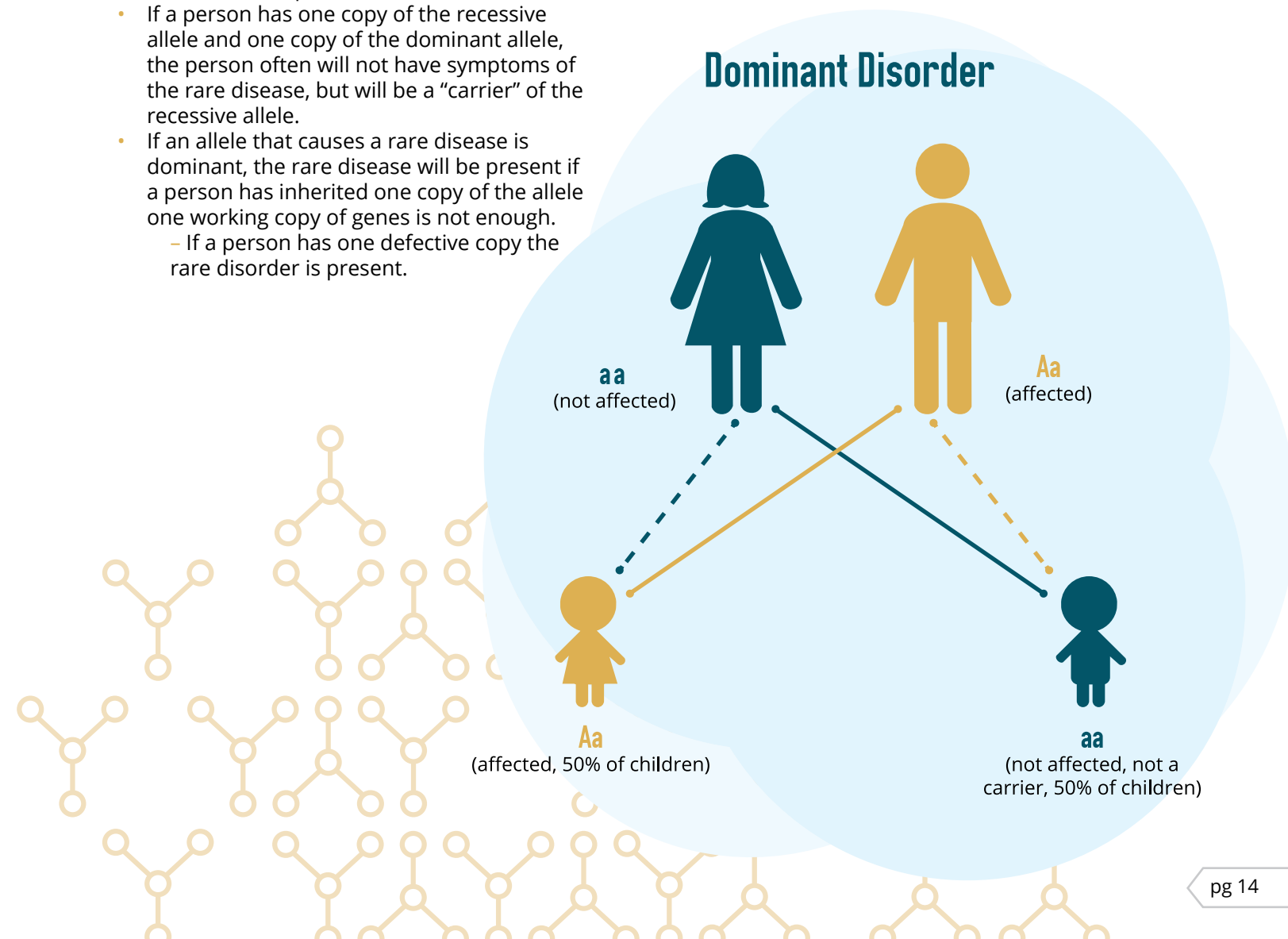
- If a person has two copies of a recessive allele or only one copy of the recessive allele (for example, a gene on the X chromosome in a person with XY chromosomes), the rare disease will be present
- If a person has one copy of the recessive allele and one copy of the dominant allele, the person often will not have symptoms of the rare disease, but will be a "carrier" of the recessive allele.
- If an allele that causes a rare disease is dominant, the rare disease will be present if a person has inherited one copy of the allele one working copy of genes is not enough.
 - If a person has one defective copy the rare disorder is present.

