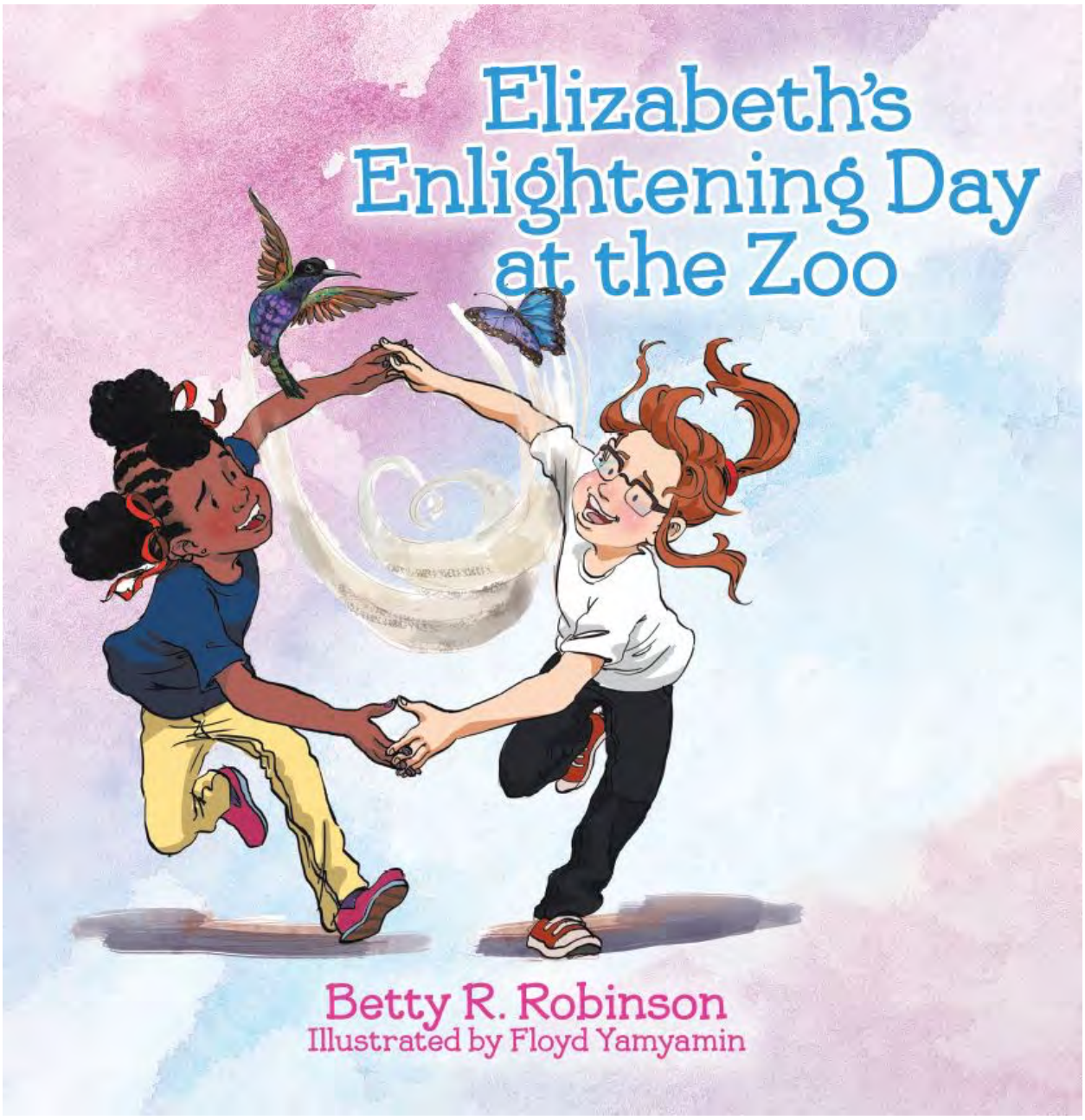
Elizabeth's Enlightening Day at the Zoo
Teacher Notes



Teacher Notes for
Elizabeth's Enlightening Day at the Zoo

Elizabeth's Enlightening Day at the Zoo is a reader intended to support science units that teach light at the elementary level. It is not intended as a textbook or replacement of any teaching material, just supplementary material that will hopefully engage students and get them excited about the importance of light. While the book was written specifically to target the grade 4 light unit in Ontario, Canada, many of the other provincial and territorial curricula in Canada and elsewhere have similar expectations or outcomes, and the book can be used to support light units there, as well. It can also be used simply as a storybook.

While the intention is to encourage girls to become interested in science, it by no means is meant to exclude other children. In fact, all children can appreciate that gender does not preclude anyone from a career related to light or any other aspect of science.

Elizabeth's Enlightening Day at the Zoo introduces many properties and applications of light within a zoo setting. Elizabeth, her friend Zahra (*Zahra* is Arabic for "bright"), and their moms are visiting the zoo for inspiration for a new line of nail polishes designed by Zahra's mom, Dalia.

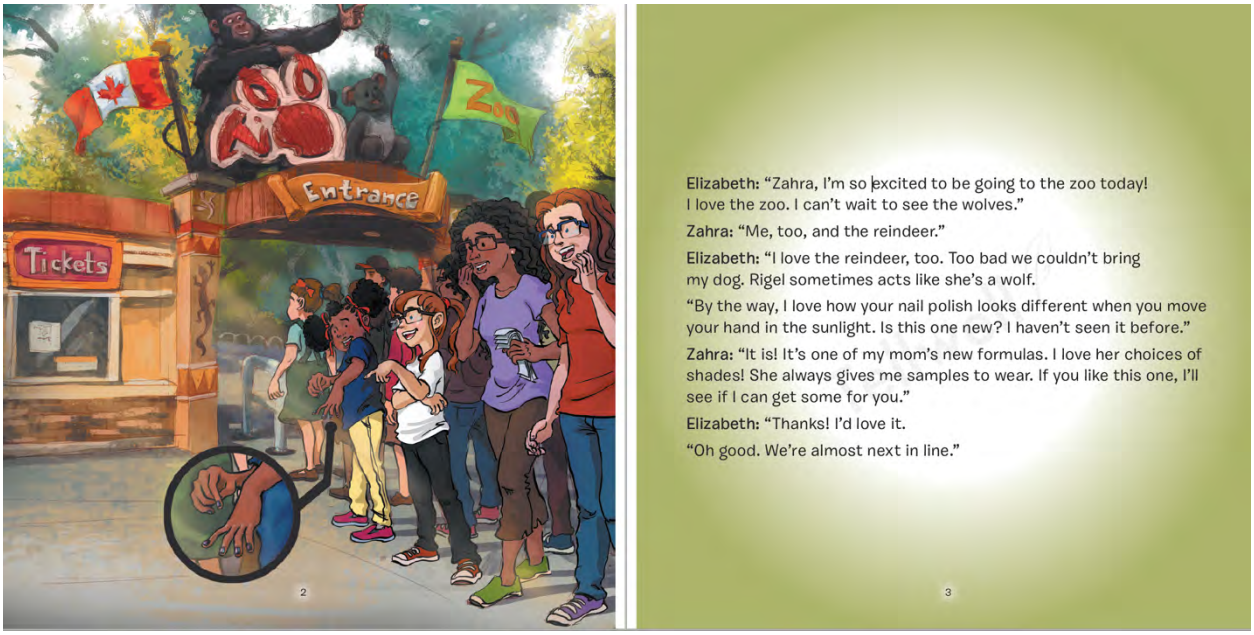
In addition to the properties of light related to animals, birds, and insects, the families also come across applications related to technology: a barcode scanner, an infrared alarm system, and a medical application related to lasers.

