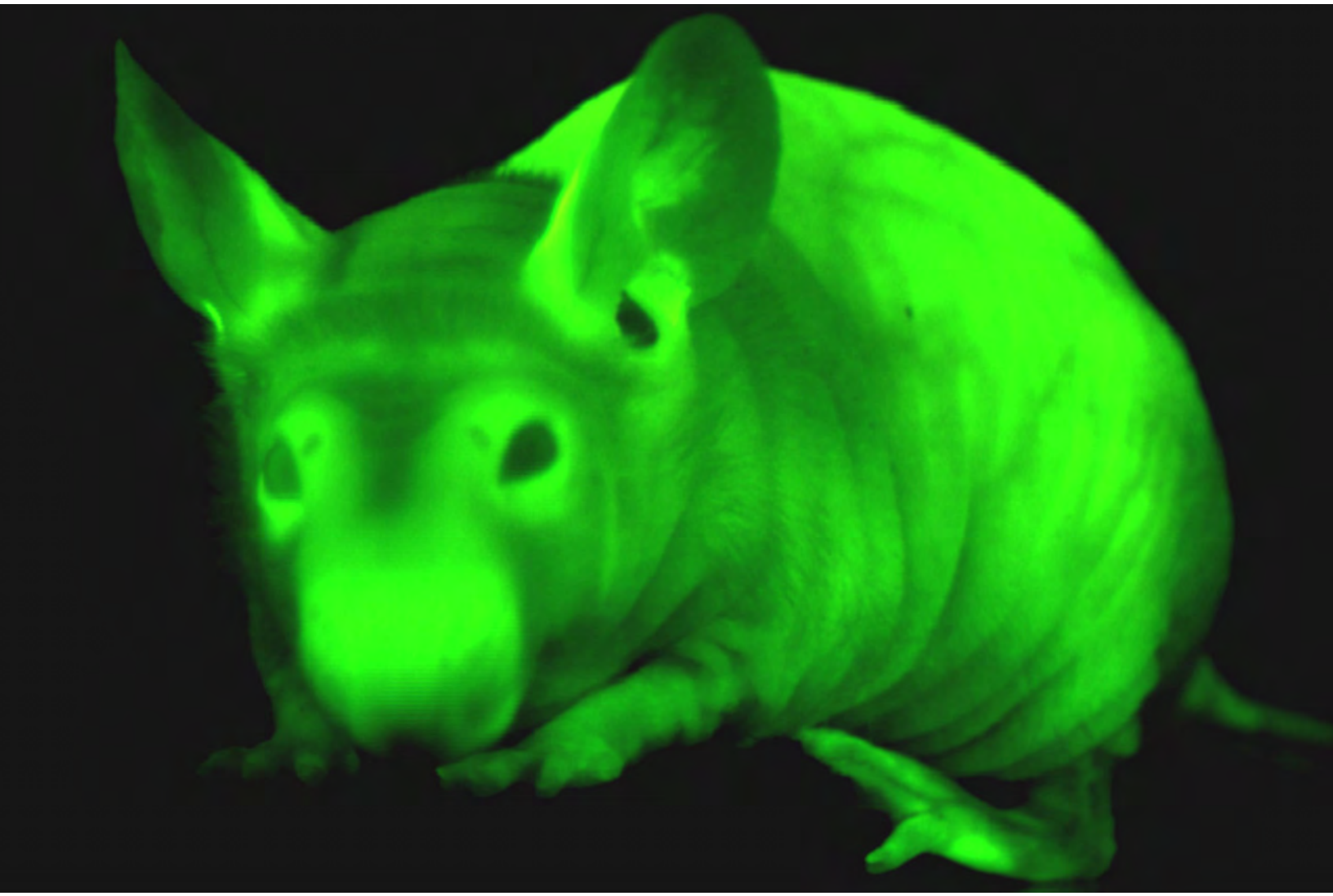
ESSENTIAL LENS

ANALYZING PHOTOGRAPHS ACROSS THE CURRICULUM



Genetics and Bioengineering: The Societal Impacts of Mutations

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Genetics and Bioengineering: The Societal Impacts of Mutations

Standards

These points are in accordance with Disciplinary Core Ideas—Life Sciences, LS3 Heredity and LS4 Biological Evolution from the 2012 Framework for K-12 Science Education from the National Research Council of the National Academy of Science.

Also consistent with the Framework, students should be ready to apply crosscutting concepts of cause and effect, structure and function, and stability and change.

Recommended laboratory activities to go with the photographs and activities are DNA extraction, bacterial transformation, PCR, plasmid manipulation, electrophoresis, and looking at cells under a microscope.

Prerequisite Knowledge

Before viewing the photos and doing the activities, students should be able to:

- Define a mutation.
- Describe the relationship between genes, DNA, proteins, and traits.
- Explain adaptation and natural selection.

Introduction

For at least 10,000 years, humans have been cultivating plants and selectively breeding them for fast growth, pest resistance, long-term survival in storage, and bigger and better fruit. We've been domesticating animals for just as long, selecting for traits that suited our needs, such as size, appearance, or even personality. For a few decades, we've also had genetic engineering methods for getting the characteristics we want in plants, animals, and microorganisms.

Genetic engineering, genetic modification, and recombinant DNA technology often refer to the same process: isolating specific pieces of DNA from one cell's chromosomes and transferring them to another cell to create a GMO (genetically modified organism). The transferred pieces of DNA often contain genes that confer a trait, such as pest resistance in plants.

In this photo collection, explore how random mutations, human selection, and genetic engineering have affected living organisms. Consider the effect of these elements of change on society, and the benefits and potential harms of genetic engineering.

Curriculum Snapshot

The content of this photo collection and associated activities aligns with and supplements a life science curriculum, particularly concepts of the central dogma (DNA, RNA and protein), heredity, natural selection, and evolution.

Grade Level

High School

Classroom Connections

Life Science; Engineering, Technology, (optional: Physical Science)

Key Learning Targets

Students will:

- Compare and contrast random, spontaneous, naturally occurring changes in DNA (mutations) against changes in DNA that are induced or directed by humans, such as in genetic engineering.
- Compare and contrast natural and artificial selection, and relate selection to evolution—change in a population over time.
- Use photographs to discuss specific examples of GMOs and their potential impact on society.

Essential Questions

Big ideas or essential questions help to organize the content and topics. Exploring the concepts of genetic engineering and modification through this collection of photographs will allow students to consider the following questions:

- How are spontaneous mutations and genetic engineering similar and different?
- How are natural and artificial selection similar and different?
- What uses of genetic engineering methods are potentially beneficial and harmful to society?
- What are some pros and cons of using genetic modification for agriculture, medicine, art, or entertainment?

ACTIVITY 1
Activating Students' Prior Knowledge

Ask students to brainstorm what genetically modified organisms look like.

Emphasize that, at this point, no answers are right or wrong. Potential prompt: ask how genetic engineering is shown in movies, television, and books. If general examples of mutants come up, review the definition of a mutation as a change in DNA.

ACTIVITY 2

Identifying Spontaneous Mutations and Genetic Engineering

Learning Targets

- I can describe examples of GMOs.
- I can compare and contrast naturally occurring mutations and genetic engineering.
- I can describe selective breeding (artificial selection) and its effect on a population.
- Optional: I can explain the difference between genetic modification and cloning.

Background

This information is not for classroom content, but to prepare teachers for the photographs, activities, and potential questions from students.

Artificial selection, natural selection, genetic engineering

Almost all the food we eat in the United States—and elsewhere—is the result of artificial selection: decades or centuries of choosing plants and animals to propagate based on desirable traits such as taste or rapid growth. Organisms in a population have varying traits because of diversity in their genetic makeup. Some of this diversity comes from naturally occurring, spontaneous mutations: changes in an organism's DNA that come from replication errors or exposure to environmental mutagens such as radiation or certain chemicals. Artificial selection mirrors natural selection, in which environmental conditions determine which organisms will survive to reproduce and pass their genetic information to the next generation. Natural selection is the basis for evolution: gradual changes in populations of organisms over time.