Within gene therapy it is much easier to add one active copy of a gene for a recessive disorder than to stop a gene from being active or to "knock down" a gene, for a disorder caused by a dominant allele.

Guard Duty: Immune Response

Difficulties in gene therapy can be related to how the new gene is delivered and how well the body accepts it. Like a dedicated sentry guarding a castle from intruders, the body's immune system is the first line of defense against sickness and helps the body protect itself in a number of ways.

While this is normally the desired response, in some situations the immune system can present a problem to the effectiveness of gene therapy and other delivery methods, the virus may stimulate the patient's immune system response.



The immune system may also work to degrade the virus delivering the gene or degrade the cells when the virus delivers the gene. If the immune system is stimulated in these ways, the patient may become sick due to the inflammation or the gene therapy may not work. Also, if another dose of the gene therapy is needed the immune system may now recognize and attack the virus or other delivery method for the gene therapy.

Pardon the Disruption

Some gene therapy approaches involve inserting a new copy of a gene into the genome of many cells. Although the chances are low, there is the potential risk that the new copy of the gene is inserted into the genome in a location that disrupts the way another gene works. In some clinical trials conducted in the late 1990s, the gene therapy inserted into a

gene controlled the way cells divide. Some of these patients eventually developed cancer because of the insertion point. Since then researchers have developed several methods to be sure the gene inserts in a safe place in the genome, and methods allowing more specific targeting are being worked on (see the discussion in this toolkit on gene editing). When the gene therapy is done while the cells are outside the body, the cells can be tested to be sure the genes have integrated into a safe part of the genome.

King's Ransom: The Cost of Gene Therapy Products

Gene therapy products can be difficult to make. Because gene therapy involves working with live cells and biological processes, the conditions are harder to control than chemical processes used for