For each spread in the book, these Teacher Notes include a table listing the Ontario grade 4 science curriculum expectations that are reached or touched on. Many of the properties related to animals are adaptations, which meet other expectations in other grades; in those instances, the expectations are also noted.

All the animals featured in this book are not necessarily at a zoo, especially the chain catshark. And the alarm system with the penguins is not real. The examples are included for informational and educational purposes only.

Elizabeth's Enlightening Day at the Zoo is the second book in the author's Elizabeth series. The first book is *Elizabeth Goes to Mars!*, published in 2020. Next up in the series: *Elizabeth's First Total Solar Eclipse* (all about the 2024 total solar eclipse) and *Elizabeth in the Kitchen* (with a focus on kitchen chemistry). Other books are to come, with the subjects to be determined.

Pages 2 and 3



Elizabeth, her friend Zahra, and their moms are going to the zoo. Zahra is wearing iridescent nail polish. While waiting in line to buy tickets to enter the zoo, the girls and their moms are admiring the different colours of the polish in the sunlight.

Iridescence is a property of light; it is the phenomenon of rainbow-like colours in an iridescent object produced when light hits the object at different angles. The science of iridescent nail polish is complicated. There are different properties of light at play, such as interference, refraction, and reflection. Interference is not appropriate for this grade level.

An interesting description of iridescence can be found here:
https://underthemoonlight.ca/2018/08/18/holographic-and-iridescent-whats-the-real-difference/

Grade 4: Understanding Matter and Energy, Light and Sound
3.2 distinguish between objects that emit their own light and those that reflect light from other sources
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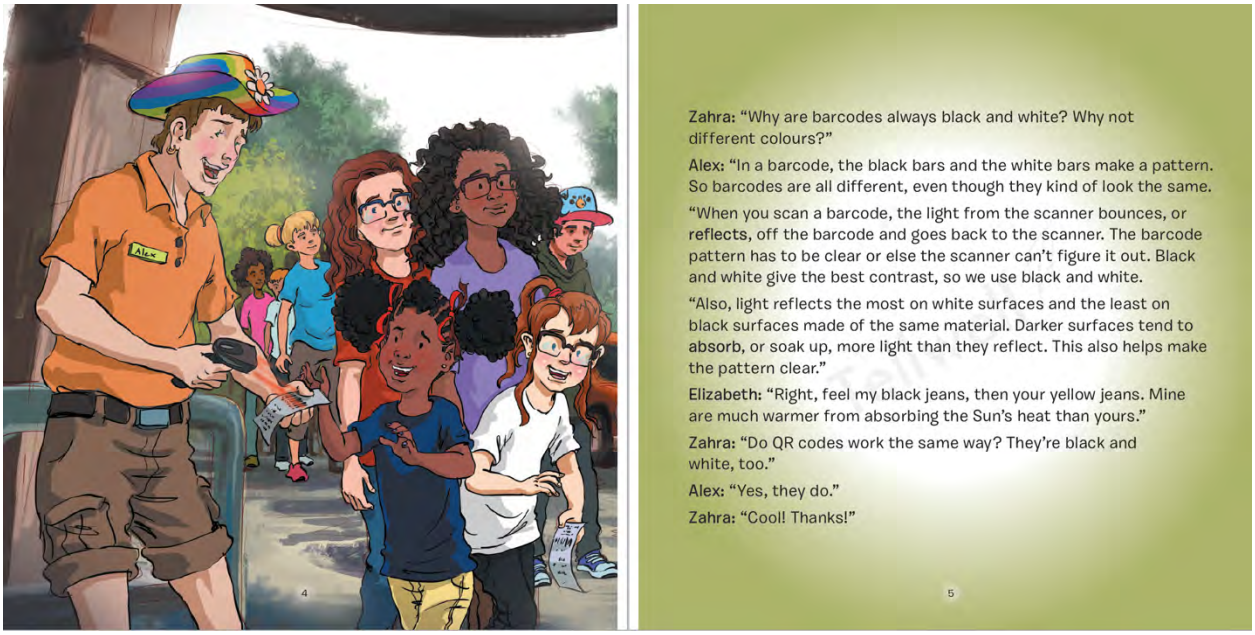
3.6 describe how different objects and materials interact with light and sound energy
Career designing nail polish that uses properties of light

Pages 4 and 5



Barcodes are one-dimensional codes, that is, they are just lines of black and white, and the lines are different widths. The lines store data, in this case perhaps the zoo ticket price and the date and time of the ticket purchase.

The barcode scanner uses light to scan the barcode. The light is reflected from the barcode back to the scanner, and a decoder within the scanner then reads and stores the data in a computer. Infrared light is very popular in scanners, but there are also scanners that use laser light or LED light.

Zahra asks Alex, the ticket taker at the zoo, about quick response (QR) codes and whether they work in the same way as barcodes. They do, but QR codes are a little different: they are two-dimensional codes. They use squares or other shapes to store data. This way they can store more data than the black and white line barcodes. The vast majority of barcodes are the black and white lines.