For the last few decades, our ability to control the traits of organisms has been supplemented by genetic engineering, also called recombinant DNA techniques. Simply put, genetic engineering is creating a genetically engineered organism (GMO) by transferring a gene from one organism to another. The gene might be from the same or different species. If your students have done a DNA extraction laboratory, they have done the first step in genetic engineering. The next step is isolating an individual gene and transferring it into cells. If students have done a bacterial transformation laboratory, they have done this step. Other laboratory techniques, such as gel electrophoresis and polymerase chain reaction (PCR), are also often used in genetic engineering. (See References and Further Reading for details.)

Photographs for This Activity (Appendix, pgs. 20-29)

2001, 2003, 2004, 2006, 2007, 2008, 2009, 2012, 2013, 2015

Medical and agricultural uses of genetic engineering

Genetically engineered microorganisms or other cultured cells are used to make insulin for diabetes; growth hormone for children with pituitary defects; Herceptin, a cancer treatment for some types of breast and stomach cancer; vaccines against hepatitis B and other infectious diseases; and other medicines.

Genetic engineering has made it easier to produce proteins such as human growth hormone and erythropoietin (EPO), which stimulates production of oxygen-carrying red blood cells, creating the potential for abuse. This has led to controversies when athletes break sports league rules by using these products.

Even people who don't use medicines from GMOs have probably eaten GMO products. An estimated 90 percent of corn and soybeans grown for food and livestock feed in the United States are genetically modified. GMO corn or soy is common in processed food, often in the form of corn syrup or starch, or soy protein. While Americans have been consuming food from GMO plants for decades, GMO foods (but not medicines) are much less common in Europe.

The genes introduced into GMO crops often confer insect resistance, which means that plants need to be treated less often with chemicals to kill insect pests. Genes added to make plants GMO might confer resistance to an herbicide, so that fields sprayed with the herbicide kill weeds but not the crop plants.

An objection to using GMOs for food is that this policy encourages a monoculture—cultivation of a single type of organism. Populations of genetically similar or cloned plants are less resistant to disease or other threats because the population doesn't have the genetic variety needed to adapt and evolve.

Another objection to GMO foods is the benefit to large agricultural corporations. For example, a single corporation might sell both the herbicide-resistant GMO plants and the herbicide, making farmers dependent on the company's products.

Some people who protest GMO food claim that commercial chickens or turkeys are genetically modified to grow faster or bigger or featherless, or that cows are genetically modified to have more muscle. This is not true. Animals might be fed GMO corn. They might be injected with recombinant growth hormone produced by and purified from GMO microbes. But the animals themselves are the result of generations of selective breeding, not genetic engineering.

We have techniques for genetically modifying some animals, but the process is often difficult and expensive. Growth hormone genes can be added to fish, for example, to make them grow faster. These animals are GMO, and food scientists, farmers, and governments are considering cultivating them for food.

An estimated 90% of corn and soybeans grown for food and livestock feed in the United States are genetically modified.

Optional information: cloning

As for cloned animals, to a scientist "cloning" means making a genetically identical copy. This can be a copy of a piece of DNA, a cell, or an organism. (Under this definition, twins are clones.) The experiments that have produced some cloned sheep, dogs, cows, and pigs are technically tricky, but becoming easier. Cloning plants is relatively easy. Many plants can be cloned by cutting a section or branch and grafting it onto another plant, or inducing root growth in water or with hormone treatment.

The photographs

Some photos in this collection show GMOs; however, some show organisms—including people—with dramatic appearances that are not the result of genetic modification. Random, spontaneous mutations in genes can drastically change traits, although these types of mutations are rare. Many mutations do not visibly change traits, and some mutations cause disease or death.

In this photo collection, some GMO cells have received a recombinant gene for a single protein that is fluorescent: it absorbs light at one wavelength and emits it at another, visible wavelength — organisms that make the protein glow green. This photo collection provides visual examples to provoke questions and discussions about mutations, selection, and genetic modification.

Begin the Activity

After the discussion in Activity 1, have students, in pairs or small groups, review the definition of a mutation and what they know about genetic engineering. Project the activity photos or give copies of the photos to the student groups. Ask students to describe what they see; that is, what kind of organism it is and how it is different from other organisms of that type. For photos that show two contrasting situations, ask them what major differences they see. Ask if they see anything else of note. Then, ask students if they think the photographs show examples of spontaneous mutations or examples of genetic engineering.

(If necessary, review spontaneous mutations as changes in DNA that occur without known or deliberate exposure to a mutagen. Spontaneous mutations can result from random errors in DNA replication.)

Ask students to share the thoughts of their group, describing the features they focused on. Emphasize that this exercise is to explore impressions, and no answers are right or wrong. When assignments of spontaneous mutation vs. genetically engineered are revealed, ask which assignments were expected, which were unexpected, and why.

Random, spontaneous mutations in genes can drastically change traits, although these types of mutations are rare.

Guide to Photographs

British Blue cows (2008): A naturally occurring, spontaneous mutation; selectively bred. The cows were first described in the 1800s. They have versions of the myostatin gene that result in extra muscling. (Myostatin is a protein that restricts muscle growth, some mutations in myostatin result in extra muscling.)

Boy (2013): A naturally occurring, spontaneous mutation. His myostatin genes have the same effect as in the British Blue cows. This combination of genes is so rare that it has been described in only a few humans. (Some people, however, including athletes, might have versions of the gene that result in more muscle than average without the dramatic change in appearance.)

Featherless chicken (2009): A naturally occurring, spontaneous mutation; selectively bred.

Salmon (2001): The large one is GMO; the smaller one is not. The large one was genetically modified to produce extra growth hormone.

Nude mice (2015): A naturally occurring, spontaneous mutation; selectively bred. Nude mice are used in research because characteristics of their immune systems make them particularly useful, especially for cancer research. The nude mouse strain is not GMO, however. The original mouse was discovered in the 1960s, before GMO methods were invented.

Fluorescent nude mice (2012): GMO. Any mice—in this case nude mice—can be genetically engineered to produce a protein called green fluorescent protein (GFP), described in the next exercise. The GFP nude mice are examples of both naturally occurring mutants that were artificially selected because of their usefulness in research, and GMOs. Any other photos of fluorescent green mammals are GMO.

Bt plants (2003, 2004): Genetically modified with the Bt gene from the soil bacterium Bacillus thuringiensis. The gene encodes a protein that interferes with insect digestion, so insects that start to eat the plant get sick or die. In the photo of the cotton field, left is GMO plants; right is non-GMO.

In vitro meat (2006, 2007): The wildcard: not mutated or GMO. These are muscle cells, probably from cows or pigs, grown in the laboratory. They don't necessarily contain any mutations—natural or induced. They aren't necessarily genetically engineered. They might become a meat source that doesn't require farming animals, but right now, muscle cells grown in vitro (Latin for "in glass") are too expensive to be practical. The cells are clones, as defined by scientists. The cells divide from one cell into two, creating genetically identical cells.

This photo collection provides visual examples to provoke questions and discussions about mutations, selection, and genetic modification.

Questions to Consider

Q: How do these photos confirm or contradict common perceptions about mutations and about genetic engineering?

A: Students will probably not be surprised that the GFP animals are GMO, but might be surprised that the dramatic muscles of British Blue cows and the hairless feature of nude mice are not the result of genetic engineering.

Q: Do you think these photographs have been manipulated or set up?

A: See "Uses of Genetic Engineering" below for an explanation of how filters are used to see and photograph GFP fluorescence. A common trick when taking sports fishing photos is to hold the fish at arm's length toward the camera to make it look larger. In this case, however, the fish are actually different sizes.

Q: Does the source of the photo (researcher, news media, blogpost, etc.) affect your opinion about whether the photographs were manipulated or staged?

The boy with extra muscles has myostatin genes that result in his physiology. His parents don't have extra muscles. Why?

A: For inheritance calculations, remember that everyone has two copies of every gene: one inherited from the mother and one from the father. A single gene with a dominant mutation, inherited from either parent, will be expressed (that is, the trait will be apparent). Recessive mutations will be expressed only if inherited from both parents.