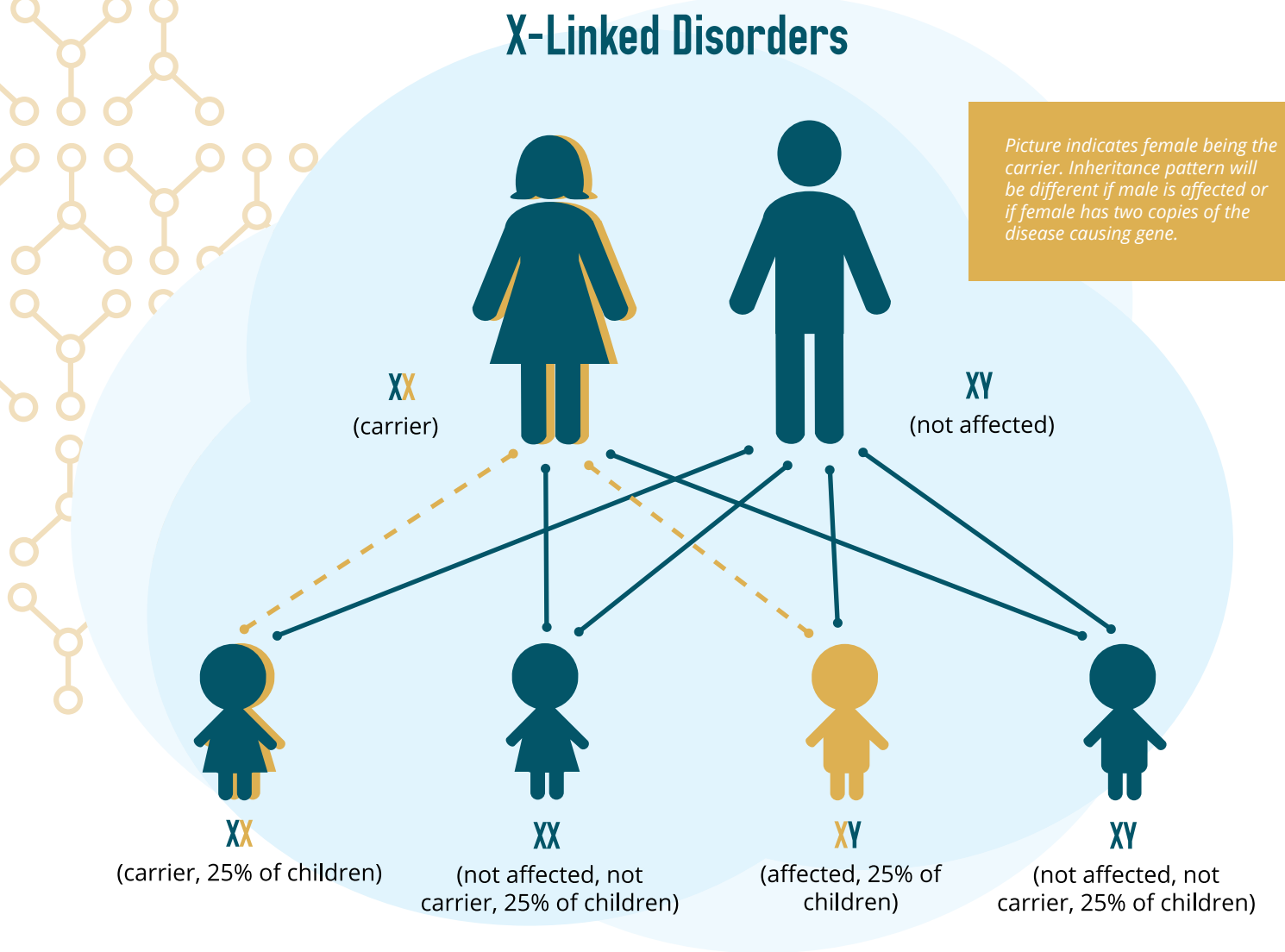
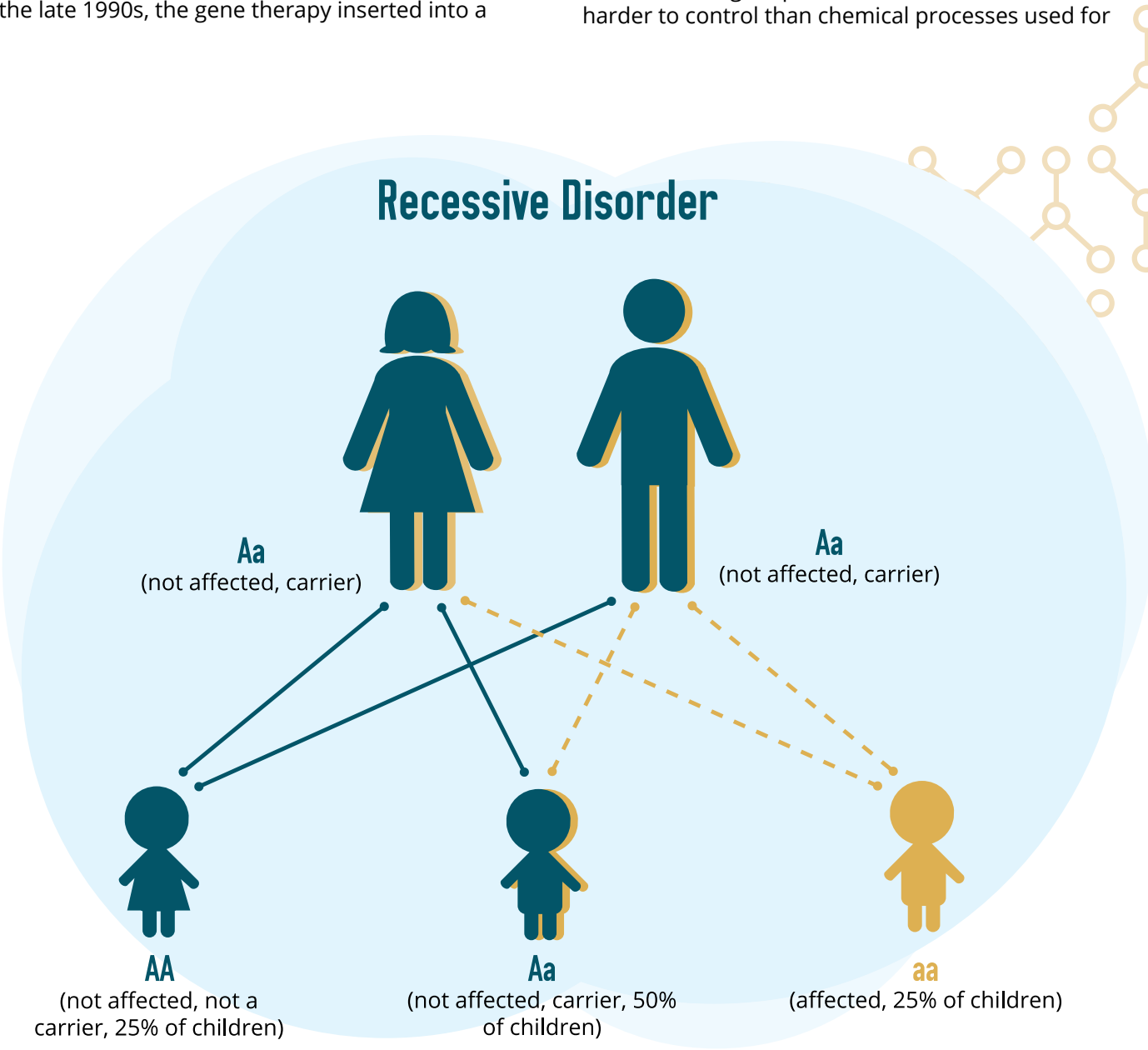
other drug therapies. It can also be hard to produce enough of the gene therapy product to provide a large enough dose to patients. There is also the challenge of keeping the gene therapy products from contamination by other bacteria or viruses. This increases both the time and cost of manufacturing gene therapy products.