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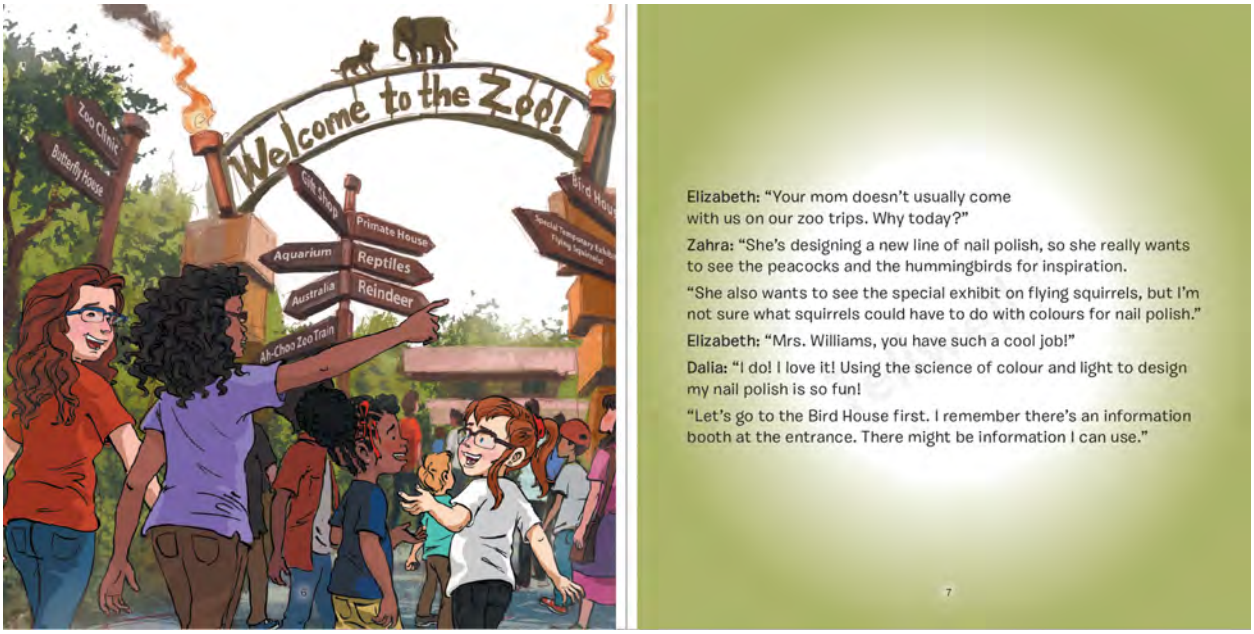
3.8 identify devices that make use of the properties of light and sound

Pages 6 and 7



Dalia, Zahra's mom, is designing a new line of nail polish and is looking for inspiration from animal and insect colours. She is also researching different effects, such as iridescence. There are countless careers and jobs related to light. Designing iridescent nail polish is just one of them.

While the first stop is the Bird House, we are learning that somehow flying squirrels have something to do with light. And we are all familiar with so many bright colours of birds, but where does the colour come from? And why are some bird feathers so bright?

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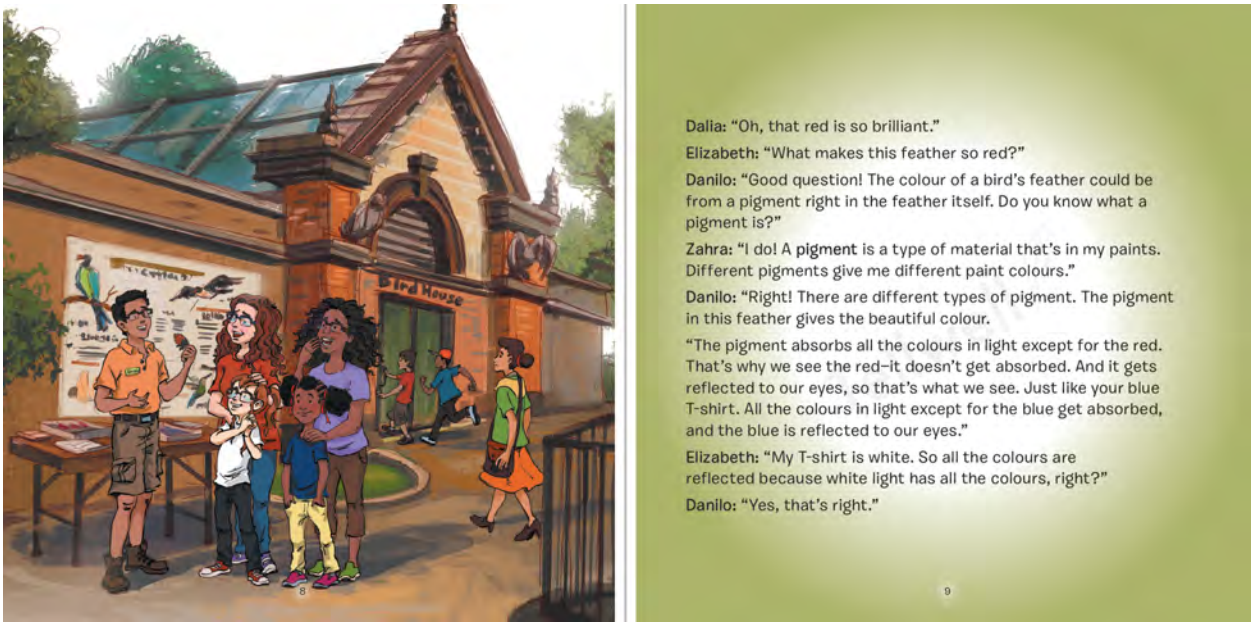
Career designing nail polish that uses properties of light

Pages 8 and 9



Zahra is an artist, so she knows about pigments. Pigments are substances that can be found in nature, such as in the bright red macaw feather that Danilo is holding. They are also manufactured. Manufactured pigments are usually a bright or strong colour so they can be used to get a certain colour, such as in paints, dyes, and inks.

Pigments absorb all the wavelengths of light except the ones that get reflected. So Zahra's blue T-shirt has been dyed with a blue pigment: the shirt absorbs all the light except blue, so blue is reflected to our eyes.

