



# MITOCHONDRIAL REPLACEMENT THERAPY

The Science, Benefits, and Implications of a New  
Reproductive Genetic Therapy

MINI-LESSON & TEACHER'S GUIDE



**PERSONAL  
GENETICS**  
EDUCATION &  
DIALOGUE



# STUDENT MATERIALS

## Introduction

Mitochondrial replacement therapy (MRT) is a new technique that enables prospective parents to avoid passing down certain serious medical conditions, called mitochondrial diseases, to their children. This therapy has drawn media attention in recent years, as scientists, ethicists, policymakers, and families discuss and debate its use in humans. Indeed, you may have come across the term “3-parent baby”, which refers to children who have been born using this technique. This mini-lesson gives an overview of the science underlying MRT.

## Background

Mitochondria are often referred to as the “powerhouse” of the cell, as one of their main roles is to provide our cells with energy. Mitochondria contain their own source of DNA. This DNA accounts for only 0.1% of the total DNA in the cell, most of which is found in the cell’s nucleus (see Figure 1). Although mitochondria contribute a relatively small amount of DNA to the cell, specific genetic changes (also known as variants) in mitochondrial DNA can have serious consequences. Variants in mitochondrial DNA can cause a number of medical conditions, known as mitochondrial diseases. Symptoms of mitochondrial diseases can include muscle weakness, limited physical growth, and organ failure and, in some cases, these conditions are fatal. Currently, there is no cure for mitochondrial diseases.

MRT is a technique that can be used to prevent the inheritance of mitochondrial diseases caused by variants in mitochondrial DNA (see Figure 1). MRT relies on the fact that mitochondria are generally passed down to offspring via the egg, not via the sperm. If an egg carries mitochondrial DNA with disease variants, MRT can transfer the nucleus of that egg to a donor egg that has “healthy” mitochondria. This procedure results in an egg with nuclear DNA from one person and mitochondrial DNA from a second person. This egg is then fertilized in a lab by the addition of sperm in a petri dish, a process known as in vitro fertilization or “IVF”. As a result, MRT gives rise to an embryo with DNA from 3 people.

**Note:** some mitochondrial diseases are caused by variants in nuclear DNA, not mitochondrial DNA. MRT does not help avoid inheritance of mitochondrial diseases caused by variants in nuclear DNA.

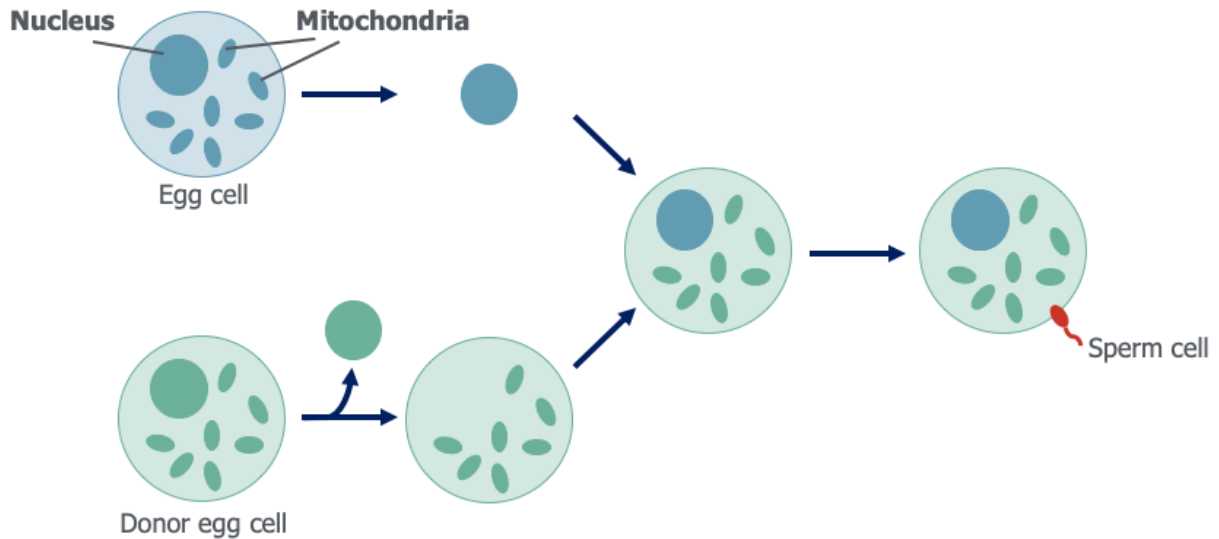


Figure 1: Schematic overview of Mitochondrial replacement therapy (MRT)

MRT is a relatively new genetic engineering technique and, as such, the laws around its use are still developing. In 2015, after years of public debate and consultation, the United Kingdom became the first country to legalize MRT for people at high-risk of having a child with a mitochondrial disease. MRT is currently not allowed under US law.