The few gene therapy products that have been approved and are being produced are sold at high costs. Because of the challenges of gene therapy and because it is designed to be administered only once or a few times over a patient's life, the cost of gene therapies is predictably very expensive compared to some other treatments.

Pioneering Spirit

Like the pioneers of the California Gold Rush of 1849 who risked everything in search of gold and a Black Friday sale at the Levi Strauss trading post, gene therapy researchers are also on the road less traveled. As with any endeavor, funding is necessary and the continued investment in the field of gene therapy research can increase the development of gene therapy. So take heart, even with its many challenges, gene therapy is actively being worked on in labs and in clinical research trials around the globe. ■

"Two roads diverged in a wood, and I—I took the one less traveled by, And that has made all the difference."
-ROBERT FROST



Getting Gene Therapy Into the Clinic

Currently gene therapy is not widely available as a clinical treatment. However, there is a lot of effort being put into research and development for gene therapy products. At the time of this writing, there are dozens of clinical trials in Phase 3, hundreds of gene therapies developed and being tested, and there are more than 200 companies actively pursuing development of gene therapy treatments for a wide variety of disorders. Although there is a lot of excitement and investment in gene therapy, the clinical trials required to show the safety and effectiveness are complex. Other drug therapies leave the body, usually, fairly quickly. Gene therapies are specifically designed to stay in the body, which means full testing of the safety and efficacy require much more time.

Examples of Advances in Gene Therapy

There are recent advances in both research and clinical trials to report. Exciting, new methods and promising results in Phase 2 and Phase 3 clinical trials are demonstrating the potential of gene therapy.

Gene Editing Techniques

One challenge in developing some gene therapies has been making sure the new gene does not insert into another critical gene and disrupt its function. Recently, methods have been developed that allow for more precise changes to be made to genes.

These methods are called genome editing. Genome editing uses engineered nucleases, which are proteins that cut nucleotides like those that make up DNA. These nucleases act as “molecular scissors” in which the nucleases recognize a specific DNA sequence and break it, allowing for a new sequence to then be stitched in.

These most promising nucleases include:

- Zinc finger nucleases
- TALENs (transcription activator-like effector-based nucleases)
- Meganucleases
- CRISPR (clustered regularly interspaced short palindromic repeats)/Cas (CRISPR-associated proteins) system

Each system has advantages and disadvantages and development is still in very early stages. With these methods of cutting the genome at precise spots, the prospect of gene therapy presents new potential opportunities.