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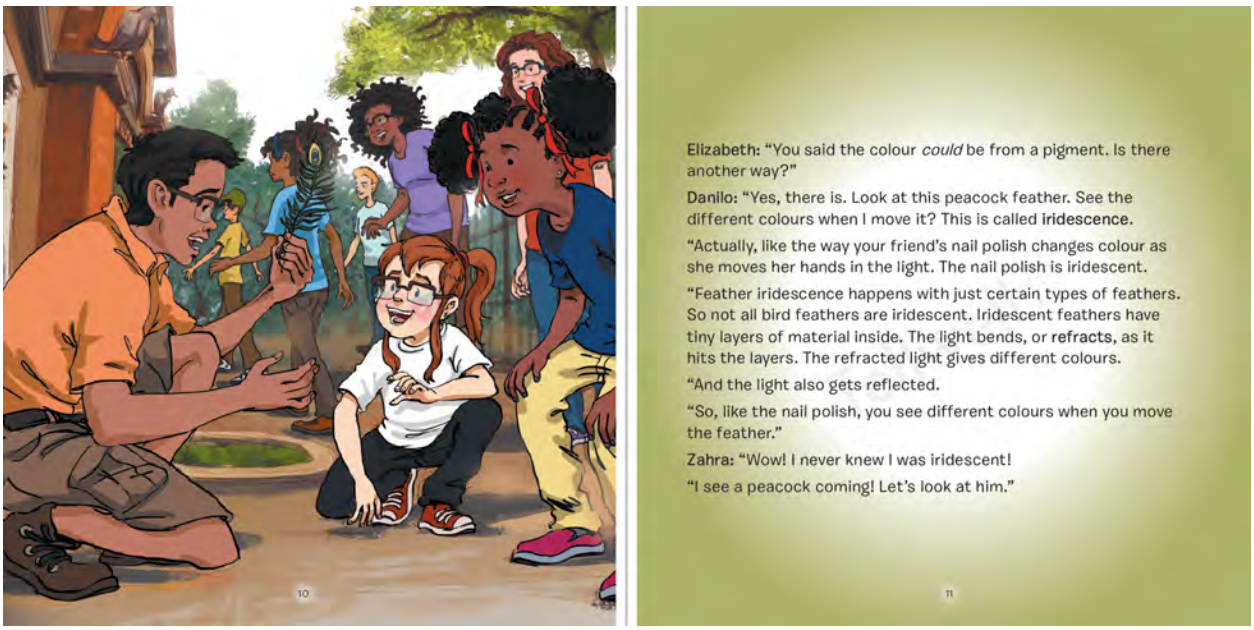
Career artist

Pages 10 and 11



Elizabeth: "You said the colour *could* be from a pigment. Is there another way?"

Danilo: "Yes, there is. Look at this peacock feather. See the different colours when I move it? This is called **iridescence**.

"Actually, like the way your friend's nail polish changes colour as she moves her hands in the light. The nail polish is iridescent.

"Feather iridescence happens with just certain types of feathers. So not all bird feathers are iridescent. Iridescent feathers have tiny layers of material inside. The light bends, or **refracts**, as it hits the layers. The refracted light gives different colours.

"And the light also gets reflected.

"So, like the nail polish, you see different colours when you move the feather."

Zahra: "Wow! I never knew I was iridescent!

"I see a peacock coming! Let's look at him."

Another way feathers produce their beautiful colours is through iridescence. Like Zahra's iridescent nail polish, the peacock feather changes colour as you turn it in the sunlight.

The structure of bird feathers makes them iridescent. Looking at a feather under a high-powered microscope you may be able to see tiny barbules, which are part of the feather's structure. The barbules refract the sunlight, just like a prism does. So we get the beautiful colours that change as you move the feather.

Some birds get their colours from light, but not through pigments or iridescence. The indigo bunting, for example, has little air pockets within the feather structure. When light enters the air pockets, it gets scattered such that we see a specific colour, similar to why we see a blue sky!

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Pages 12 and 13

The male peacock is magnificent! Male body lengths are typically about 130 cm in length, but their tail feathers are longer, up to 150 cm in length. Adaptations in nature are all about reproducing. The colours, the dances, the songs—these are all to attract a female to mate with for the purpose of reproduction. The females are calling the shots: they want to select the mate that will give them the healthiest offspring.

When the male peacock is interested in a female peacock, or peahen, he opens up his tail feathers in a beautiful display and shakes them to catch the light and make the feathers shimmer with a rustling sound. With such a magnificent tail, how could she not be impressed? It is physically strenuous for the male to raise, hold, and then shake his feathers. This is also part of the attraction to peahens. They want their offspring to come from strong, healthy parents.

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Just like with the peacock, the feather structure of the hummingbird is the source of iridescence.

Male hummingbirds impress females with their beautiful colours, especially around the throat, or gorget. Some species put on an aerial show in front of the female they are trying to impress. She sits on a branch, and the male soars up high, then arcs down in the front of the female, then up and down and up again, like a parabolic arc. He does this several times to make sure she sees his gorget from different angles, which offers the best view of his beautiful colours. As the male gets closer to the female he chirps and sings, too. The whole package!

The colourful gorgets are also a statement to other hummingbirds: Beware! Hummingbirds are very territorial and will chase away any intruder, be it another hummingbird, crow, hawk, or person.

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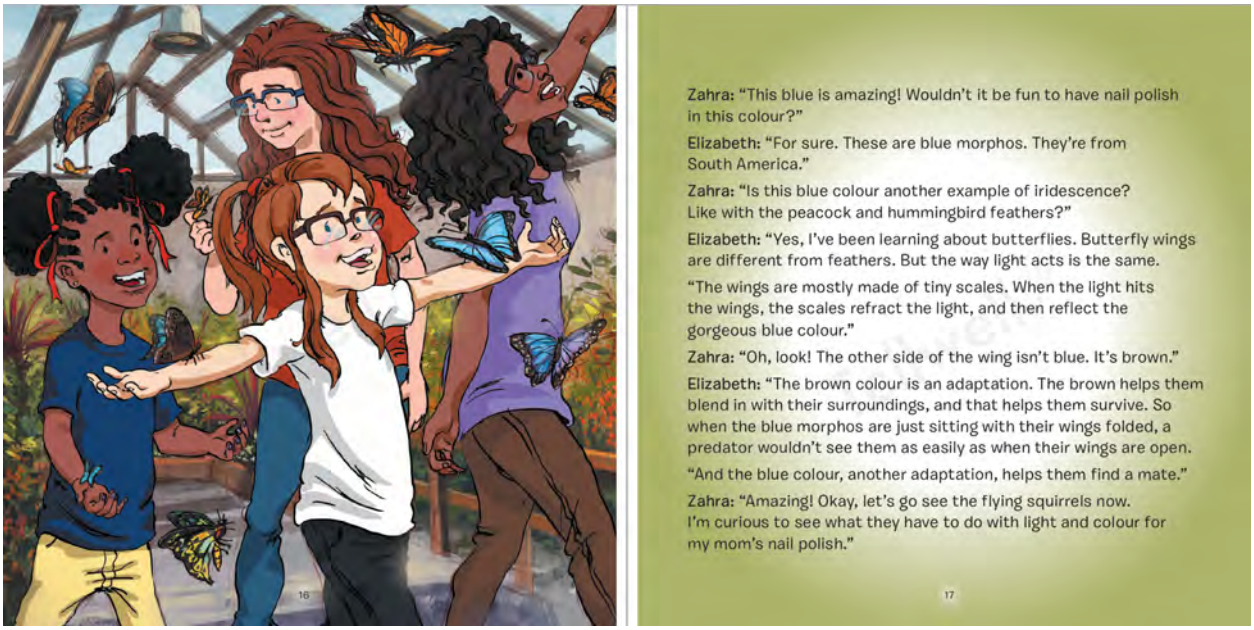
Pages 16 and 17



Zahra: "This blue is amazing! Wouldn't it be fun to have nail polish in this colour?"