**Please read the following news article and complete accompanying worksheet:**

["An Experimental Procedure Could Help More Families Have Healthy Babies. But It's Not Allowed in the U.S."](#) by Alice Park, January 2019, *Time*.

## STUDENT WORKSHEET

Name: \_\_\_\_\_

Date: \_\_\_\_\_

1. The article states: "... scientists face much stricter rules when it comes to studies involving altering eggs, sperm or embryos, given that those modifications can be passed on to future generations, and ethicists and lawmakers are not ready to accept the social implications of such a scientific leap."
  - a. What are three possible reasons that make people hesitant to accept technologies that cause genetic changes that are passed on to future generations?
    - 1.
    - 2.
    - 3.
  - b. What is your personal opinion on technologies that cause genetic changes that are passed on to future generations?
  - c. Imagine a person who disagrees with your personal opinion as stated in 1b. What is your best guess as to why they disagree with you?

2. The article states: "We are breaking down a barrier that has certainly never been crossed before," says Dr. Michio Hirano, medical director of the laboratory of molecular genetics at Columbia University, who plans to perform MRT for the Shulmans as part of a study. "Clearly biologically the embryo or person generated has three different sources of DNA, and that's a unique or novel concept."
  - a. Based on today's reading: can you explain MRT in your own words? In your answer, please specify the 3 sources of DNA that contribute to the embryo.
  - b. The term '3-parent baby' is often used in the media to describe children that are born using MRT. This term is considered controversial by many people and specifically raises questions around what it means to be a parent. What do you think some of the controversies might be?

## TEACHER'S GUIDE

### Activity

This mini-lesson asks students to consider the use of MRT as a way to prevent the inheritance of mitochondrial diseases. Students read a brief overview of MRT and then read a longer article about the procedure that also provides personal, societal, and ethical views on this technology in "[An Experimental Procedure Could Help More Families Have Healthy Babies. But It's Not Allowed in the U.S.](#)" by Alice Park, January 2019, *Time*. This article is lengthy and can be shortened to suit your classroom.

A worksheet is provided for students to further explore the implications of MRT. You may choose to ask students to respond to the questions in writing or in a classroom discussion. Note: question 2b addresses the controversy about the term "3-parent baby" and whether the term "parent" is justified from the 0.1% DNA contribution from the donor egg. Furthermore, the idea that it is the contribution of DNA that makes someone a "parent" is troublesome for many people, such as adoptees and children raised by same sex couples.

After completing this lesson, students will: 1) increase their understanding of basic cell biology, including the functions of mitochondria; 2) understand that a "hybrid" egg can be created - containing nuclear DNA from one person and the mitochondrial DNA from another - with the goal of reducing the suffering of future generations from mitochondrial disease; 3) realize the various viewpoints around the technique known as mitochondrial replacement therapy.

### Related PGED Resources

Part of the challenge in teaching students about reproductive genetic technologies is that it can lead to discussion about one of the most contentious and difficult topics in the United States – the moral status of the embryo. Some people fear increased, earlier genetic testing edges close to the "slippery slope" of eugenics; others see these tests as an important medical and decision-making tool. Providing students – who are also future health care consumers and possibly voters - with a venue to discuss complicated

topics may require some additional supports. We recommend the guide "[Facilitating challenging conversations in the classroom](#)" from Washington University in St. Louis.

Our lesson plan *Reproductive Genetic Testing: Technology, Access, and Decision Making* discusses the science behind various major innovations in reproductive genetic technologies as well as their social and ethical implications. This lesson plan can be found in the resource hub at [www.pged.org](http://www.pged.org).

# THANKS FOR USING PGED'S MINI-LESSON!








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