Promising Late-Stage Clinical Trials

There are several gene therapy products in clinical trials, at the time of this writing. A few have been approved by regulation authorities. Growth of research into gene therapy continues to expand. ■





Gene Therapy: Future Forecast

Gene therapy presents a unique potential by providing a potential for a one-time treatment for a disorder instead of continual treatments. However, before a gene therapy approach for a rare disorder can be considered, there are many questions that have to be answered. The study of a potential gene therapy must start with a solid understanding of what caused the specific disease. This makes continued research on the mechanisms of diseases a priority for advancing gene therapy treatments.

Ongoing research is also needed to determine the most effective way to deliver gene therapies so the treatment gets to the correct cells and is active within the cells for a long time. It will also be necessary to study the long-term effects of the treatment.

But even with these challenges, gene therapy has the tremendous potential to provide effective treatments for many disorders that currently don't have any or very limited treatments. With the current advances in gene therapy, there are many reasons to be hopeful. There is confidence in the field that current research is paving the way for a safe and very effective treatment for some rare disorders in the not so distant future.



Gene Therapy Interactive

Having read this toolkit, list 3 things about gene therapy you would like to discuss with your doctor.

- 1. _____
- 2. _____
- 3. _____

Meet the Calliope Joy Foundation

Founder: Maria Kefalas

In 2013, the published results of a pioneering gene therapy trial led our Philadelphia-based charity, The Calliope Joy Foundation, to start helping families get to the Telethon Institute in Milan, Italy. As a parent advocate for leukodystrophy, the breakthrough in gene therapy to treat late-infantile onset metachromatic leukodystrophy (MLD) offered a remarkable opportunity.

Leukodystrophies are fatal, inherited white matter disorders with limited (to nonexistent) treatment options. On average, children with MLD do not survive beyond age 5. Experts in the field described this new therapy as miraculous and stunning. Kids who typically would have been paralyzed and dying were walking and talking and avoiding the disease's most devastating symptoms. So, we wanted to get involved.

At the time, the problem was that the children had to be treated before the onset of symptoms. Without newborn screening or genetic testing, this meant an older sibling with the disease would be diagnosed and a younger sibling was found to be presymptomatic. The trial brought up heartbreaking challenges for the doctors and families. From our perspective, the sacrifice of one child to the disease made our work even more urgent, we wanted to help families facing the prospect of losing more than one child to the same disease.

Since 2014, our foundation, which hosts community based fundraisers (from bake sales to galas) and had no major corporate sponsorships, sought to be strategic about making high impact gifts. We used the money we raised to help send five families and nine children to Italy for treatment. Each family received a travel grant of \$1,000 per child and care packages of toys, I-Tunes cards, books, and

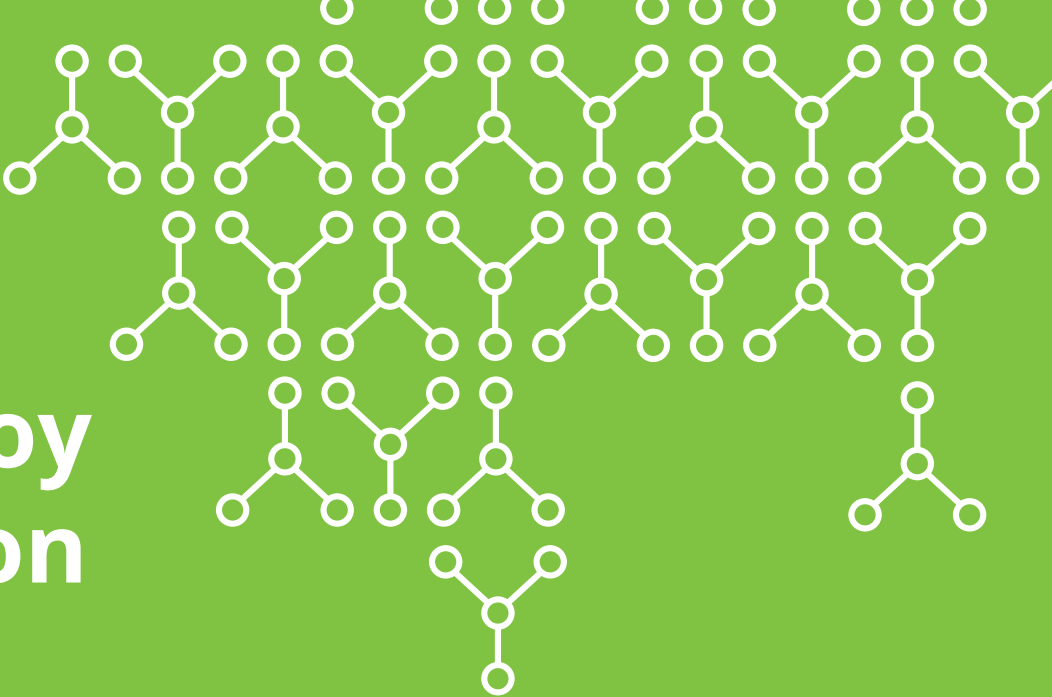
handmade quilts to support the child during the long periods away from home.