The more nuanced point is that the myostatin mutation is incompletely dominant. This means anyone who inherits the mutation probably has extra muscles, but the super-muscled trait requires inheritance of two mutated genes—one from each parent. In addition, other genes and, of course, environmental and behavioral factors, affect muscle development. The British Blue cows all have hypertrophied muscles because of generations of artificial selection.

Q: The boy's mutation is extremely rare: he might never meet another person with the same muscle characteristics. If he has children someday, will they have the same musculature?

A: See notes above about the inheritance pattern of the myostatin mutation that results in extra muscles.

Q: What might be some advantages and disadvantages of GMO crops (such as the insect-resistant plants) for 1) farmers? 2) companies that generate and sell seeds for GMO crops? 3) consumers? 4) society?

A: Students might list advantages in cost, yield, and profit; and disadvantages of monoculturing or other environmental effects, corporate control over farmers, and concerns about eating genetically engineering food. These could be used as starting points for the Extension Activities.

ACTIVITY 3

Uses of Genetic Engineering

Ask if students have seen cells under a microscope or seen photos of cells under a microscope. (Their textbook might have examples.) Ask them to describe how the cells looked: easy or hard to see, flat or 3-dimensional, shape, size (scale), and colors. Ask them to consider whether the cells were living or dead, and if they had been processed in some way (for example if they were stained before they were viewed or photographed).

Emphasize that at this point, no answers are right or wrong. Potential prompt: ask if they think cells from a biopsy (tissue sample from a patient) that a doctor looks at are living or dead.

Learning Targets

- I can describe an example of how genetic engineering is used in research.
- I can use a photograph to get and present data.

Background

This information is not for classroom content, but rather to prepare teachers for the photographs and activities and potential questions from students.

One of the genes that is most commonly transferred into organisms—from bacteria to mammals—is green fluorescent protein (GFP). GFP occurs naturally in the jellyfish *Aequorea victoria*. GFP protein is fluorescent: it absorbs light at one wavelength and emits it at another. (This is different from bioluminescence, such as light from fireflies, which is generated by a chemical reaction by specific enzymes and substrates.) GFP absorbs blue light and emits green light. GFP photographs are taken with camera filters, so only the emitted green light is seen. GFP fluorescence can be so strong, however, that a test tube of purified GFP glows faintly green in natural light.

Photographs for This Activity (Appendix, pgs. 30 and 31)

2019, 2020

Begin the Activity

Part 1

Explain to students:

- Cells are hard to see. Illustrations of cells in textbooks are brightly colored, but real cells are transparent. To see cells under a microscope, scientists usually stain them. For example, pathologists stain tissue biopsies to be able to see if cells are abnormal or normal. Staining kills cells, however, and makes them expand or shrink. GFP allows researchers to see living cells by using a special fluorescence microscope.

- GFP is a naturally fluorescent protein. The gene originally comes from fluorescent jellyfish. Scientists use GFP as a "reporter" protein: it "reports" on the location, size, movement, or metabolism of cells. Transferring the GFP gene into cells makes them fluorescent so scientists can observe them in their natural, living state. Scientists use GFP to track the growth of neurons, organ development in embryos, and the spread of cancer cells. In 2008, scientists who developed use of GFP as a reporter won in the Nobel Prize for medicine.

- In this activity, GFP is used to measure myotubes, which are developing muscle fibers. The photographs were taken with a fluorescence microscope by scientists who are studying the effect of myostatin, the protein whose gene is mutated in British Blue cows and in people with the hypertrophied muscles. Myostatin inhibits muscle development. That is why when the gene for it is mutated and less myostatin or defective myostatin is made, extra muscle is produced.

Part 2

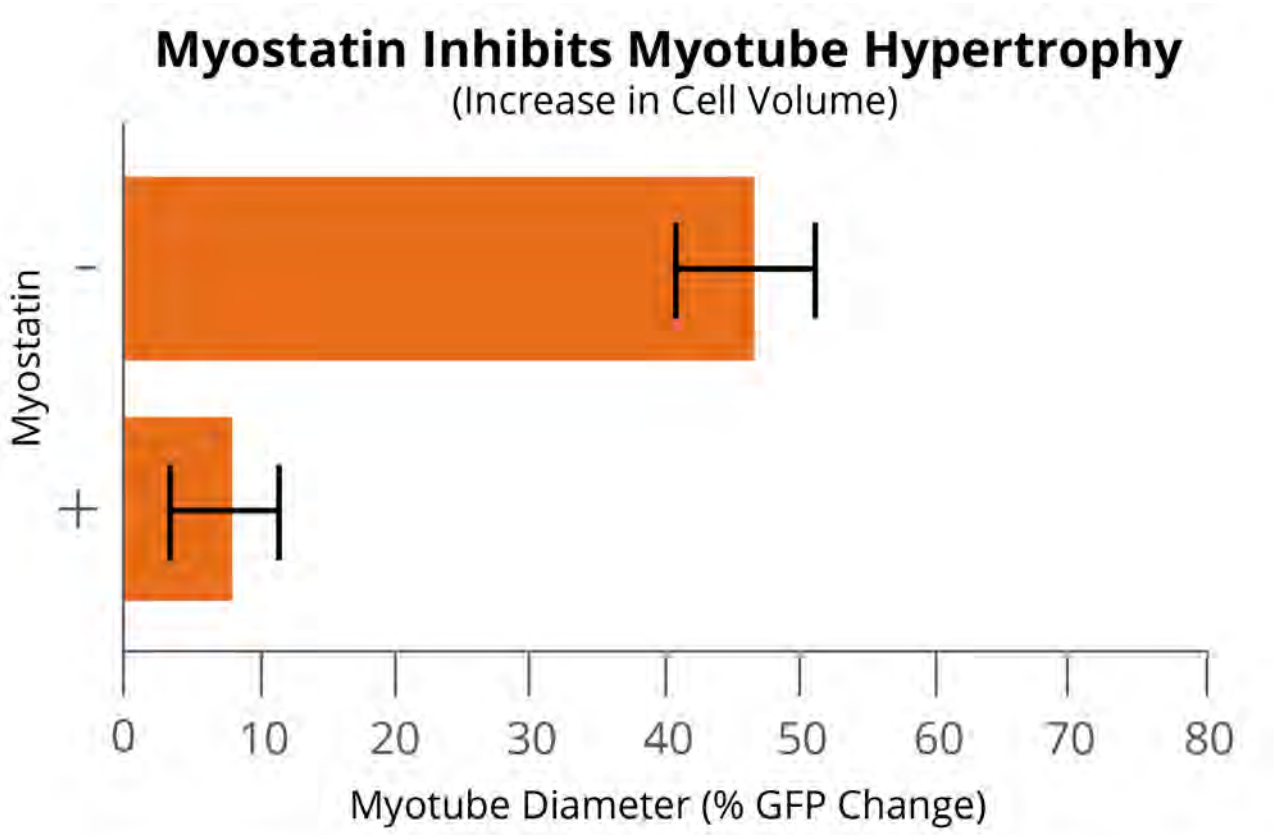
Give students handouts of the photos. In pairs or small groups, have students measure the width in millimeters of as many cells as possible from the photos of GFP cells, and then calculate an average width for each cell type. Ask students to make a bar graph of their results.

Note that students will need to make decisions about how many cells to measure and where to measure. They'll need to consider and report on the precision of their measurements based on their equipment. Assure them that all scientists deal with these issues.

Graph features should include width in millimeters on the Y axis and cell types on the X axis, labels for both X and Y axes, a Y axis that begins at 0 and has correctly spaced unit marks, and a title and a legend that explains graph features.

Materials:

- Rulers, pencils, graph paper



Morissette MR, Cook SA, Buranasombati C, Rosenberg MA, Rosenzweig A. Myostatin inhibits IGF-I induced myotube hypertrophy through Akt. *Am J Physiol Cell Physiol* 297: C1124–C1132, 2009.