Elizabeth: "For sure. These are blue morphos. They're from South America."

Zahra: "Is this blue colour another example of iridescence? Like with the peacock and hummingbird feathers?"

Elizabeth: "Yes, I've been learning about butterflies. Butterfly wings are different from feathers. But the way light acts is the same.

"The wings are mostly made of tiny scales. When the light hits the wings, the scales refract the light, and then reflect the gorgeous blue colour."

Zahra: "Oh, look! The other side of the wing isn't blue. It's brown."

Elizabeth: "The brown colour is an adaptation. The brown helps them blend in with their surroundings, and that helps them survive. So when the blue morphos are just sitting with their wings folded, a predator wouldn't see them as easily as when their wings are open.

"And the blue colour, another adaptation, helps them find a mate."

Zahra: "Amazing! Okay, let's go see the flying squirrels now. I'm curious to see what they have to do with light and colour for my mom's nail polish."

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Blue morphos are among the largest and most beautiful species of butterflies. The wingspan can be up to 20 cm. The iridescence in butterfly wings arises from the structure of the wings, which is not the same structure as bird feathers, but the effect is the same.

Each wing has many tiny scales, which reflect and scatter the sunlight. As mentioned earlier, there are other properties of light at play here, especially interference. The bright blue serves as an attraction for females for mating, especially if the blue is extra bright. The blue also helps females find a male of their species to mate with.

The brown underside helps protect these butterflies from predators, such as birds. When the butterfly is flying, a predator would see flashes of blue and brown. This is confusing to the predator because it's never sure where the butterfly is.

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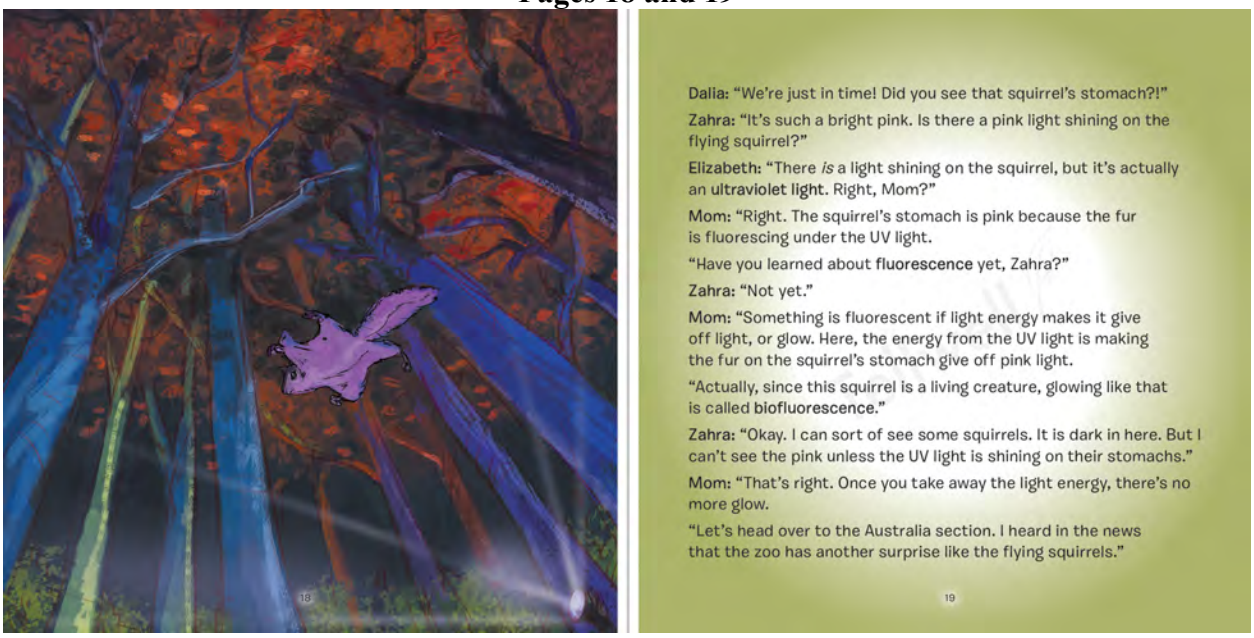

Fluorescence is another property of light. It's a phenomenon in which a material exposed to high-energy light starts giving off visible light. The high-energy light is often ultraviolet, or UV, light. UV light is beyond the wavelengths of visible light, so we cannot detect it; it is too high energy for our eye structure.

UV light is damaging if we are exposed to it for too long (e.g., sunburns, skin cancer). But most of the Sun's UV light doesn't make it to Earth's surface; our atmosphere absorbs most of it, as well as other harmful wavelengths, such as X-rays. In fact, when the Sun is at its highest point above us, the sunlight that reaches Earth's surface is 44% visible light and 3% UV. The rest is infrared. The process of fluorescing is fairly fast, so once we take the light away from the object, the glowing stops. In the case of the flying squirrels shown here, the object fluorescing is a living creature, so the phenomenon is called biofluorescence.

The flying squirrel biofluorescence is a relatively new discovery. Researchers at Trent University in Ontario, Canada, discovered this phenomenon in early 2020. These nocturnal creatures fluoresce bright pink under UV light.

Very few mammals are known to be biofluorescent, for example flying squirrels, opossums, platypuses, and bandicoots. The phenomenon could be related to being nocturnal because flying squirrels and opossums are nocturnal. At time of writing, researchers don't know what advantage biofluorescence provides to the flying squirrels.