Through social media, we received updates on the treatments in real time and offered support to families who had risked so much on an unproven treatment. Without raising huge amounts of money, our small foundation was able to invest in these brave families and their chance for a miracle. Last April, we hosted a luncheon to honor the study's principal investigator, Alessandra Biffi, now the director of gene therapy at Dana-Farber/Boston Children's Hospital.

The highlight of the day was reuniting Dr. Biffi with her patients. The children, who because of treatment were not in wheelchairs or dependent on feeding tubes, were instead playing on their parents' phone and embracing Dr. Biffi. And, through a series of unforeseen events, we find ourselves in the middle of the revolution in gene therapy. If you're interested in reading more about Dr. Biffi's work and to see the article that sent us down this path visit: <http://bit.ly/DrBiffi-GeneTherapy>

Here is a personal piece that was published about my journey and the work I set out to do: bit.ly/cupcakerevolution

Meet one of our families, Dr. Biffi and us:
bit.ly/ourmiracle
bit.ly/thesechildrenaremyfamily
bit.ly/miraclefromOmaha ■



Welcome to Something Bigger!

You are a part of something bigger—The rare community! Building connections within your specific disease community is absolutely the most vital part of your efforts. Members will tell you that the depth of the connection they feel with others in their rare disease community is hard to describe. There is an innate sense of closeness and empathy that comes with a rare disease diagnosis.

Like we said in the beginning you are not alone. You are part of an estimated 30 million Americans and 350 million people worldwide that are affected by a rare disease. While the diseases and the symptoms may be different, people in the rare community often share the same challenges and fight for the same changes. This is a powerful thing! Rare is everywhere and is frankly not-so-rare.

*"It's not in the stars
to hold our destiny,
but in ourselves."*

- WILLIAM SHAKESPEARE

Glossary of Terms

DNA (Deoxyribonucleic acid): a molecule that carries the genetic instructions used in the growth, development, functioning and reproduction of most living organisms and many viruses.

RNA (Ribonucleic acid): a molecule implicated in various biological roles in coding, decoding, regulation, and expression of genes.

Genes: a unit of heredity that is transferred from a parent to offspring and is held to determine some characteristic of the offspring.

Proteins: large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues. Proteins perform a vast array of functions within organisms, including catalyzing metabolic reactions, DNA replication, responding to stimuli, and transporting molecules from one location to another. They are also structural.

Chromosomes: a packaged and organized threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of genes.

Nucleus: a compartment within some cells bounded by a double membrane, containing the genetic material.

Genome: the complete set of genes or genetic material present in a cell or organism.

Nucleotides: organic molecules that serve as the subunits, of nucleic acids like DNA and RNA.

Enzymes: biological molecules (proteins) that act as catalysts and help complex reactions occur.

Gene Therapy: the delivery of genetic material into cells with the intention of correcting diseases.

Genetic Mutation: a permanent alteration in the DNA sequence that makes up a gene, such that the sequence differs from what is found in most people. Mutations range in size; they can affect anywhere from a single DNA building block (base pair) to a large segment of a chromosome that includes multiple genes.

De Novo: the change, mutation or alteration is new to the person.

Somatic Cells: any cell of a living organism other than the reproductive cells.

Germline Cells: reproductive cells.

In Vivo: is often used to refer to a process taking place in the body.

Ex Vivo: is often used to refer to a process taking place outside of the cells isolated from the body.