2018 - *This graph shows data that the scientists obtained from measuring at least 50 myotubes and averaging the results. In the graph, "0" was defined by measuring GFP myotubes that were not exposed to the hormone or to myostatin (photo not shown). Error bars show standard error. (Note: Students will probably draw a graph with vertical bars, which is a more standard orientation.)*

Questions to Consider

Q: What conclusions can you draw from your measurements and graphs?

A: Genetically modifying myotube cells with the GFP gene made it easier to see, photograph, and measure the cells. Without the GFP gene, researchers would have to kill, process, and stain the myotubes, which might change their shape and size.

Normally, myostatin balances myotube growth. Normal myotubes are smaller than myotubes that are altered or treated to block the myostatin pathway. The scientists who did this experiment saw about a four-fold difference in diameter between myotubes with and without myostatin. Myostatin slows and controls muscle growth.

Q: What is the connection between your results and the appearance of people or animals who make less myostatin than usual.

A: Myostatin restricts muscle growth, so animals or people with certain mutations in myostatin have extra muscles.

Q: What medical or commercial implications might these findings about myostatin have?

A: People with muscle-wasting diseases, such as muscular dystrophy, might benefit from therapy to block myostatin, which might grow their muscles. Athletes might want to use the same therapy for a competitive advantage.

Q: What issues came up in your data collection that you would report if you were writing about this experiment?

A: See notes above about deciding how many cells to measure, where to measure, etc.

Q: If you could genetically modify any organism, what would you modify and why? How might you do it?

A: Students might think of applications in agriculture, arts, or science. This could be a starting point for a writing assignment or presentation, investigating whether anyone has tried that application before and, if so, what the results were.

Essential Lens Video Connections

- Watch ***A Closer Look*** to learn more about analyzing photographs.
- Watch the ***Evidence*** video to view a middle school teacher conducting a modified activity from this collection, as well as an interview with scientist and photomicrographer, Dennis Kunkel, and environmental photographer, Gary Braasch.

Extension Activities

1. Case study analysis: Choose a GMO case study, either: 1) herbicide-resistant corn (maize), 2) insect-resistant corn (maize), 3) golden rice, or 4) NewLeaf potatoes. Investigate and write about or give a presentation on how and why the plant was genetically modified. Describe advantages and disadvantages to society of the GMO plant.

2. Writing activity: Write persuasively about whether myostatin inhibitors should be allowed in amateur or professional sports.

3. Cross-disciplinary writing activity: Investigate and write about how growing crops that are selectively bred or genetically modified affects biodiversity. Describe what scientists and farmers are doing to preserve biodiversity; for example, creating seed banks, preserving habitats, or encouraging diversity in agriculture.

4. Cross-disciplinary lesson **(2010, 2011)**: For research purposes, scientists have made directed mutations in GFP to alter the color of light it emits. Genes for other fluorescent proteins have also been isolated, creating a spectrum of fluorescent proteins available for research. This means that individual living cells can be distinguished by their different colors, even when they are in a mass of cells—such as the mouse brain cells. The color spectrum of fluorescent proteins with the wavelengths of light emitted by each protein could be the basis of a cross-disciplinary lesson with physical sciences.

Photographs for Extension Activity 4 (Appendix, pgs. 32 and 33)

2010, 2011

References and Further Reading

Basics of heredity, DNA, genes, genetic modification

Commonwealth Scientific and Industrial Research Organisation of Australia
http://www.csiro.au/Outcomes/Food-and-Agriculture/WhatIsGM.aspx#

Annenberg Media: Rediscovering Biology
http://www.learner.org/courses/biology/textbook/gmo/index.html

AFP News
http://www.youtube.com/watch?v=HZmZ161njr8

Independent Filmmaker
http://www.youtube.com/watch?v=LSBnoGZoAHs

MIT
http://www.youtube.com/watch?v=nfC689ElUVk

Lab kits, education programs, and supporting materials

Bio-Rad
http://www.bio-rad.com/en-no/education

Carolina
http://www.carolina.com/resources/home.jsp

Project Lead the Way
http://www.pltw.org

Khan Academy (requires free registration)
https://www.khanacademy.org

Framework for Science Education
A Framework for K-12 Science Education. Practices, Crosscutting Concepts, and Core Ideas.
http://www.nap.edu/catalog.php?record_id=13165

GMO food videos, activities, book and film

PBS Botany of Desire
http://www.pbs.org/thebotanyofdesire/potato-control.php

Pollan, Michael. *Botany of Desire.* Random House, 2002.

Michael Pollan TED talk on "A Plant's Eye View"
https://www.ted.com/talks/michael_pollan_gives_a_plant_s_eye_view

Future of Food documentary
www.thefutureoffood.com

Myotube and myostatin experiments
Morissette, et al. 2009. American Journal of Physiology.
http://ajpcell.physiology.org/content/297/5/1124

APPENDIX

Activity 2 - **2001** - *Transgenic Atlantic Salmon, AquAdvantage® Salmon, (background) and a sibling non-transgenic Atlantic salmon of the same age (foreground). The genetic modification is the insertion of one gene from a Chinook salmon that produces growth hormone and a promoter sequence from the ocean pout that acts as the "turn on" switch. This gene construct allows the AquAdvantage Salmon (AAS) to produce its own growth hormone all year round instead of in the spring and summer months. 2009. (AquaBounty Technologies)*

Activity 2 **2003**
Comparison of unsprayed conventional cotton crop and Bt GM cotton crop in Australia.

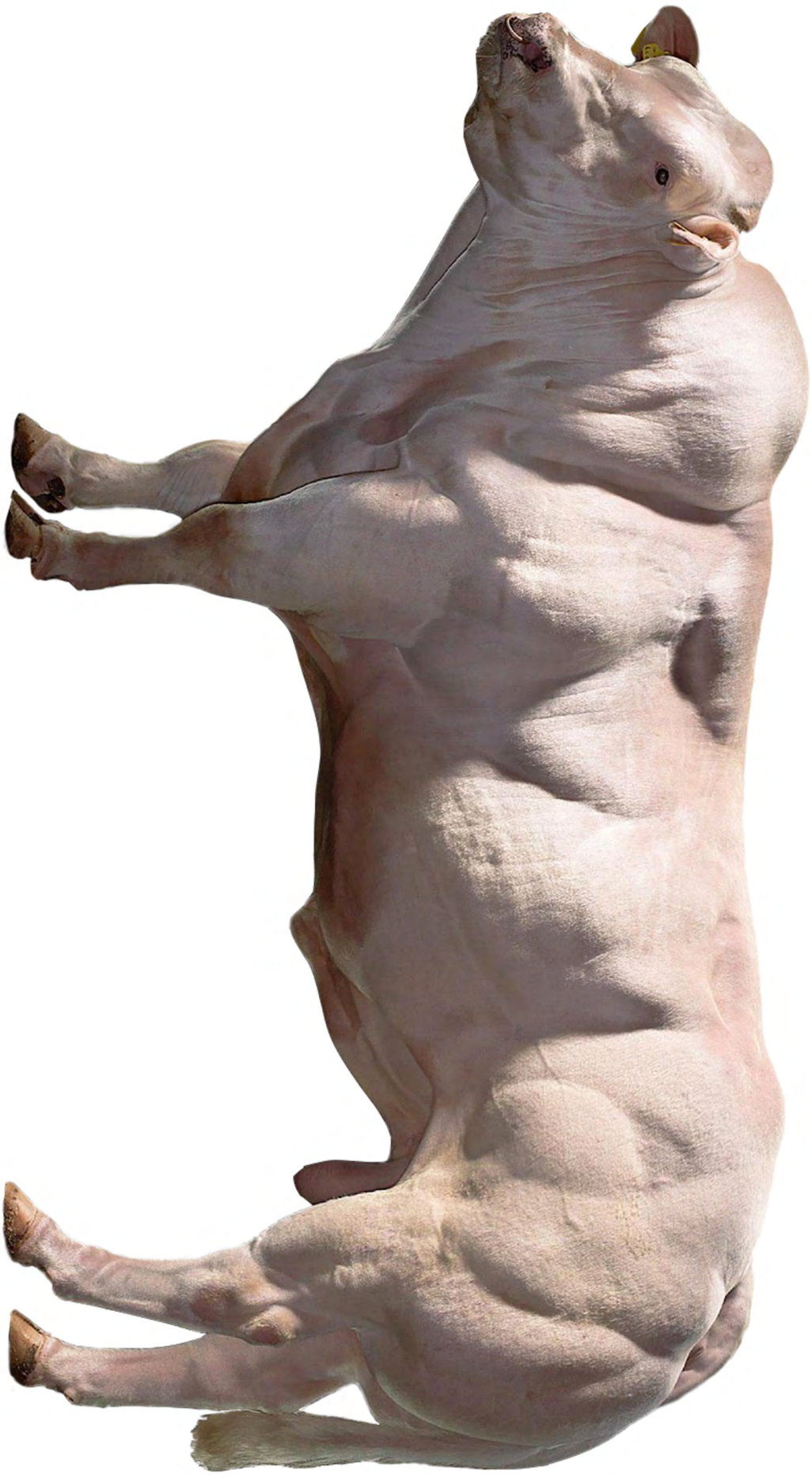
Bacillus thuringiensis (Bt) is a spore-forming bacterium that produces crystal proteins that are toxic to many species of insects. Crops have been modified with short sequences of genes from Bt to express the crystal protein Bt makes. With this method, plants themselves can produce the proteins and protect themselves from insects without any external Bt and/or synthetic pesticide sprays. 2006. (Cotton Australia)

