THE CRISPR Whisperer

PICTURE Series

for Ages 11 to 111

By Dorothy Semenow, PhD

Episode 01

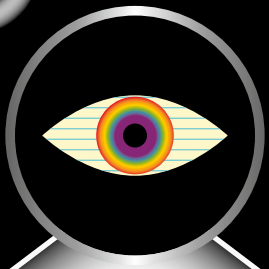
CRISPR Smarts via the Arts Starts Here

Illustrations by
Jane Burns &
Dave Wheeler

Graphic Design by
Eric Hansen

THE CRISPR Whisperer

PICTURE Series



Episode 01

CRISPR Smarts via the Arts Starts Here

Written by
Dorothy Semenow, PhD

Illustrated by
Jane Burns and Dave Wheeler
Graphic Design by Eric Hansen

Episode 01 CRISPR Science Smarts Via The Arts
DEDICATION

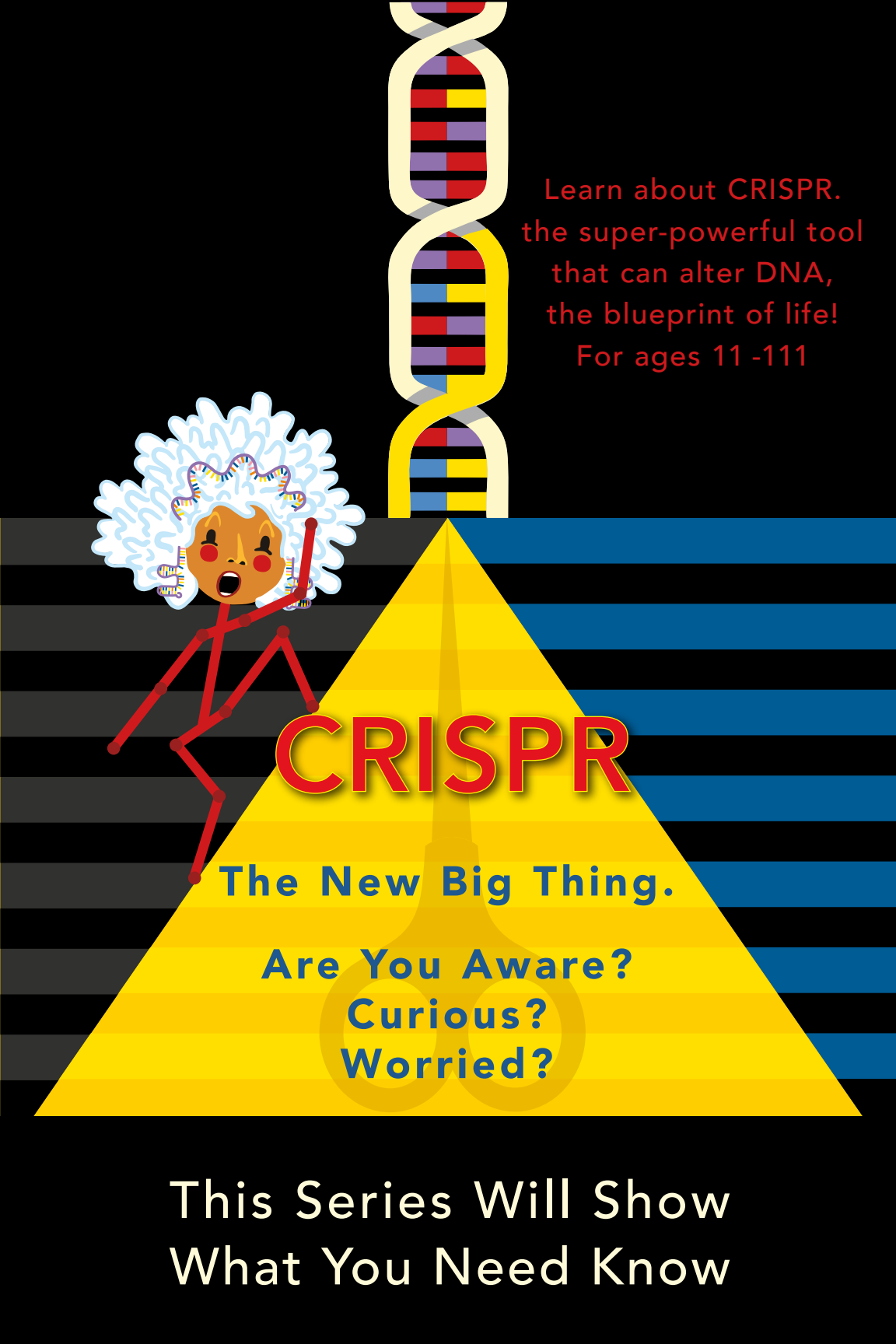
Chemistry & Teaching Were Their Calling

Emma Perry Carr (Mt. Holyoke College)

Anna Jane Harrison (Mt. Holyoke College)

Jack Roberts (MIT & Caltech)


You Don't Have To Be a Scientist
To Think Like One!


Learn about CRISPR.
the super-powerful tool
that can alter DNA,
the blueprint of life!
For ages 11 -111
CRISPR
The New Big Thing.
Are You Aware?
Curious?
Worried?
This Series Will Show
What You Need Know

Art shows. Words tell.
The CRISPR Series is a Science Show and Tell!

The CRISPR Series marries ***Art & Science*** in a humorous, hands-on romp designed to ***spark your creativity*** while clueing you in on an exciting new DNA editing tool called

CRISPR

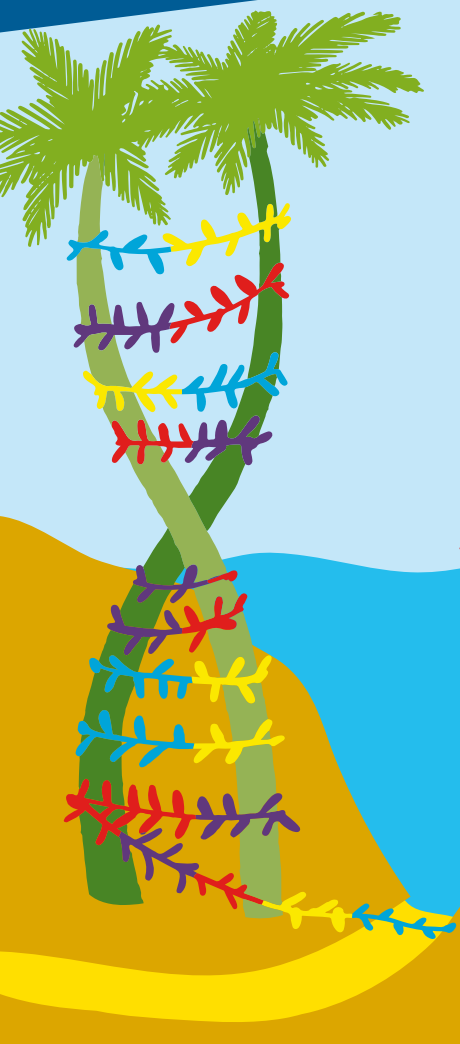
A for ART goes here

STE M

ALL ABOARD

THE CRISPR Whisperer

PICTURE Series



CRISPR can change the DNA of any living thing, even you!

Hop on the STEAMship for all the Whos, Whats & Myriad Whyfors.