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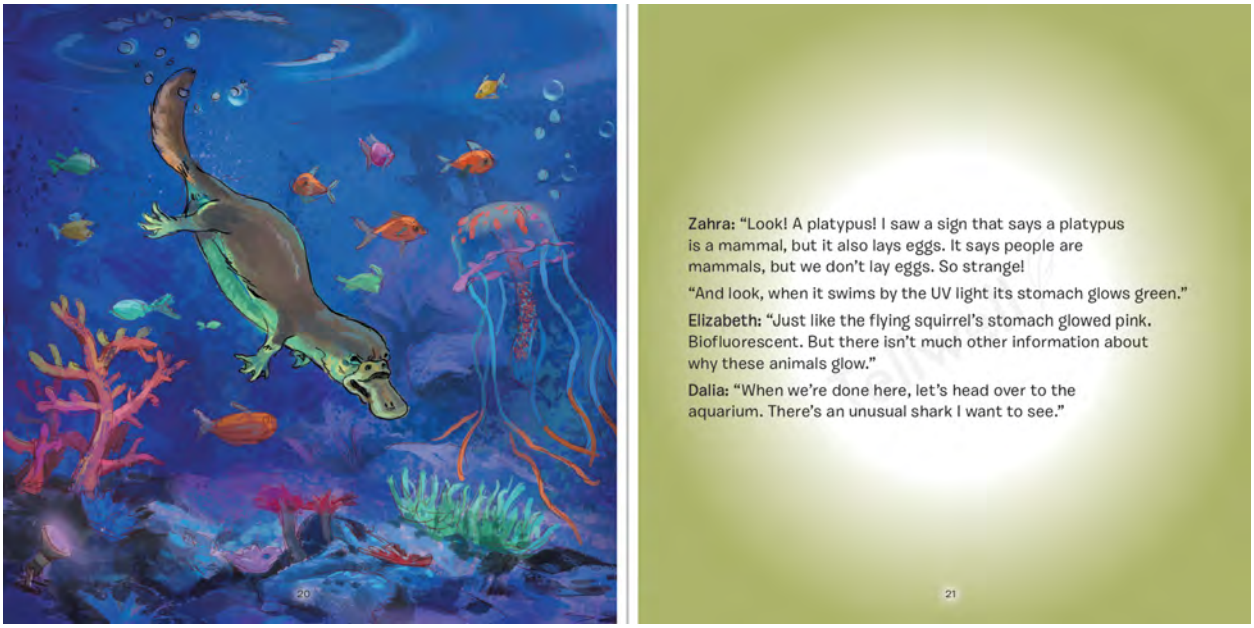
Pages 20 and 21



The platypus is a monotreme, that is, it's a mammal but it lays eggs. Monotremes can't nurse their young like other mammals because they don't have the equipment. A monotreme's milk is secreted from pores on the female's stomach. Another example of a monotreme is the echidna, found in Australia and New Guinea. The echidna looks like an anteater with porcupine quills. The platypus is the only known biofluorescent monotreme.

Some researchers suggest that an advantage of the biofluorescence in the platypus is that it helps these creatures to see each other better at night, since they are nocturnal.

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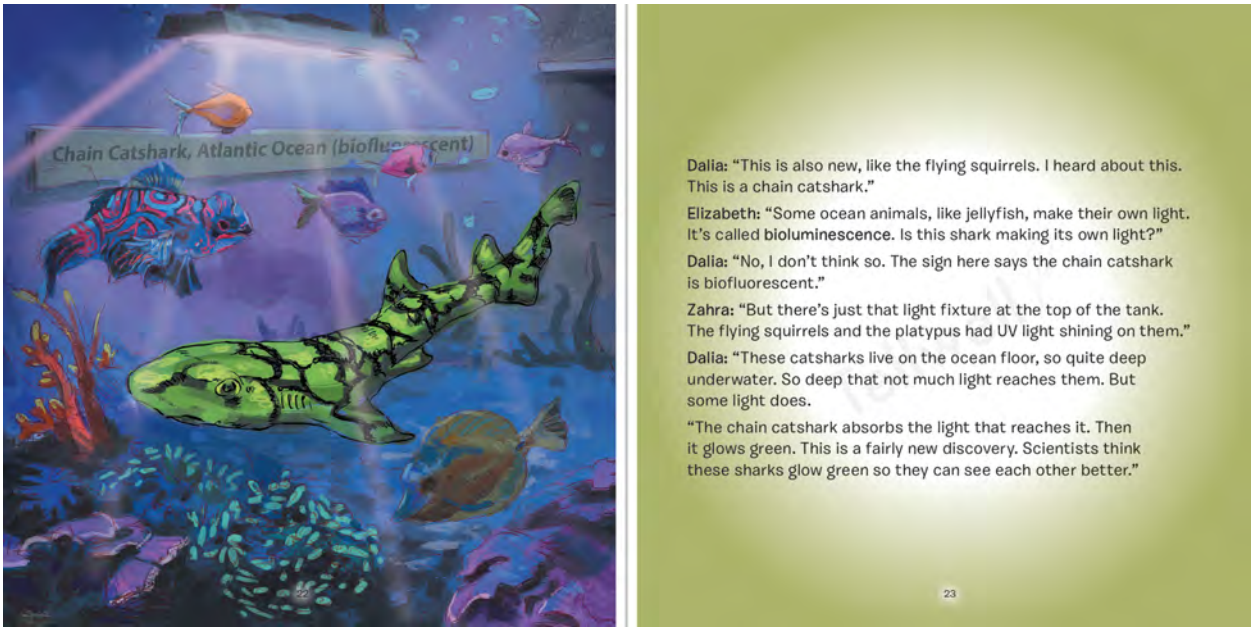
Pages 22 and 23



A new term is introduced here—bioluminescence—but no examples are featured in this book. Bioluminescent animals, such as jellyfish, some coral, and some squid, make their own light. Bioluminescence is a chemical reaction: chemical energy is converted to radiant energy, or light. One advantage to a bioluminescent ocean organism is that it may be able to communicate using light in parts of the ocean where it's extremely dark.

But the chain catsharks shown here are another example of biofluorescence. Catsharks are shy and live in crevices in the sea floor, in deep water. The water filters the sunlight, so not much light reaches the catshark. The biofluorescent catshark skin absorbs the light that reaches it and emits green light.

Here, the zoo officials have installed a light to help viewers see the biofluorescence.

Researchers don't understand yet what purpose this serves, but they think the phenomenon could be related to communication and mating.

Note: Catsharks are not normally at zoos. They are included here for education and illustration purposes only.