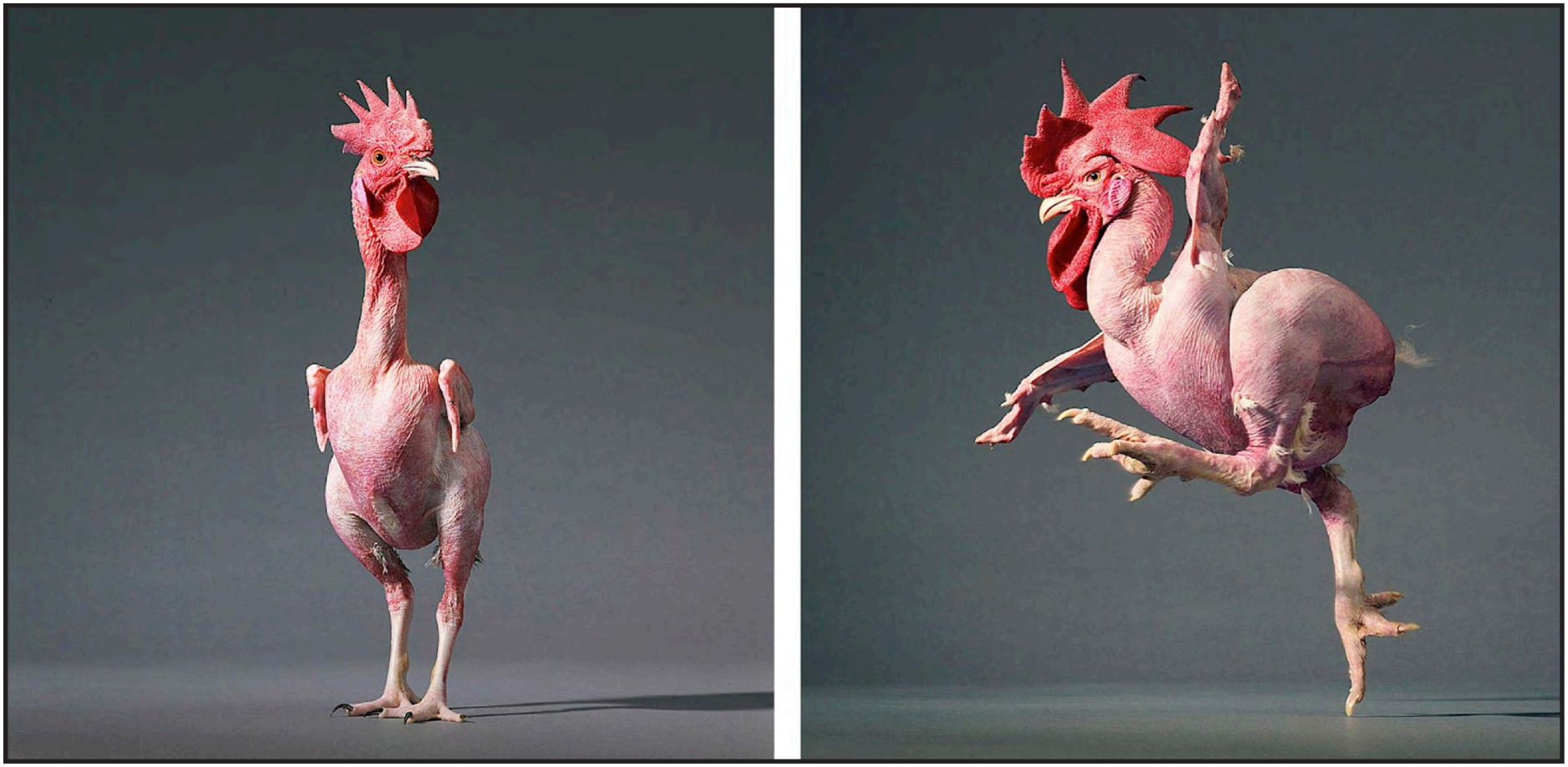
Activity 2 - **2004** - *Left: After only a few bites of peanut leaves with built-in Bt protection, this lesser cornstalk borer larva crawled off the leaf and died. Right: Lesser cornstalk borer larvae extensively damaged the leaves of this unprotected peanut plant. 1999. (Herb Pilcher/USDA)*

Activity 2 - **2006** - *A burger made from Cultured Beef, which has been developed by Professor Mark Post of Maastricht University in the Netherlands. August 5, 2013. London, England. (David Parry/PA Wire/Cultured Beef/Maastricht University)*

Activity 2 - **2007** - *A burger made from Cultured Beef, which has been developed by Professor Mark Post of Maastricht University in the Netherlands. August 5, 2013. London, England. (David Parry/PA Wire/Cultured Beef/Maastricht University)*

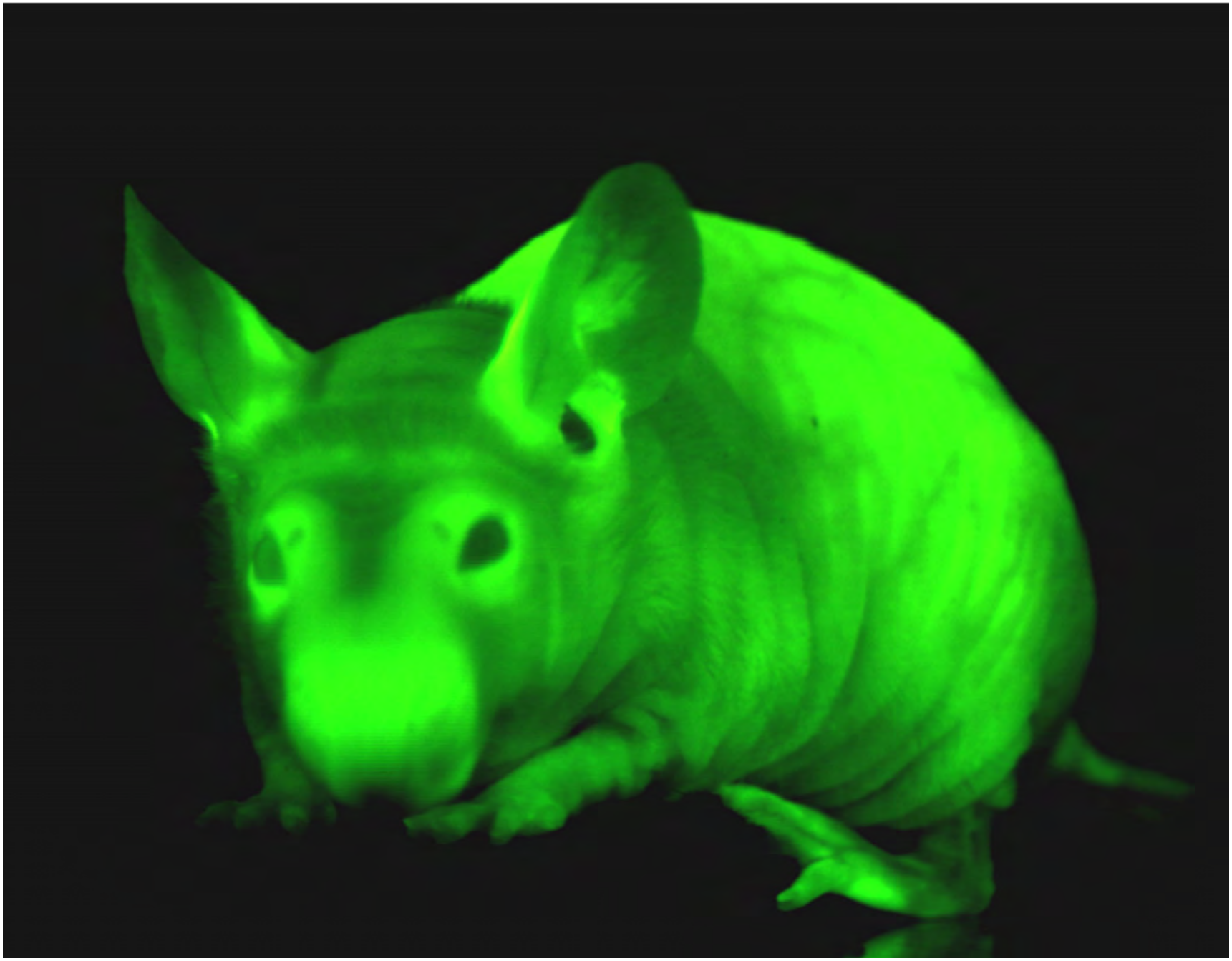
Activity 2 - **2008** - *Myostatin deficiency in a Belgian Blue cow. October 13, 2011. (Tim Flach Photography, LTD.)*