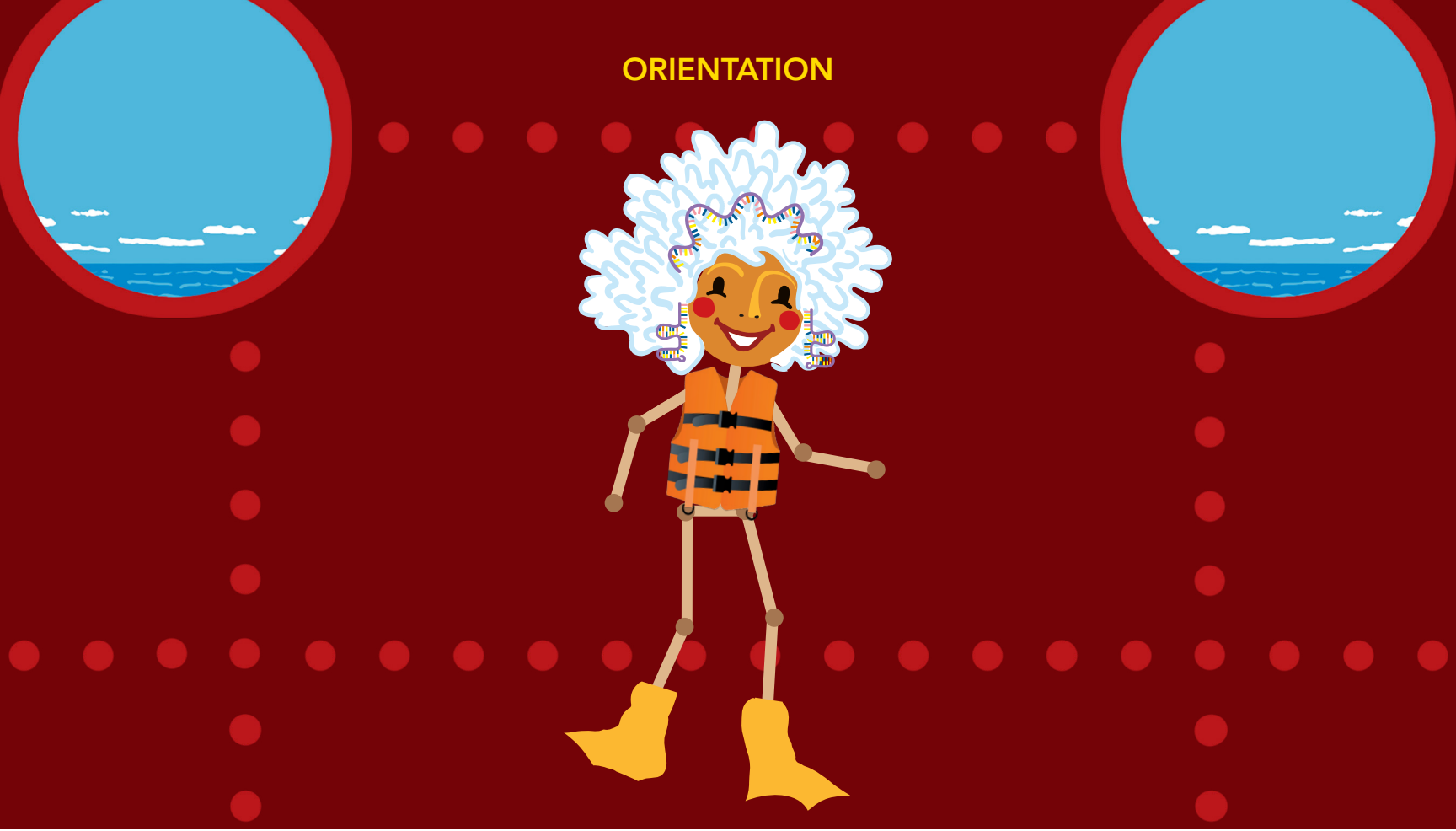
SIGN UP TODAY thinking caps provided

Ahoy! Welcome!

We're approaching CRISPR Island. Look through the porthole to see CRISPR greeting you from the roof of the CRISPR Science Lab.

The CRISPR molecule is portrayed throughout as a stick figure, made female in honor of the 2 women who launched her as a genome editor. You'll learn who she is, what she does and why she's pictured the way she is.

Episode 01 CRISPR Smarts Via The Arts
TABLE OF CONTENTS



The Tour's Orientation exhibit greets you as you embark. Note the locations of your hype filter and thinking cap ahead.

Who's Who?

Hello, I'm Doc Dorotheanna, the CRISPR Whisperer and your guide for this Picture Series. I'm also a chemist, psychologist, and creator of the DNA Ahead Board Game™. While adding CRISPR to the DNA game, I became so fascinated by her huge potential that I created this Series.

The Series aims to spark ideas for CRISPR's possible uses and help you decide which ones you support and which you don't. It also invites you—on your own or with others—to create art that captures bold, new scientific ideas.

Hello, I'm CRISPR, the star editor of DNA (and RNA). I'm made up of 2 connected molecules: an RNA strip that hunts down the target bases for me to edit and the Cas9 protein enzyme that carries out the edit. Just ahead, you'll see more about those component molecules and what makes them able to do their jobs.

I'm pictured here as a female, in honor of Emmanuelle Charpentier and Jennifer Doudna, who introduced my editing expertise to the world of science. Soon, Doc Dorotheanna will dive deeper into how my molecular partners work their magic. Plus, I'll show you how they appear in pictures of me.

Greetings, I'm WhatIf Scicoon. I propose ideas and WHAT IFs that hint at what's coming next, as do the icons on my Magic Clue Hats, like the compass you see here.

Who's Speaking?

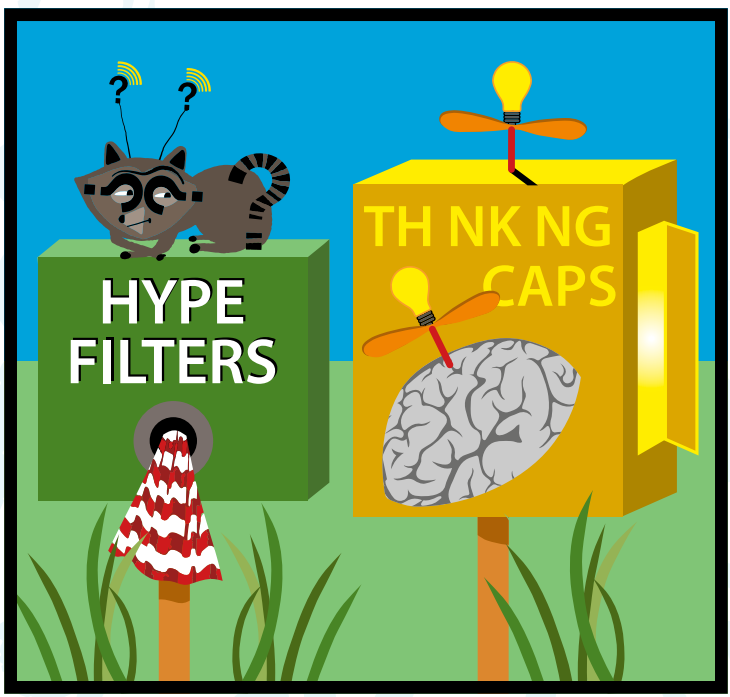
CRISPR's communications appear as speech bubbles on her profile pictures or as captions on pictures featuring her. WhatIf speaks in red print like this. For all the rest in black print, I, Doc Dorotheanna, am the speaker, with my icon popping up now and then to emphasize that what appears are my insights or opinions.

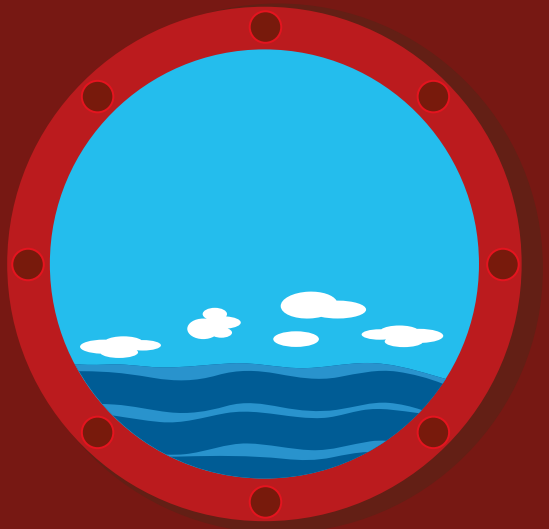
Purple print like this marks prompts to prime your idea pump and encourage you to speak up.

What's Where?

Some episodes contain terms defined in the Glossary and highlighted light blue. Click on a highlighted term to see its definition in the Glossary, which links back to the term in the text.

PICK UP YOUR, ESSENTIAL GEAR HERE!





TREAD THOUGHTFULLY!!

Realistic Goals Reached

OR

Hype-Induced Peril

This exhibit is an overview of CRISPR's potential uses plus associated hype and perils.

What is CRISPR & Why Is She Such a Big Deal

No doubt you've heard of DNA. Even if you're unfamiliar with its beautiful, double-helix structure, you probably know that the saying, "It's in my DNA." means "That's a part of me, you can't change that." But guess what? CRISPR CAN CHANGE DNA—traits you once thought were immutable are now up for alteration. And that's a HUGE DEAL!

Moreover, CRISPR can rewrite the code of life easier, faster, and cheaper than the few DNA editing tools that came before her, making her much more accessible. With so many researchers using CRISPR, her skills are constantly being improved. She can even edit many DNA sites at once.

What Fueled CRISPR's Swift Ascent to Science Celebrity?

In June of 2012, word of the first lab use of CRISPR blitzed through the biologist community. Within a year, molecular biologists worldwide were using her, or at least thinking about how she might advance their research.

I Cover the world!

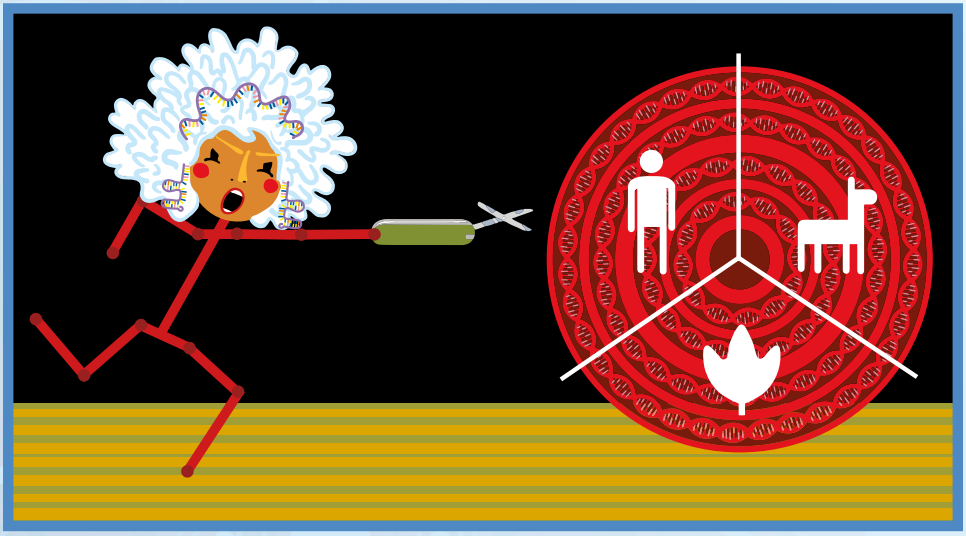
In August 2013, *Science*, the leading US multidisciplinary science journal, took stock of CRISPR's blazingly swift adoption. In an article entitled "The CRISPR Craze," Elizabeth Pennisi wrote, "various groups have used it to delete, add, activate, or suppress targeted genes in human cells, mice, rats, zebrafish, bacteria, fruit flies, yeast, roundworms, and crops, demonstrating the broad utility of the technique... This year's CRISPR craze may yet slow down as limitations of the method emerge, but George Church and other CRISPR pioneers are already forming companies to harness the technology for treating genetic diseases."