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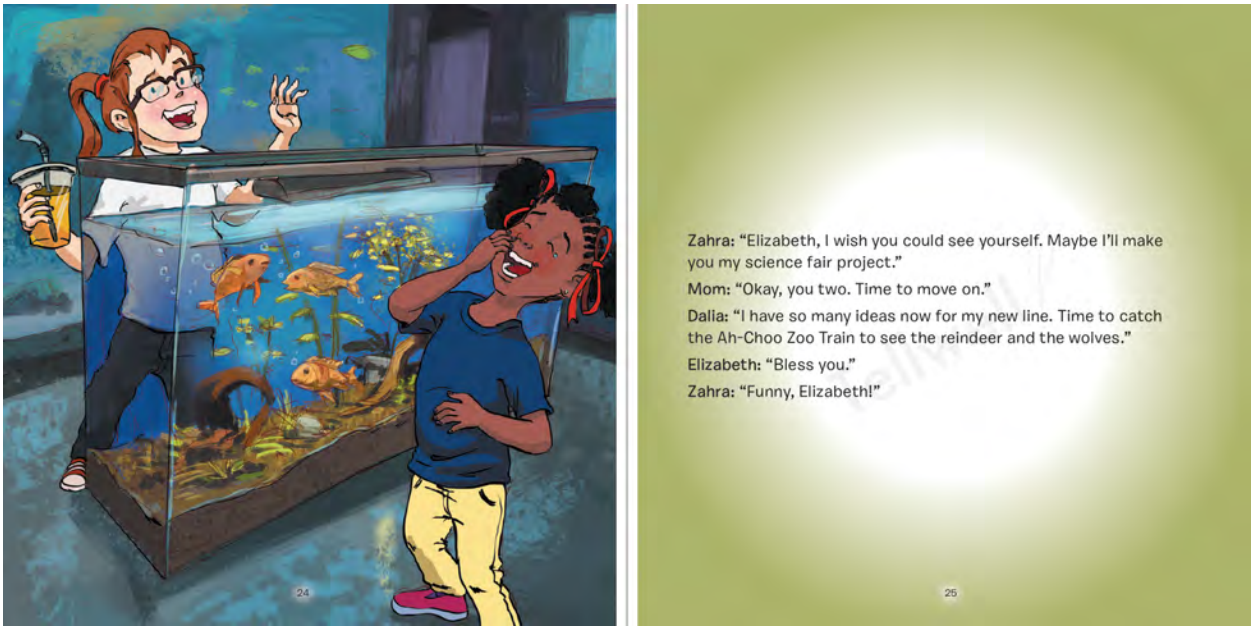

Elizabeth and Zahra stop for a moment for some fun with refraction. Elizabeth stands behind a small aquarium tank, knowing that her body is being distorted by refraction of light through the water from Zahra's perspective. Elizabeth makes sure her arms and one leg are beyond the tank so that Zahra can see how silly she looks.

The drink and straw in her hand show a close-up of how light bends as it enters a different medium (the soft drink in this case) from air.

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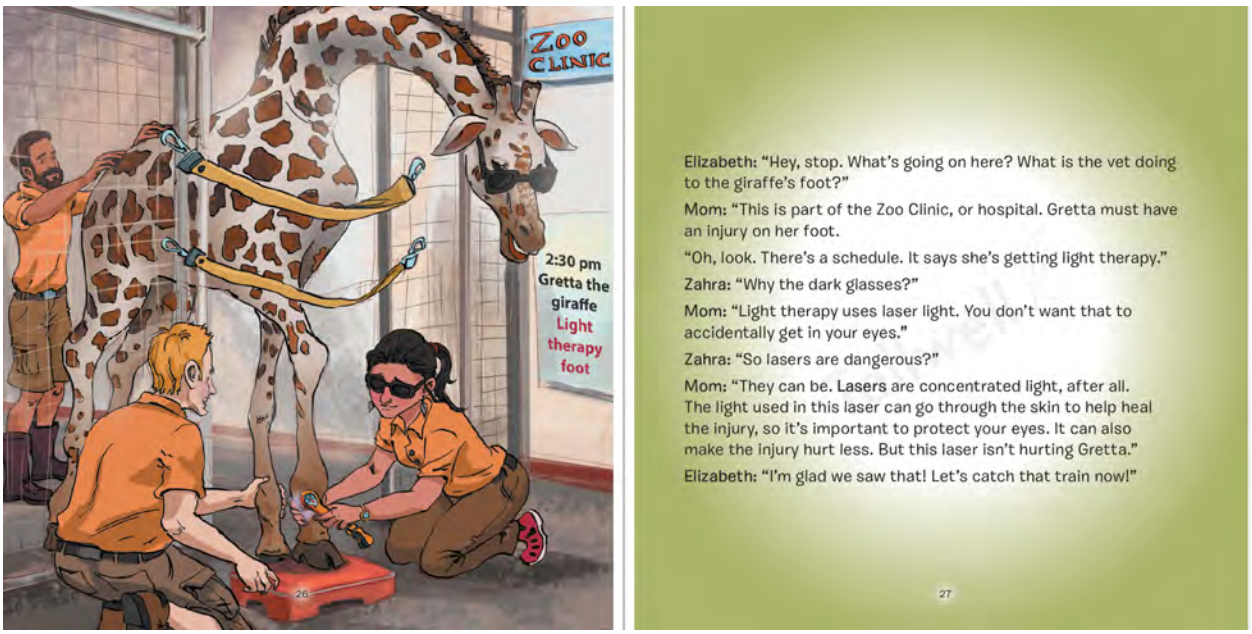
Pages 26 and 27



There are so many ways we use light. The example shown here is a medical treatment using laser therapy.

Gretta the giraffe has a foot injury, and the First Nations veterinarian is using a laser device to help heal the damaged tissue under the skin. Lasers are not toys and can be dangerous. They should not be pointed directly at anyone's eyes. However, the treatment is safe and does not hurt Gretta.

Laser treatment is known to reduce inflammation and help speed up tissue repair.

The word "laser" is an acronym for "light amplification by stimulated emission of radiation." So the laser instrument stimulates molecules or atoms to produce a beam of light that is one concentrated wavelength. Some lasers are powerful enough to cut leather, but the lasers used in light therapy are not as high energy, so they are not harmful to the patient.

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3.8 identify devices that make use of the properties of light and sound
Career doctor or other professional using light as medical treatment

Pages 28 and 29

At last the families come to the reindeer and wolf pens, which are highlights for Elizabeth and Zahra. They are very fortunate that the train arrives at a time when the reindeer and the wolves are visible and not off in the distance as they often are in the huge enclosures that house them in zoos.

These wolves are Arctic wolves, so their fur is white, unlike grey wolves. Zahra notices this and wonders about how they fare in the winter against the snow, because she knows that wolves eat reindeer and reindeer live in the Arctic where there's always lots of snow.