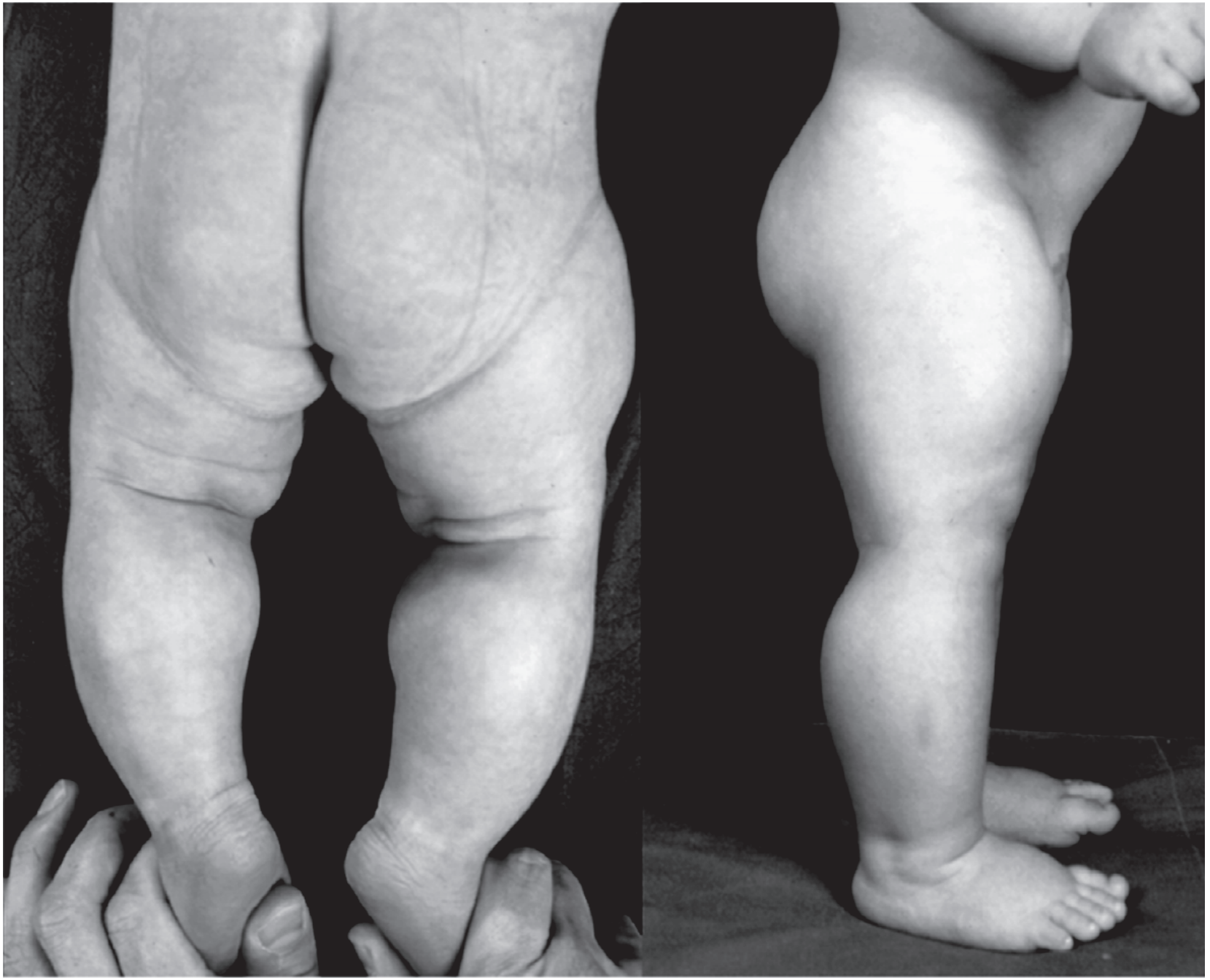


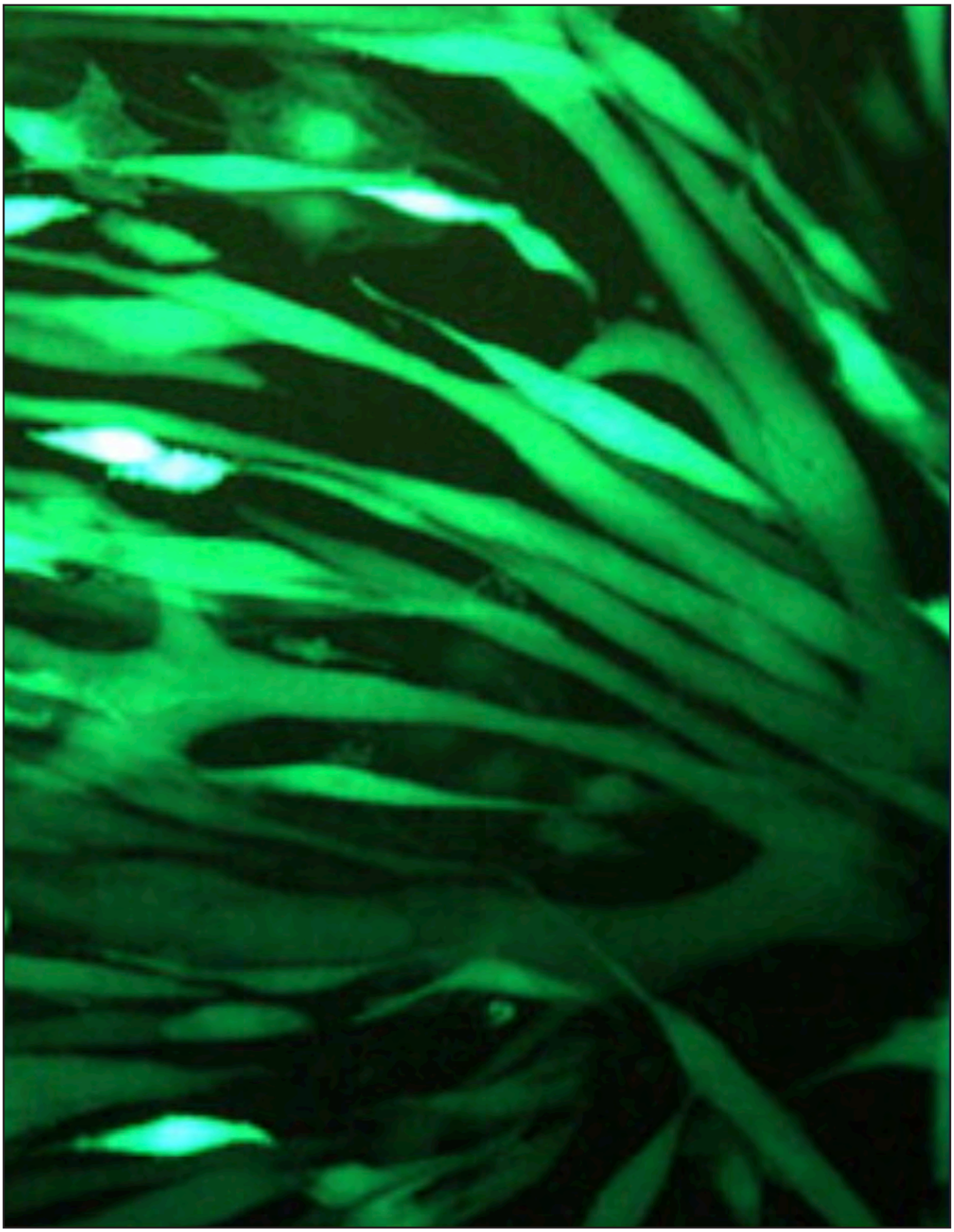
Activity 2 - **2009** - *Cross-breeding and the back-crossing of fat-growing meat-type chickens with individuals with a natural mutation produces "scaleless" or featherless chickens. September 12, 2011. (Tim Flach Photography, LTD/Avigdor Cahaner/The Hebrew University of Jerusalem)*