Dramatic headlines predicted specific CRISPR uses:

- Cure many of the more than 10,000 single gene diseases
- Make drugs to cure cancers and even prevent them
- Kill off pests, such as malaria-carrying mosquitoes
- Help endangered species adapt to changed environments, and even resurrect animals already gone
- Help solve our looming food crisis

And the highly controversial possibility of CRISPR upgrading (aka enhancing) your genes and those of your unborn children rocketed into the limelight!

In 2015, CRISPR became *Science's* breakthrough of the year. By then, feature articles were starting to appear in a number of mainstream media outlets.



Editing genes is my game; all bullseyes are my aim!

WHAT IF All the CRISPR Hype Promotes Her Fall?

With the publicity came the hype. The July 2015 edition of *WIRED* boasted: "The Genesis Engine. No hunger. No pollution. No disease." The rhetoric spawned a satirical tweet storm.

CRISPR'd drought-resistant soybeans and super-starchy corn in processed foods are already on grocery store shelves, and the first FDA approval of a CRISPR treatment (for sickle cell disease) was granted in December 2023.

No delivery dates yet.

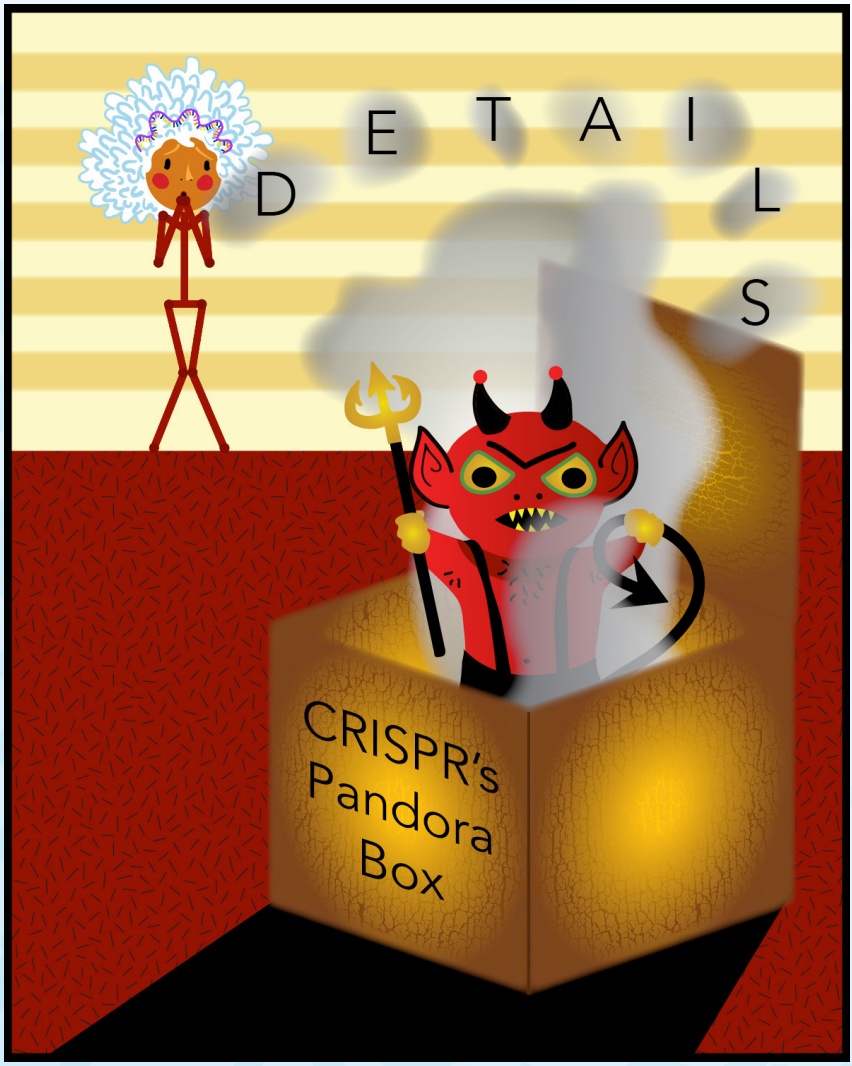
However, most of the predicted CRISPR triumphs will take a while—biotech tools and human decisions will determine if/when they will materialize.

Which of CRISPR's Potential Uses Will Scientists Pursue?

Which efforts will the public support? Oppose?
What devils will they confront in the details?
Will they succeed?

Will you help to decide?

Quite an impressive tool kit amassed in CRISPR's short lab life. Yet, the devils in the details are bound to have their strong, even vociferous, say!



CRISPR's ease of use, low cost, and wide range of potential applications have made her the most quickly adopted tool in modern biology. And in her 13 years of lab life, quite an impressive toolkit has already been amassed.

Yet because getting her to work in the lab is often more art than science, for some uses the devil in the details still has its strong—if not vociferous—say. Might all the hype make both researchers and the public turn a deaf ear to that devil?

The Devil-in-the-Details Devours HYPE!

Might the hype lifting CRISPR to Cloud 9 someday send her spiraling downward? Might the possible misuses of her editing power doom CRISPR's future? These became big concerns for CRISPR's stakeholders, especially her codeveloper, Jennifer Doudna.

So much so that in the spring of 2014, Doudna's subconscious started sending her messages in the form of nightmares. Like one in which she dreamed that she taught the technology to a keenly-interested Adolph Hitler. The awake Doudna took serious heed.

Green Egg on My Face:
My Reputation besmirched!

Doudna had been skeptical of earlier procedures that proposed to alter human germline cells (eggs, sperm, embryos), but hadn't really given "should we" questions much thought. Now, she became increasingly concerned with the growing likelihood that someone somewhere would actually create a pregnancy with a CRISPRed human embryo. She worried, too, that CRISPR might be turned to evil purposes.

She was brought to reckon with the reality that, as she put it, "the gene-editing revolution was unfolding behind the backs of the people whom it would affect."

Doudna feared that CRISPR researchers would not work openly—and that they wouldn't educate the public about the possible risks of their work *before* conducting any experiments with potentially irreversible effects. She worried that public disappointment at any big failures, or even undue slowness in meeting hyped expectations, would reduce CRISPR's future chances to do good?

MY WORST NIGHTMARE:
OUT OF USE!

Galvanized by her fears, Doudna forced herself to venture forth from the comfort of her lab to spearhead public discussion about the implications of CRISPR research.

She and her team at the Innovative Genomics Institute (IGI) arranged for the January 2015 invitational conference, "IGI Forum on Bioethics." The 17 attendees addressed how to begin public discussion of IF/when/how to allow germline editing. That CRISPR capability would be arriving a lot sooner than anyone had expected.

The Forum soon published a 5-page report, "A Prudent Path Forward for Genomic Engineering and Germline Gene Modification," in *Science*. It culminated with a request that "scientists refrain from attempting to make heritable changes to the human genome." (For now!) It didn't use the words "ban" or "moratorium," but the message was clear.

The article met with an enthusiastic reception by the science community and drew wide media coverage. The Forum was followed up by the December 2015 "International Summit on Human Gene Editing," attended by more than 400 persons representing over 15 professions and other interest groups from 20 countries on 6 continents. The National Academies of Sciences Engineering Medicine issued an official report of the Summit (2016).

The official report from that meeting states that "it would be irresponsible to proceed with any clinical use of germline editing unless and until (i) the relevant safety and efficacy issues have been resolved, based on appropriate understanding and balancing of risks, potential benefits, and alternatives, and (ii) there is broad societal consensus about the appropriateness of the proposed application."

Changes Inherited or Not? CRUCIAL DIFFERENCE: Somatic Vs Germ Cells!

First off, don't think that mere exposure to CRISPR can suddenly change your intelligence or hair color or any other of your traits.

I overheard people discussing the clinical trial to use CRISPR to cure sickle cell disease. Some people said they feared that the patients' children would be stuck with any new mistakes introduced into their parents' DNA by the edits! We need to emphasize why DNA edits made in body cells of living persons won't be inherited by their offspring, whereas those made in sex cells will be.

Correcting the misconception cited, plus related fallacies, requires an understanding of the crucial difference between somatic and germ cells!

Here's the nutshell version.

1. ***You have two types of cells. Somatic (aka body) cells are all the cells in your body except germ cells (aka sex cells or gametes)—commonly known as eggs and sperm.***
2. ***CRISPR edits of somatic cells won't be inherited by offspring, whereas edits made to germ cells will be. Currently, all edits to DNA of living persons are in somatic cells.***
3. ***CRISPR edits to the DNA in somatic cells are present only in the type of cells that is directly edited—heart, lung, etc.—and do not spread to other types of body cells. By contrast, edits in embryos or germ cells will be present in every cell of the offspring.***

FINAL DECREE: What happens in somatic cells stays in somatic cells, PERIOD!