Resource Guide

ONLINE RESOURCES

Genome Editing, MIT Technology Review:
bit.ly/Genomeediting

Genome Surgery, MIT Technology Review:
bit.ly/Genomesurgery

Gene Therapy, University of Utah:
bit.ly/learn genetics-genetherapy

Gene Therapy, NIH:
bit.ly/understandgenetics

Genes and Gene Therapy, MedLine Plus:
bit.ly/Gene-therapy

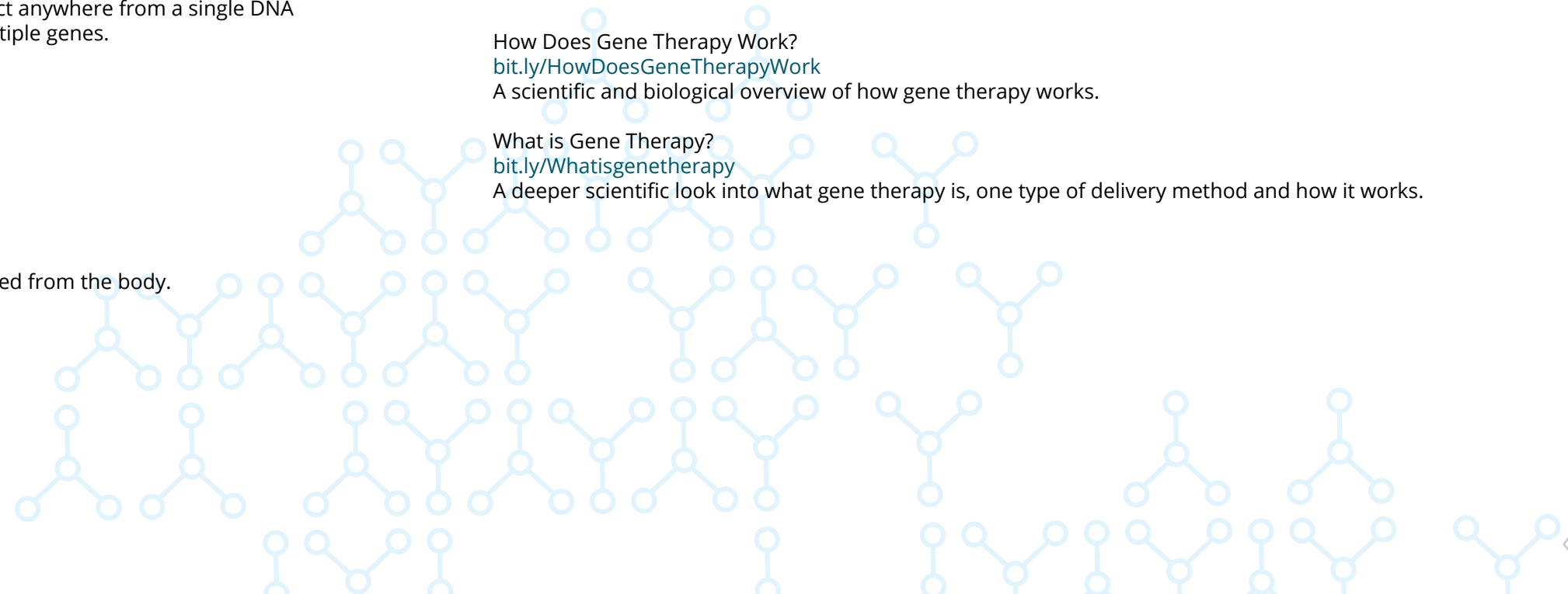
VIDEO RESOURCES

Genetics 101
bit.ly/genetics-101
A series of videos that go over the basic of genes, genetics, and more.

Gene Therapy
bit.ly/genetherapyexample
An animated video that describes normal vs. mutated genes and how gene therapy helps, using the example of retinal blindness.

How Does Gene Therapy Work?
bit.ly/HowDoesGeneTherapyWork
A scientific and biological overview of how gene therapy works.

What is Gene Therapy?
bit.ly/Whatisgenetherapy
A deeper scientific look into what gene therapy is, one type of delivery method and how it works.



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Let's Stay Connected!

Global Genes is invested in collecting and then sharing best practices and lessons learned as well as devoted to celebrating successes of the rare disease community.

Submit questions, feedback and your action steps here:
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