Activity 2
2012
GFP expression in the tissues and cells of the transgenic GFP nude mouse. 2004. (Courtesy of AntiCancer, Inc.)

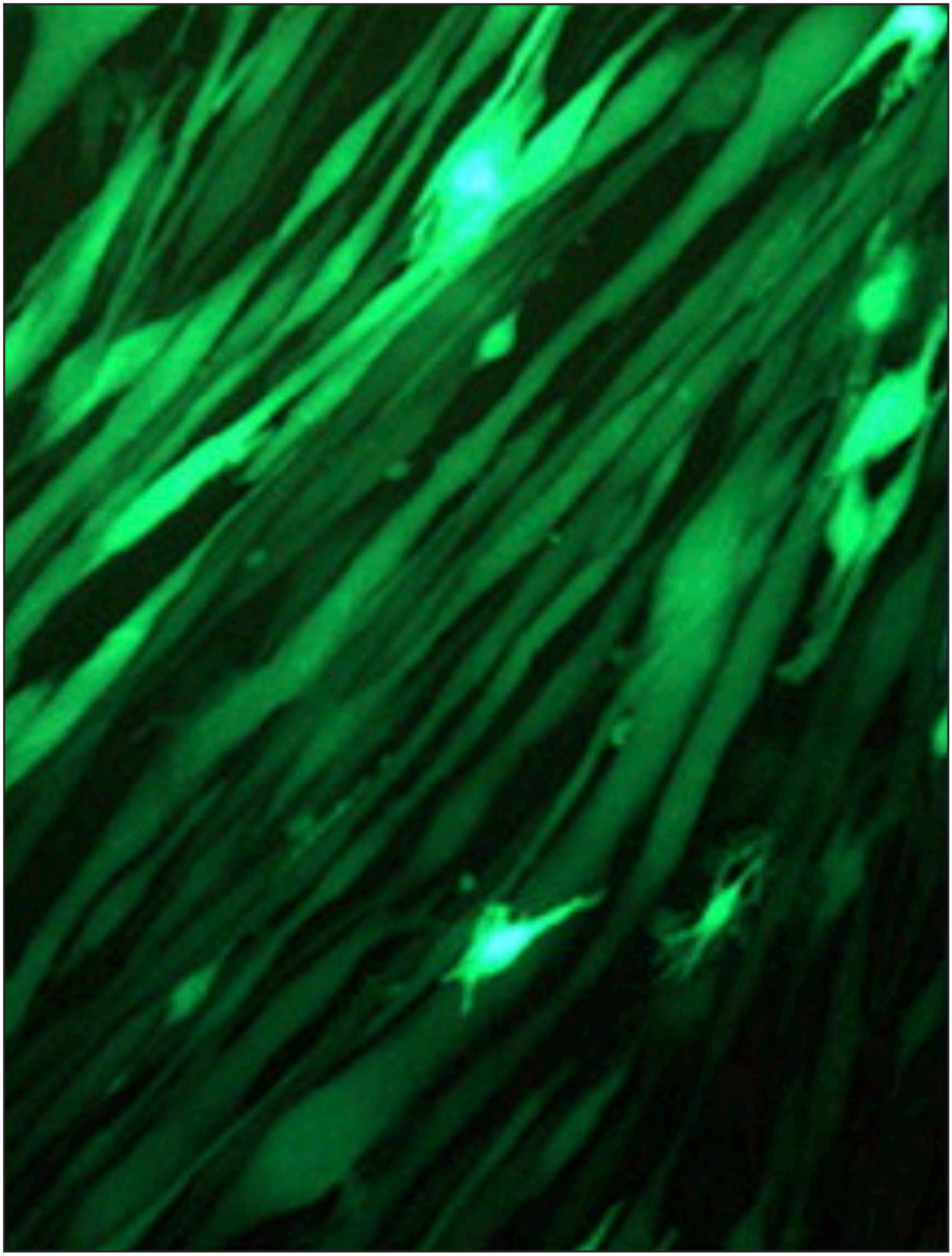


Activity 2
2013
Photographs of the child at ages six days and seven months. (From The New England Journal of Medicine, Markus Schuelke, Kathryn R. Wagner, Leslie E. Stolz, et al., Myostatin Mutation Associated with Gross Muscle Hypertrophy in a Child, Volume No.350, Page No. 2682–88. 2004 Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society.)