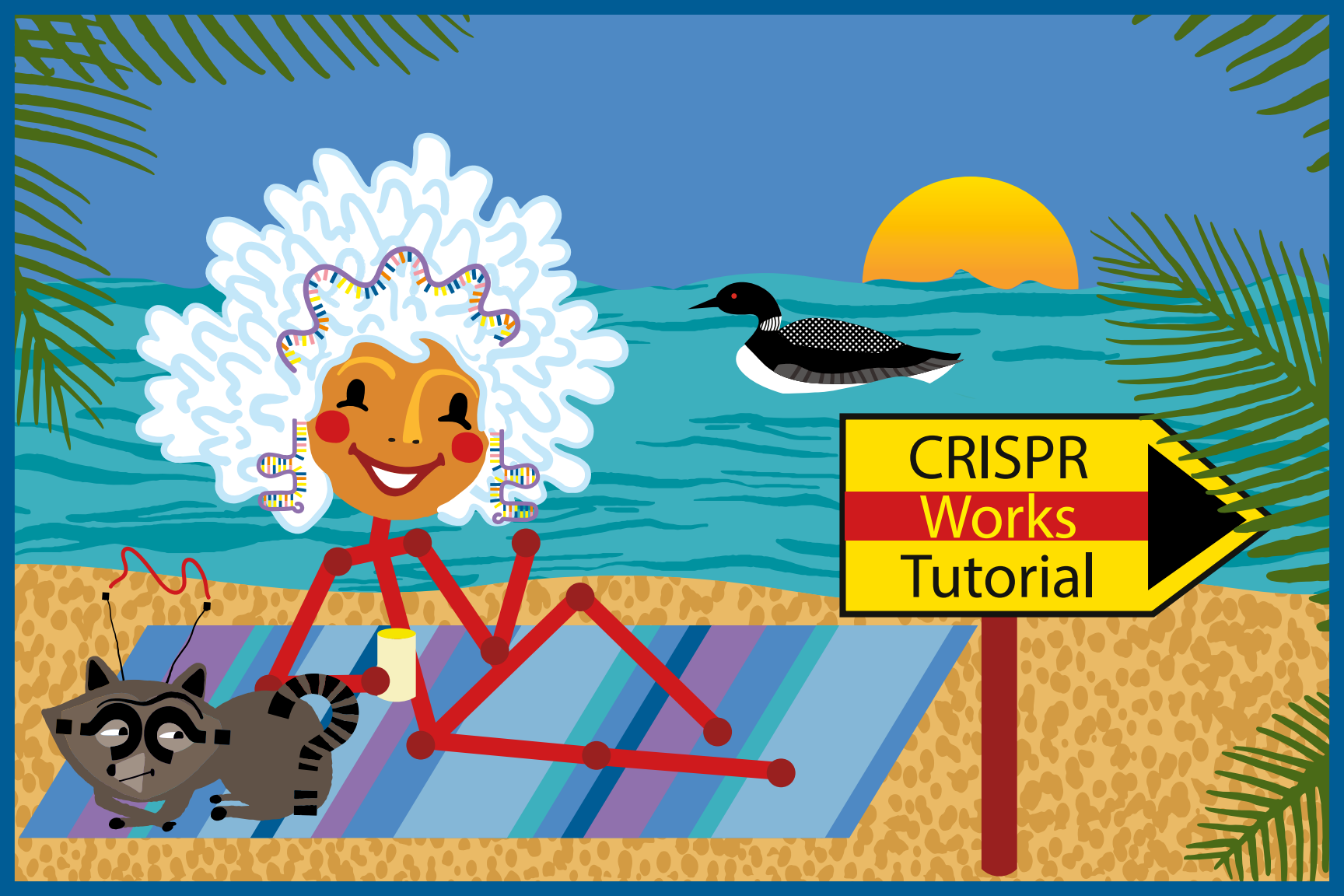
Mom: Somatic Green Tailight-Glow from CRISPR Edit

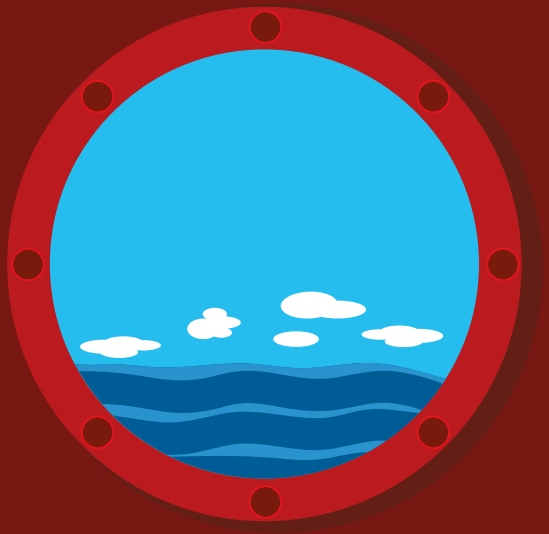
Puppies: Germline Green All-Glow from CRISPR Edit

All current clinical trials for CRISPR-based treatments of genetic diseases in humans target somatic cells. As we'll explore later, the main obstacle in editing somatic cells is getting CRISPR to the right tissue, where she must enter enough cells to do her job without causing harmful mishits—edits in the wrong spot on the DNA.

As far as is known, human germ cell editing has been limited to very early embryos not destined for pregnancies, except for the three babies CRISPR'd by Chinese researcher He Jiankui. Such editing remains highly controversial. As of 2025, the World Health Organization (WHO) strongly warns researchers not to edit DNA of embryos intended for pregnancies (via IVF). But laws and regulations on gene editing of embryos vary worldwide.

In agriculture, all CRISPR editing targets germ cells or embryos—most often, plant embryos in seeds. Food from edited plants is already on grocery store shelves. Supporters point to the potential of such crops to cure world food insecurity. If and when food from animals reaches the market, it too will come from the descendants of CRISPR'd embryos.


CRISPR
Works
Tutorial



CRISPR SCIENCE

CRISPR Science

CRISPR genome editing is an example of molecules reacting with each other. To understand CRISPR's editing of DNA, we'll examine some properties of her DNA target and her own components, sgRNA and Cas9 protein enzyme.

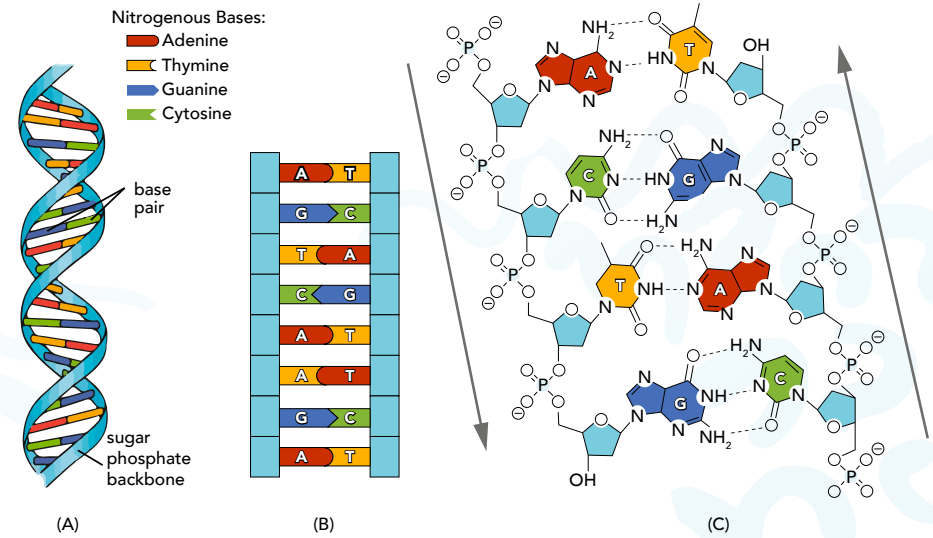
CRISPR Target: DNA

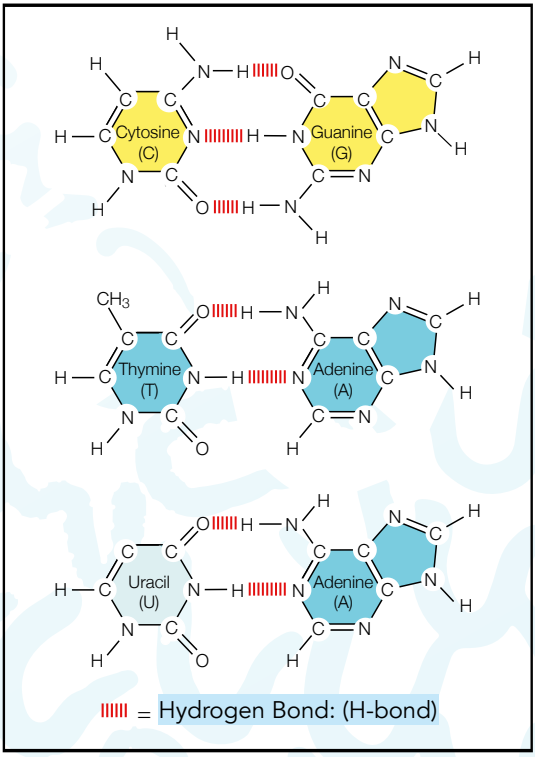
You've likely seen pictures of the DNA double helix and know that DNA contains the instructions that determine a living organism's physical and behavioral traits. But, in organisms with cells containing nuclei, like plants and animals, including humans, DNA also depends on other molecules—notably, proteins and RNAs (similar to DNAs in their component molecules, as shown in the picture [C] on the next page)—to convert those instructions into those traits.

Think of CRISPR editing of DNA as similar to editing text on a computer. The DNA "letters" are specific base molecules: adenine (A), cytosine (C), guanine (G), and thymine (T). Each trio of letters (e.g., ACC, GTG) is a word dictating that a specific amino acid occupy a specific place in the protein chain formed when the gene for that protein is expressed. The assembled proteins make each living thing what it is.

On the next page, we'll zoom in on the DNA helix in 3 stages, [A], [B], and [C]. [A] shows the double helix at rest—that is, when not unwinding during copying itself or producing proteins. Unwinding the helix [A] results in the middle picture [B], a DNA ladder, with paired half-rungs shown in 4 colors to illustrate DNA's 4 bases— A, T, C, G. The base rings that form the 2 halves of each rung pair up, making the DNA structure the beautiful double helix that it is: the base pairings are always A with T and G with C.

Notice that for the A, T, G, and C letters of the DNA alphabet, the base pairings are always A with T and G with C. Each trio of letters (e.g., ACC, GTG) is a word telling that a specific amino acid occupies a specific place in the protein chain formed when its gene is expressed. The assembled proteins make each living thing what it is.





(a) Both DNA & RNA Have C & G Bases
(b) DNA Has T & A Bases
(c) RNA Has U & A Bases

The adjacent picture zooms in on the H-bonds, shown as strips of red bars. In the bottom row, T is replaced by Uracil (U), a hallmark of RNA molecules, while the other bases—A, C, and G—remain the same as in DNA.

The 2 strands of the DNA helix are held together by the H-bonds within the A-T and G-C base pairs, and the same holds true for the C-G and U-A base pairs in DNA-RNA matches. These pairings involve ideal jigsaw fits.

CRISPR's RNA hunters are much easier and cheaper to make than the protein hunters of previous DNA editors.

But Wait, One More Thing!

PAM: The DNA Gatekeeper at CRISPR Works!!

A target DNA sequence must contain the gatekeeper PAM, a specific string of 2-6 bases, right next to it. PAM (Protospacer Adjacent Motif) is the key that enables CRISPR to unlock the DNA target area, making it accessible to her edits. If PAM isn't there, CRISPR cannot edit the target DNA!

HEAR YE!
HEAR YE!
THE DNA TARGET MUST CONTAIN PAM, BUT CRISPR HERSELF MUST NOT!

IF SHE DOES, SHE WILL CUT UP HER OWN sgRNA AND END UP LIKE HUMPTY DUMPTY.

GOODBYE CRISPR!!

CRISPR Components

CRISPR Single Guide RNA (sgRNA)

RNA's role as the target hunter is key in CRISPR's DNA editing. It's what makes CRISPR the star editor that she is. I consider all editors that use RNA as a hunter to be members of the CRISPR family.

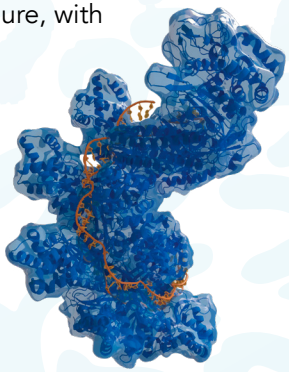
We saw 2 pages ago that RNA bases are identical to those of DNA except that uracil (U) replaces thymine (T). That means that an RNA with a base sequence matching a target DNA sequence will fit with that target sequence just like the matching DNA strand of the double helix did before RNA displaced it. What match of hunter to target could be better than that!

My sgRNA hairpins help to reduce my mishits!

In the picture, we see CRISPR holding her single guide RNA (sgRNA). To edit DNA, the guide's 'head' end nabs the target DNA by base-pairing with it, while its hairpin binds to CRISPR's Cas9 enzyme and ensures that it cuts the DNA on target.

CRISPR Cutter Enzyme: Cas9

This section takes a quick look at key aspects of Cas9's molecular structure—features that determine what it does. The same principles apply to protein enzymes across biology—the proteins that make life run.



In the picture, CRISPR's Cas9 enzyme appears as a lion-like figure, with her sgRNA hunter hugging it as a thin orange line. The order of amino acids in Cas9 dictates how it folds, which in turn shapes it. That shape determines what it can do: if Cas9's active site—its 'tool jaws,' so to speak—fits snugly with its DNA target, it can carry out its cutting job. I call this kind of reaction-promoting match a "jigsaw fit," where the enzyme and its target align well enough to allow the reaction to proceed. Even small structural changes far from the active site can have big effects on that fit, hence on what Cas9 does.

Cas9, however, isn't the only cutter in the game. Before Doudna and Charpentier adapted CRISPR for lab use, scientists had already identified different CRISPR systems across bacteria and archaea, each wielding its own Cas enzyme to fend off viral invaders. CRISPR engineers soon took note, uncovering other Cas enzymes that, in specific situations, outdo Cas9 as molecular scissors.

So, that's CRISPR with her sgRNA and Cas components at the ready. The picture shows how she's depicted throughout the Series.

CRISPR: Wherever I show up, my sgRNA molecule is shown as my headband, earrings, and/or scarf accessories; and my Cas enzyme appears as my wigs.

Principles to Explain Actions of CRISPR and Other Life Molecules

I've now outlined enough about RNA, DNA, and the 2 CRISPR components to consider principles that explain CRISPR's action on DNA.

For molecules to interact, they must first get close—something easily done in the gel-like protoplasm of the nucleus, where they move freely..

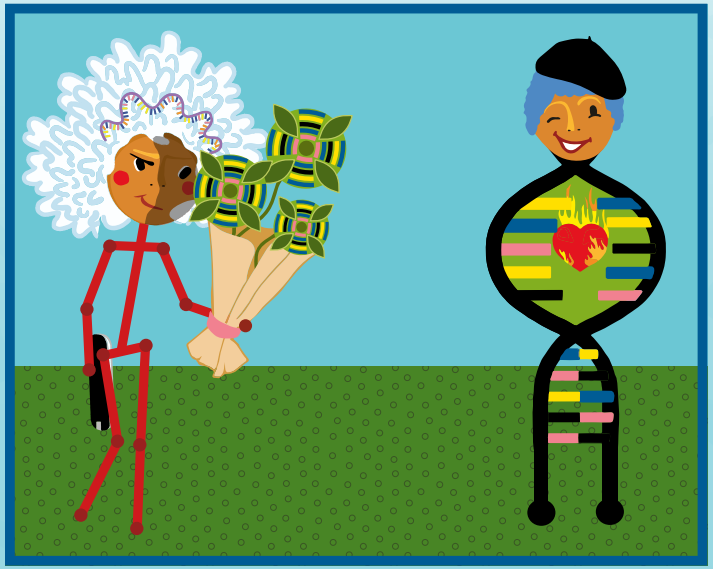
Once close, molecules test their fit. For CRISPR, this involves DNA and CRISPR's hunter molecule, sgRNA. The DNA and RNA diagrams (p. 09) show that the base shapes in sgRNA make them ideally suited to match and bind with corresponding target DNAs—G with C, A with U—creating a 'jigsaw fit.'

Bases that match bind and latch!
BUT bases that misfit make CRISPR mishit!

The slight positive charge on hydrogen atoms in regular and the slight negative charge on oxygen and nitrogen atoms in regular (covalent) bonds create an electrical attraction, adding to the binding of sgRNA to DNA.

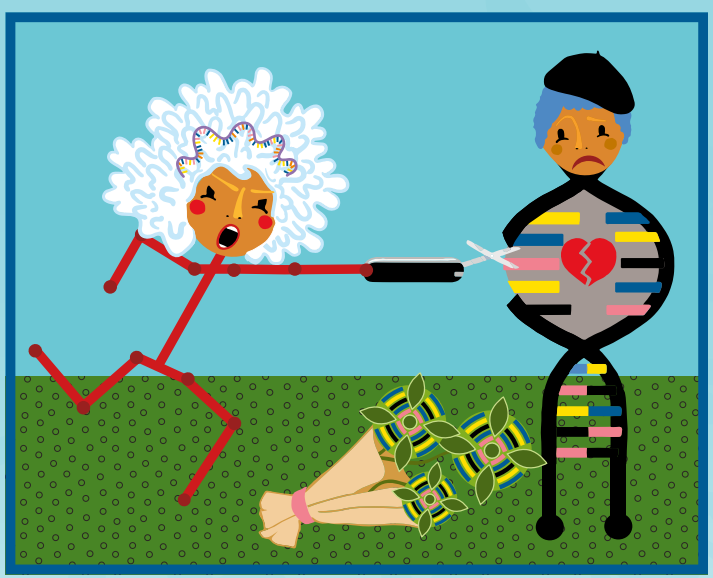
These 2 principles—JIGSAW FITS and ELECTRICAL ATTRACTIONS BETWEEN MOLECULES—explain much about how CRISPR works. They also apply broadly to other molecular interplay essential for life.

So that's the explanation at the molecular level of CRISPR's power to cut a given DNA target. A playful non-scientific version of CRISPR in action coming up next, followed by an overview of CRISPR's reach, and a map of that reach on CRISPR Island.



Ever ready to
lift his helix
latch, DNA
welcomes
CRISPR's
flirty match

CRISPR bases
grab their fits;
Cas9 pounces,
cuts 2 slits.
DNA, betrayed
in this affair,
Must call 911 to
seek repair!



5 CRISPR Labs & Clinics

CRISPR Science Lab (aka Sci Lab): Here, CRISPR constantly undergoes upgrades and extensions of her skill set; she also plays a key role in basic genomic studies, among others.

DNA Repairs & Upgrades Mall: CRISPR is used to develop cures for genetic diseases in humans & animals and perform some animal upgrades. The Mall hosts discussions about future potential human upgrades.

Pest Control: CRISPR participates in potential strategies to control creatures that cause diseases or harm the ecosystems.

Extinction Prevention & Returns Center: CRISPR edits genomes of endangered species to favor their survival and tries to de-extinct species already gone.