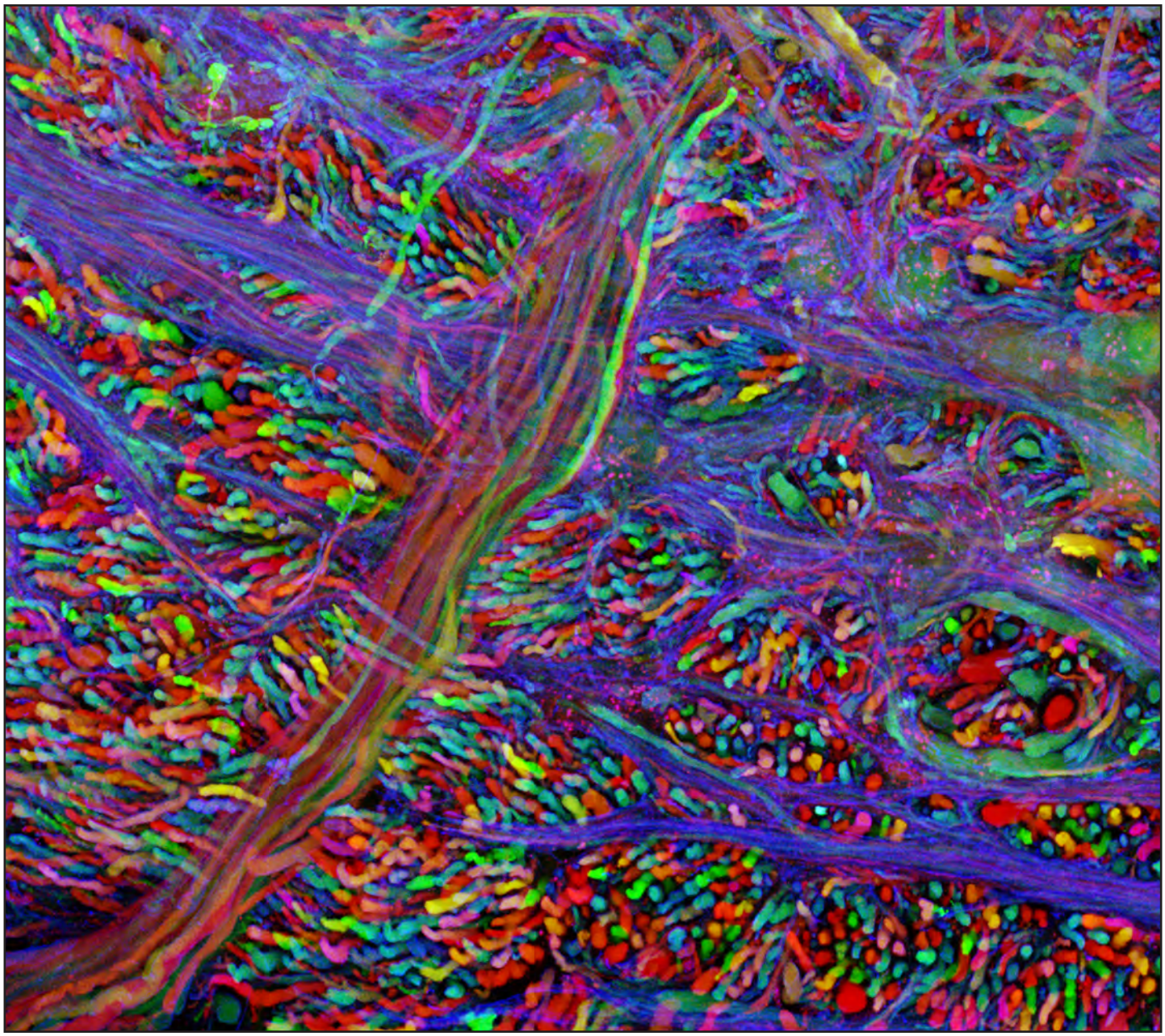




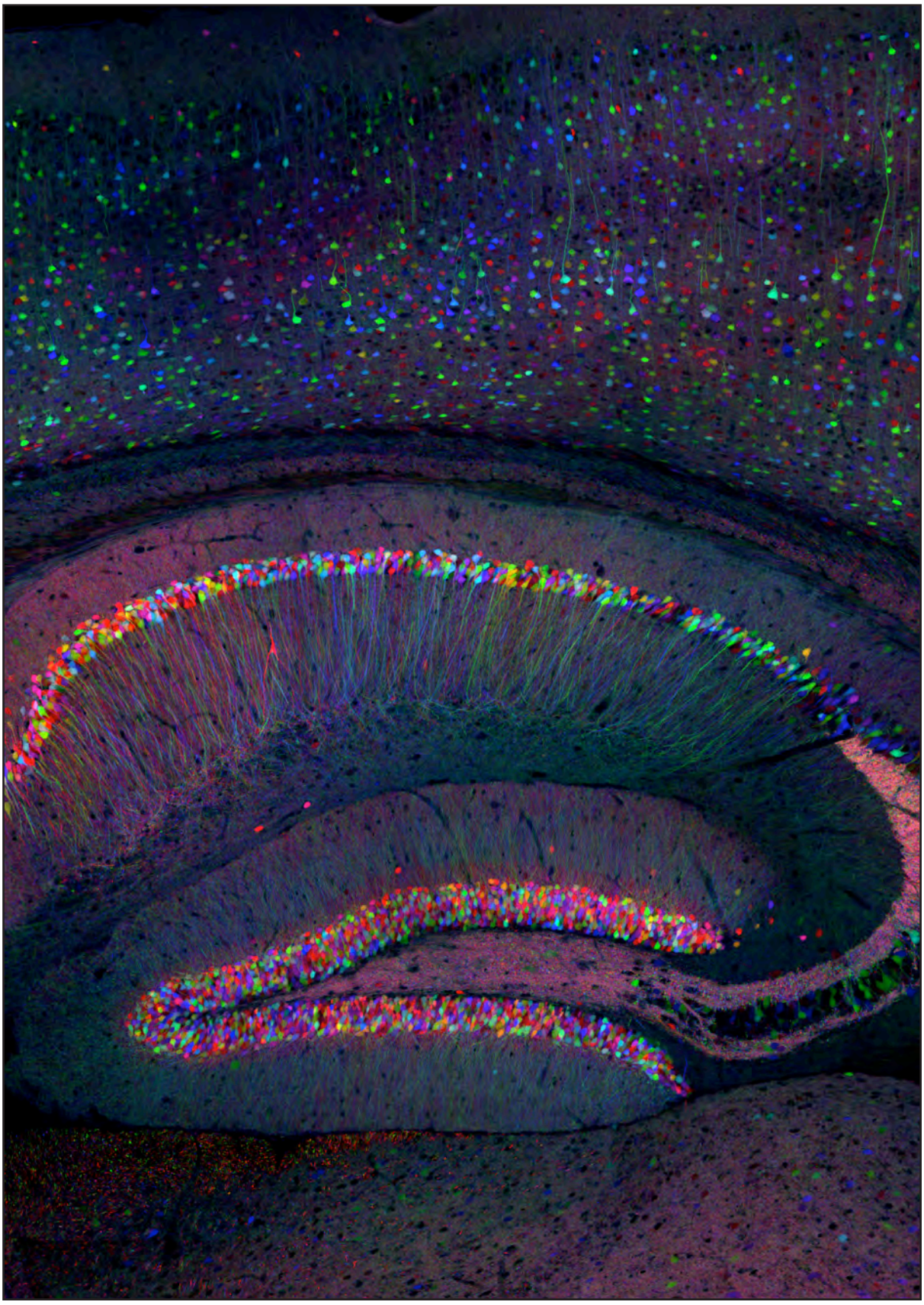
Activity 3 - **2019** - *The micrograph (microscope photo) shows mouse myotubes (developing muscle fibers) engineered to produce GFP so they can be seen with a fluorescent microscope. These myotubes were grown in a Petri dish and exposed to a hormone that stimulates development. (Michael R. Morissette, Stuart A. Cook, Cattleya Buranasombati, Michael A. Rosenberg, Anthony Rosenzweig "Myostatin inhibits IGF-I-induced myotube hypertrophy through Akt." American Journal of Physiology—Cell Physiology, Published 1 November 2009, Vol. 297, no. 1124-1132, DOI: 10.1152/ajpcell.00043.2009)*



Activity 3 - **2020** - *The micrograph (microscope photo) shows mouse myotubes (developing muscle fibers) engineered to produce GFP so they can be seen with a fluorescent microscope. These myotubes were grown in a Petri dish and exposed to both a hormone that stimulates development, but also myostatin.(Michael R. Morissette, Stuart A. Cook, Cattleya Buranasombati, Michael A. Rosenberg, Anthony Rosenzweig, "Myostatin inhibits IGF-I-induced myotube hypertrophy through Akt." American Journal of Physiology—Cell Physiology, Published 1 November 2009, Vol. 297, no. 1124-1132, DOI: 10.1152/ajpcell.00043.2009)*



Extension Activity - **2010** - *Brainstem of transgenic mouse. To trace the longer pathways that interconnect different brain regions, CBS labs developed a genetic method to label each individual nerve cell a different color to identify and track axons and dendrites over long distances. With light microscopy, scientists image the branching patterns and connections of all the axons within a region of the nervous system in transgenic mice that express a number of different fluorescent proteins in individual neurons. The idea here is to color-code the individual "wires" and "nodes." 2007–08. (Livet, Weissman, Sanes and Lichtman/Harvard University)*



Extension Activity - **2011** - *Hippocampus and cortex in mouse brain. To trace the longer pathways that interconnect different brain regions, CBS labs developed a genetic method to label each individual nerve cell a different color to identify and track axons and dendrites over long distances. With light microscopy, scientists image the branching patterns and connections of all the axons within a region of the nervous system in transgenic mice that express a number of different fluorescent proteins in individual neurons. The idea here is to color-code the individual "wires" and "nodes." 2007–08. (Livet, Weissman, Sanes and Lichtman/Harvard University)*

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