Super Seedy Greenhouse & Bioreactor: CRISPR is used to upgrade plants and customize microbes; improve crop survival, yields, and quality; and create other non-food products for specific purposes.

Beyond Labs & Clinics: 5 Indispensables

Critics Cavern: Collection of criticisms and associated evidence. Some criticisms are well founded, others not.

Funds Dispensary: Grants, venture capital, sponsors, and any other funding sources.

Publications, Patents & Regulations Bureau: Gateways to the building blocks of scientists' reputations and consumer products.

Public Opinion Well: Repository of a powerful collective say!

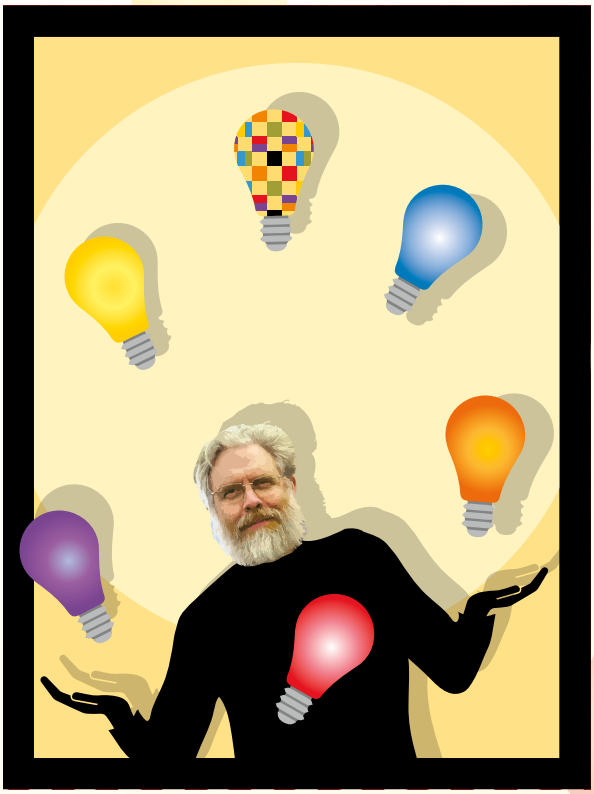
Please deposit your opinions!

Mentoring & Creativity: A key theme that runs through all content in the CRISPR Whisperer Picture Series.


CRISPR Island STEAMship
A
G
C
T
CRISPR STEAMship Berth
Pest Control Corps
DNA Repairs
CUTS
EXTENSIONS
RESTYLING
& Upgrades Mall
CRISPR Science Lab
WELCOME
Extinction Prevention
Extinction Returns Center
& Returns Center
Public Inputs Well
Mentoring
& Creativity
CRISPR ISLAND
Critics' Cavern
Super Seedy Greenhouse
& Bioreactor
Publications and Patents
& Regulations Bureau
Funds Dispensary
Critics' Sub

George Church's Legacy Threads Through All Episodes Ahead

Church's pioneering contributions span nearly every facet of genetics and biotechnology. This glimpse into the vast range of his team's innovations offers a virtual menu of where CRISPR's revolutionary power is likely to take hold.



Though ideas come cheap,
Juggler George makes them reap!

Standing 6'5", George Church towers over the field of genetics, both literally and figuratively. Often called a "rock star" of genetics, Church has left his mark far beyond the academic world.

Human Genome Project

At Harvard Medical School, Church's lab has spun out around 50 biotech companies. His pioneering work in genome sequencing helped lay the foundation for the Human Genome Project, the monumental effort that mapped the entire human genome.

CRISPR Editing of Mammalian Cells

His landmark adaptation of CRISPR for mammalian cells, along with Feng Zhang's, opened the path to the genetic engineering of *in vitro* human cells. He then developed techniques to make multiple edits within a genome simultaneously—a key capability for complex genetic missions, such as making pig organs safe for human transplants.

Age Reversal

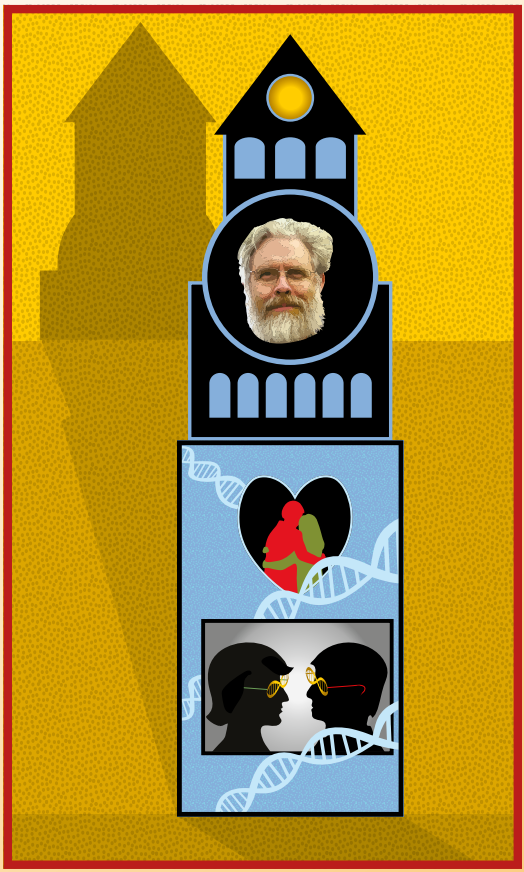
See Episode 03.

Full Selection Cell Banks

Church's new start-up, GC Therapeutics, officially launched in 2023 after a decade in stealth mode. Armed with $65 million in funding, it promises to revolutionize stem cell therapy. Using Church's own skin cells and the TFome—a toolkit of genetic "switches"—they transform stem cells into any specific cell type in 4 days with 99% efficiency. Traditional methods take months and often fail. Their dream? Cell banks for all.

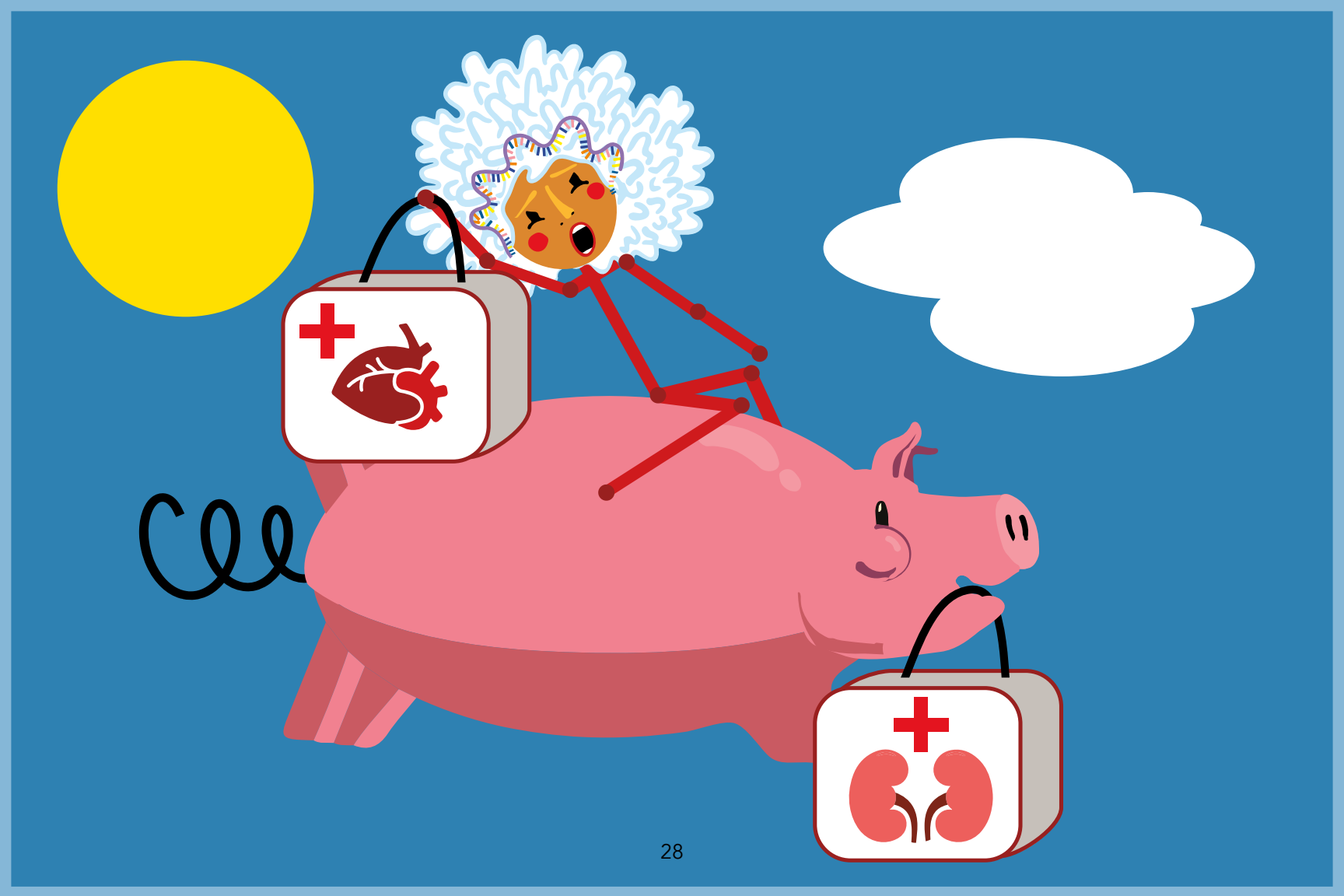
Prevention of Age-Related Diseases

Church is an outspoken proponent of preconception genetic counseling. The whole-genome sequencing required is estimated to cost $285 – $500 in 2025.



Pig Organ Transplants to Humans (Xenotransplants)

The pig kidney used in the first human transplant in March 2024 was engineered by eGenesis Bio, a company cofounded by Church and his grad student, then postdoc, Luhan Yang, in 2015. The patient, 62-year-old Richard Slayman, was well enough to be discharged home 2 weeks after his surgery. But he passed away 2 months later due to an "unexpected cardiac event" that his doctors said was unrelated to the transplant.



Pest Control

In 2014, Kevin Esvelt and coworkers in George Church's lab, published a paper explaining how CRISPR gene drives can target malaria-carrying mosquitos and other pests. You can find out a lot more about this powerful tool in Episode 08 of this Series.

De-Extinction & Preservation

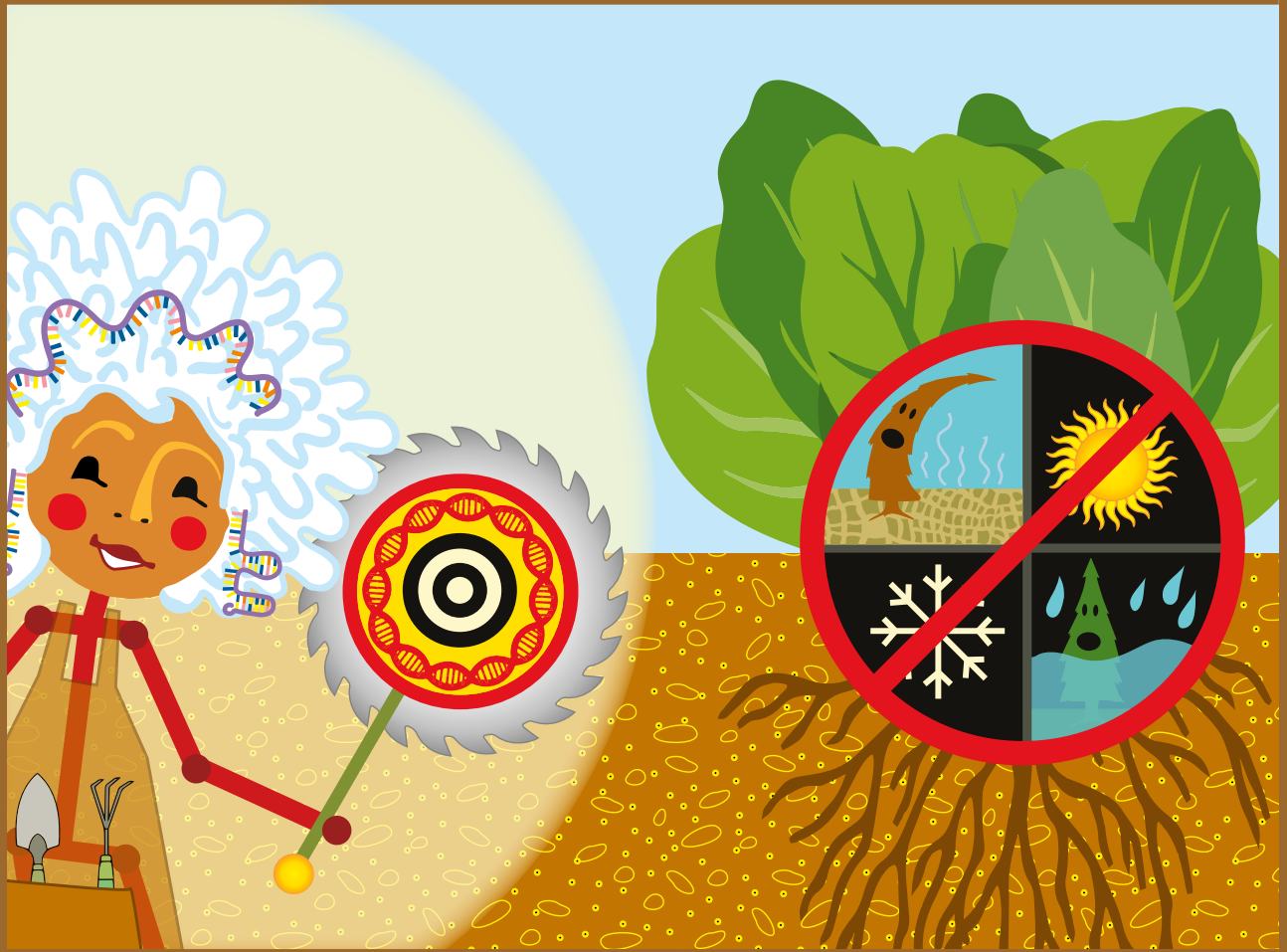
Perhaps Church's most audacious venture is his effort to bring back the woolly mammoth—or, more precisely, a woolly mammoth-like Asian elephant.

This ambitious project builds on his pioneering work with CRISPR, especially in developing her ability to perform many gene edits at the same time.

The project's scope extends far beyond resurrecting a single species. At its heart, it's about preserving endangered species and rejuvenating entire ecosystems.

Colossal Biosciences, co-founded by Church, leads this charge. With the recent addition of esteemed evolutionary biologist and science communicator Beth Shapiro as Chief Science Officer, and a total of $228 million in venture capital backing the effort, they've upped the odds of success in this ambitious vision.

Church's influence extends into agriculture, the first field to successfully embrace and commercialize modern genetic engineering. At Inari, a startup spun off from his lab, where he serves as scientific co-founder, they're developing seeds that not only resist environmental stresses but also thrive in local conditions.



Neither snow nor rain nor heat nor gloom Will keep CRISPR'd seeds from reaching bloom.

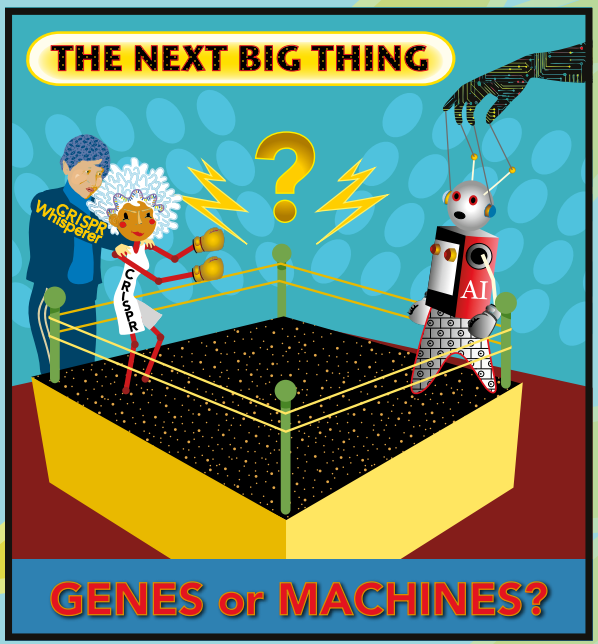
Episode 01 CRISPR Science Smarts
ACKNOWLEDGEMENTS

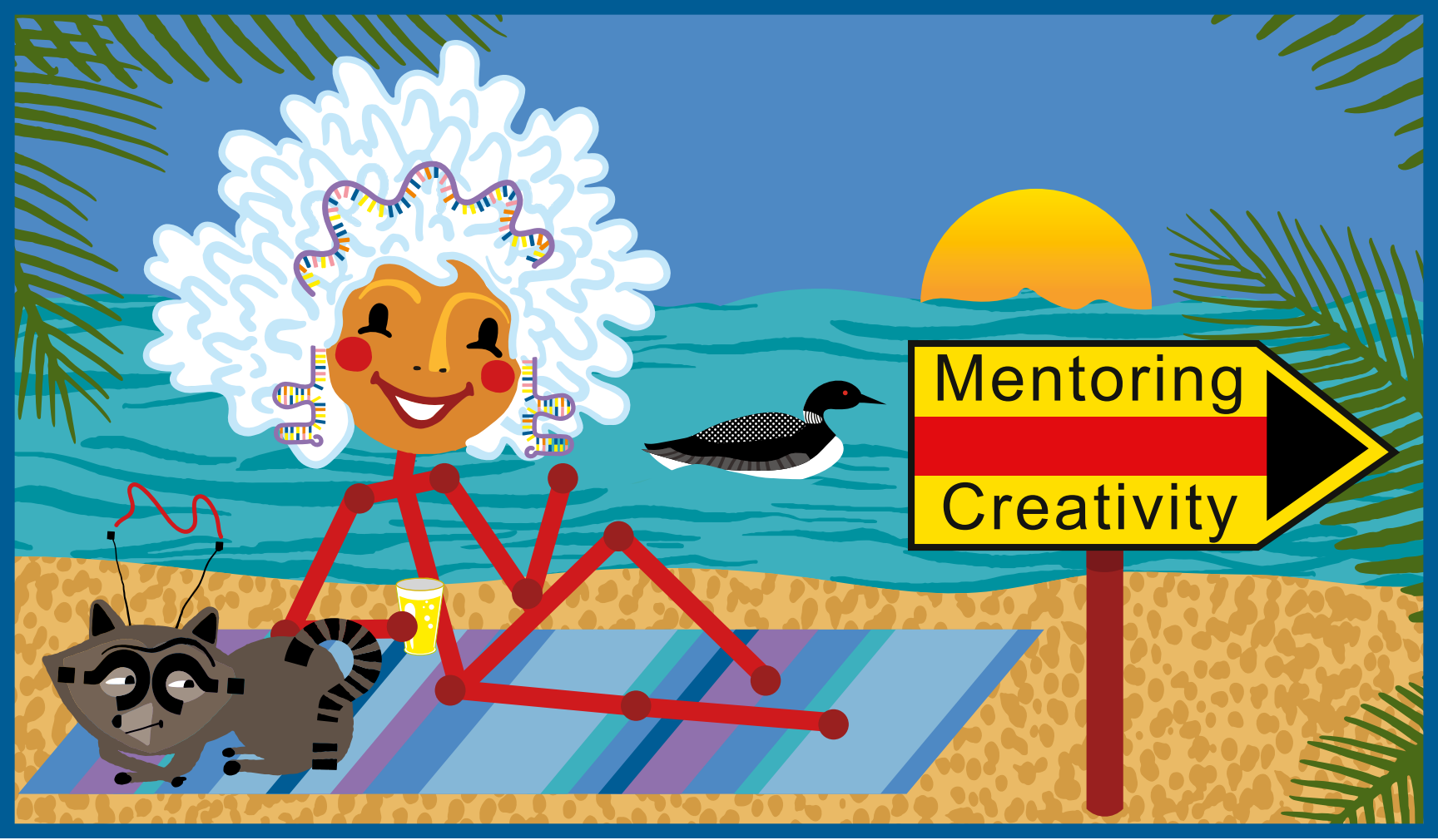
Lynne Bisagno gave vital feedback on all Series content

Caron Perkal made editing suggestions on early draft

Joe Levit, Reedsy non-fiction editor, spurred depiction of approaches to all workplaces on CRISPR Island

We close this episode with CRISPR pitching her uniting message—it's your invitation to visit the upcoming episodes of The CRISPR Whisperer Picture Series. We look forward to seeing you there!





Refreshed and recharged, she's set to go—
Next Stop: "Mentoring Trio"

CRISPR Whispers Picture Series
EPISODES LIST

CRISPRwhisperer.org
and
PGED.org
Personal Genetics Education & Dialogue

Glossary

Amino Acid
The chemical building block of proteins. During translation, different amino acids are strung together to form a chain that folds into a protein.

Archaea
Archaea look like bacteria but are actually more closely related to eukaryotes, such as humans. Archaea are single-celled organisms that don't have a nucleus and can only be seen with a microscope. They're found in many different habitats, and many of the first known examples were found in extreme environments.

Bacteria
An abundant type of microbe. These single-celled organisms are invisible to the naked eye, don't have a nucleus, and can have many shapes. They're found in all types of environments, from Arctic soil to inside the human body. Most bacteria are not harmful to human health, but certain bacteria can cause illness.

Bases
The four "letters" of the genetic code (A, C, T, and G) are chemical groups called bases or nucleobases. A = adenine, C = cytosine, T = thymine, and G = guanine. Instead of thymine, RNA contains a base called uracil (U).

Biotechnology
The use of living organisms or other biological systems in the manufacture of drugs or other products or for environmental management, as in waste recycling: includes the use of bioreactors in manufacturing, microorganisms to degrade oil slicks or organic waste, genetically engineered bacteria to produce human hormones, and monoclonal antibodies to identify antigens.

Cas9
A protein derived from the CRISPR-Cas bacterial immune system that has been co-opted for genome engineering. Uses an RNA molecule as a guide to find a complementary DNA sequence. Once the target DNA is identified, Cas9 cuts both strands. Has been compared to "molecular scissors" or a "genetic scalpel." In CRISPR immunity, cutting viral DNA prevents it from destroying the host cell. In genome engineering, cutting genomic DNA initiates a repair process that ends up making a change or "edit" to its sequence.

Cell
The basic unit of life. The number of cells in a living organism ranges from 1 (e.g. yeast) to quadrillions (e.g. blue whale). A cell is composed of 4 key macromolecules that allow it to function (protein, lipids, carbohydrates, and nucleic acids). Among other things, cells can build and break down molecules, move, grow, divide, and die.

CRISPR
Pronounced "crisper." An adaptive immune system found in bacteria and archaea, co-opted as a genome engineering tool. Acronym of "clustered regularly interspaced short palindromic repeats," which refers to a section of the host genome containing alternating repetitive sequences and unique snippets of foreign DNA. CRISPR-associated surveillance proteins use these unique sequences as molecular mugshots as they seek out and destroy viral DNA to protect the cell.

DNA
Abbreviation of deoxyribonucleic acid, a long molecule that encodes the information needed for a cell to function or a virus to replicate. Forms a double-helix shape that resembles a twisted ladder. Different chemicals called bases, abbreviated as A, C, T, and G, are found on each side of the ladder, or strand. The bases have an attraction for each other, making A stick to T while C sticks to G. These rungs of the ladder are called base pairs. The sequence of these letters is called the genetic code.

DNA Double Helix
Each DNA molecule consists of 2 nucleotide chains wrapped around each other in a double helix and held together by hydrogen bonds, which are reversible, like restickable glue.

DNA Editor (aka Genome Editor)
A tool that allows for precise, targeted changes to be made in the DNA sequence of an organism. These changes can include inserting, deleting, or modifying specific DNA sequences, effectively altering the genetic makeup of an organism.

Embryo
An unborn animal or human being in the very early stages of development.

Enzyme
A molecule, typically a protein, that causes or catalyzes a chemical change. Usually an enzyme's name describes a molecule involved in the activity it performs and ends with the suffix -ase. For example, lactase is a well-known enzyme that breaks down lactose, a sugar found in milk. Cas9 is a nuclease, an enzyme that breaks apart the backbone of nucleic acids (RNA or DNA).

Gene
A segment of DNA that encodes the information used to make a protein. Each gene is a set of instructions for making a full set of chromosomes; all the inheritable traits of an organism.

Gene Drive
A mechanism for preferential inheritance of a particular DNA sequence. Usually, offspring have a semi-random chance of inheriting a given stretch of DNA from either parent. In a scientist-designed gene drive, a gene is engineered to have a 100% chance of being passed on. Gene drives can force the inheritance of a desirable trait through a population of organisms. For example, this approach could potentially make all mosquitoes incapable of transmitting the malaria parasite.

Genome
A full set of chromosomes; all the inheritable traits of an organism.

Genome Editor
Tool to alter the genetic code of a living organism—ZFN, TALEN, or CRISPR. These systems are used to create a double-strand break at a specific DNA site. When the cell repairs the break, the sequence is changed. Can be used to remove, change, or add DNA.

Genome Sequencing
A laboratory process used to learn the exact sequence (order) of the 4 building blocks, or bases, that make up DNA. Information is stored in DNA in a code made by arranging the four bases (identified by the letters A, C, G, and T) in different orders. DNA sequencing can be used to find DNA mutations (changes) that may cause diseases, such as cancer.

Germ Cells
The cells involved in sexual reproduction: eggs, sperm, and precursor cells that develop into eggs or sperm. The DNA in germ cells, including mutations or intentional genetic edits, is passed down to the next generation. Note that genome editing in an early embryo is considered to be germline editing since any DNA changes will likely end up in all cells of the organism that is eventually born.

Hydrogen Bond (H-bond)
A weak bond between 2 molecules resulting from an electrostatic attraction between a proton in one molecule and an electronegative atom, such as nitrogen, in the other.

Innovative Genomics Institute (IGI)
IGI is composed of diverse researchers at UCB & UCSF, who conduct world-class research, driven by the real possibility to use genome engineering to treat human diseases and end hunger. IGI also works to advance public understanding of genome engineering, provides resources for the broader community, and guides the ethical use of these technologies.

Jigsaw Fits
The surfaces of two molecules fit together closely, like 2 pieces of a jigsaw puzzle.

Nucleus
The structure in a cell that contains the chromosomes, where DNA resides.

Off-Target in Genome Editing
When a genome engineering enzyme cuts DNA at an unintended, "off-target," site that is similar to the intended target.

PAM
A short sequence that must be present next to a DNA target sequence for Cas9 to bind and cut. Prevents cleavage of host CRISPR array, where PAM is not present.

Preconception Genetic Counseling
Genetic counseling often involves genome sequencing of a prospective parent's genome. The process can help the counselee understand their risk factors as well as the medical, emotional and familial implications of genetic disease

Protein
A string of amino acids folded into a 3-dimensional structure. Proteins are each specialized to perform a specific role to help cells grow, divide, and function. The 4 Types of macromolecules that make up all living things are proteins, lipids, carbohydrates, and nucleic acids.

RNA
Abbreviation of ribonucleic acid. Transcribed from a DNA template and typically used to direct the synthesis of proteins. CRISPR-associated proteins (Cas) use RNAs as guides to find matching target sequences in DNA.

Single Guide RNA (sgRNA)
A version of the naturally occurring 2-piece guide RNA complex engineered into a single, continuous sequence. The simplified single-guide RNA is used to direct the Cas9 protein to bind and cleave a particular DNA sequence for genome editing.

Somatic Cells
All the cells in a multicellular organism except for germ cells (eggs or sperm). Mutations or changes to the DNA in the soma will not be inherited by subsequent generations. The genetic material in somatic cells cannot be inherited by offspring.

Species
The basic category of biological classification, composed of related individuals that resemble each other, are able to breed among themselves, but are not able to breed with members of another species.

Stem Cells
Unspecialized cells with the ability to divide and differentiate into various specialized cell types. They play a crucial role in tissue repair, growth, and development.

Xenotransplant
A tissue graft or organ transplant from a donor of a different species from the recipient.