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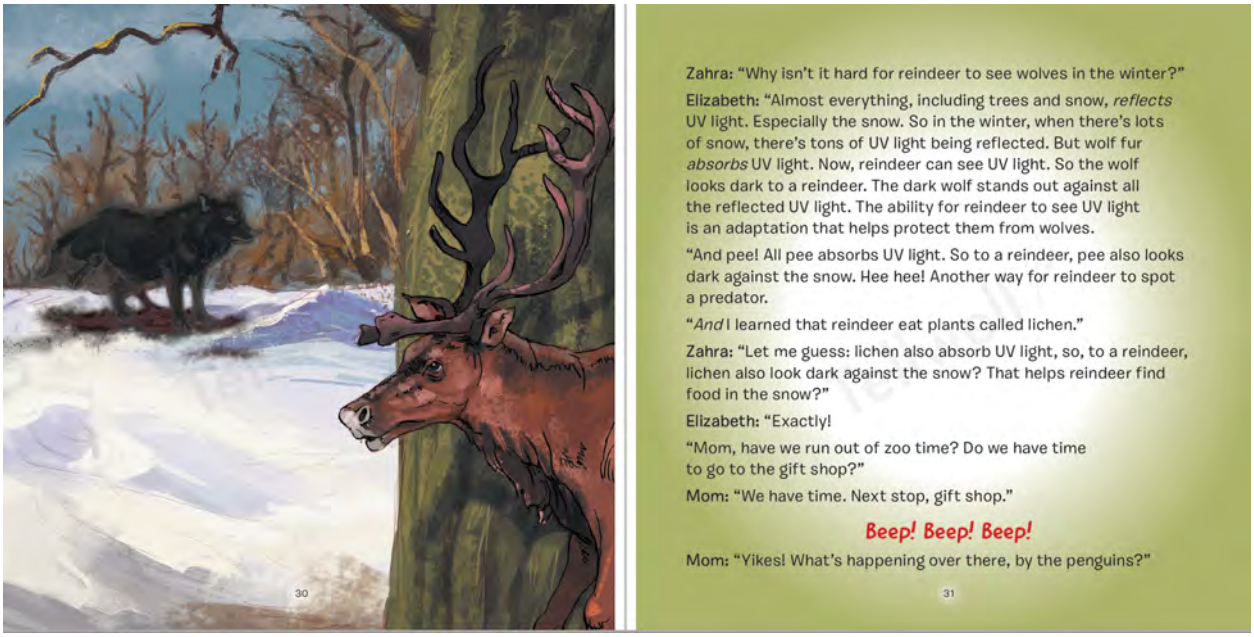

Even though we cannot detect UV light, many animals and insects can. Reindeer are just one of many examples.

The reindeer's cornea and lens allow some of the UV light in, which benefits reindeer, because being able to detect UV light helps protect them from wolves and find food in the snow. It also extends their vision range during the Arctic winters, when the amount of sunlight is strongly reduced—the highly reflective snow and ice reflect the UV light, giving reindeer more visual range.

This illustration shows what a wolf might look like to reindeer in the winter. Because wolf fur absorbs UV light, it looks dark to reindeer. Note that the wolf is peeing, which also appears dark to reindeer because *all* pee absorbs UV light. Fortunately for reindeer, lichen also absorb UV light, so reindeer are also able to find lichen in the snow.

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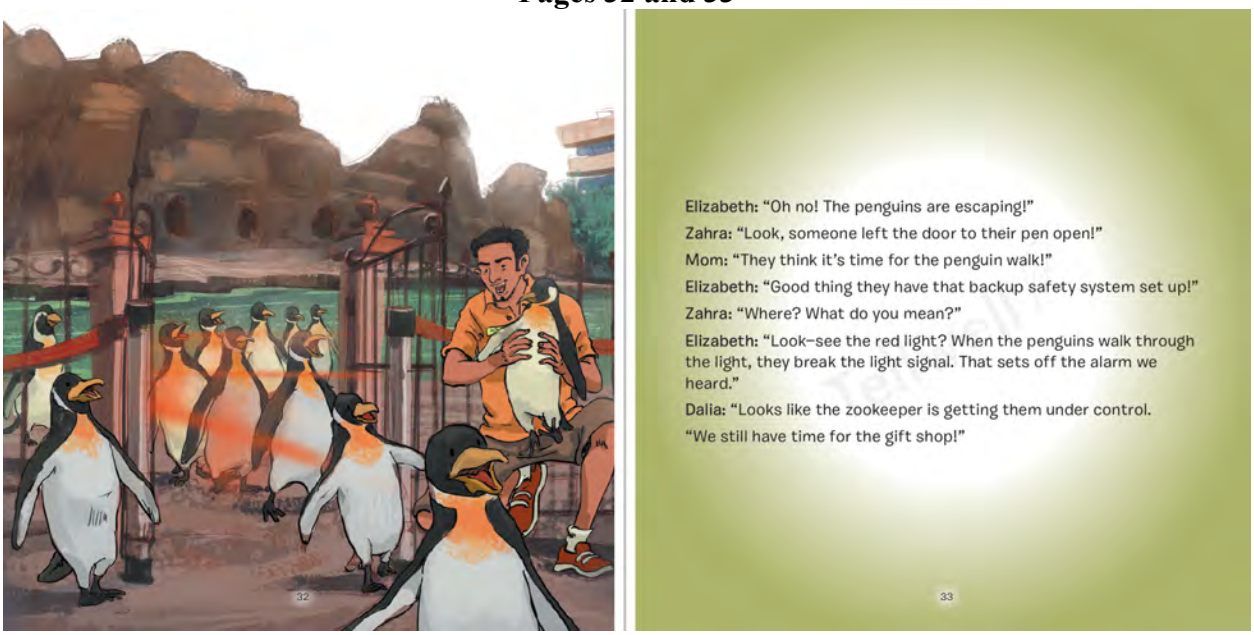
Pages 32 and 33



These pages feature another example of how we can use light in our society. In this case, there is a security system that alerts the zookeepers if the penguins leave their pen before it's time for their daily penguin walk. Note: This technology is not necessarily in place at zoos. It is used here for education and illustration purposes.

Systems such as this use infrared light. Our eyes cannot detect infrared light, but we can feel it—as heat. Unlike UV light, infrared light is low energy so as the penguins walk through the infrared beams and trigger the alarm, they are safe and not harmed in any way.

The technology is simple: When the beam of infrared light is on, it reaches a photodetector on the other side of the gate opening. When the beam is broken, by say a wandering penguin, the photoreceptor notices the sudden change in light level and trips the alarm.

Most of the 18 penguin species live in Antarctica and islands in the southern hemisphere, but one species lives at the equator. No penguin species live farther north than the equator.

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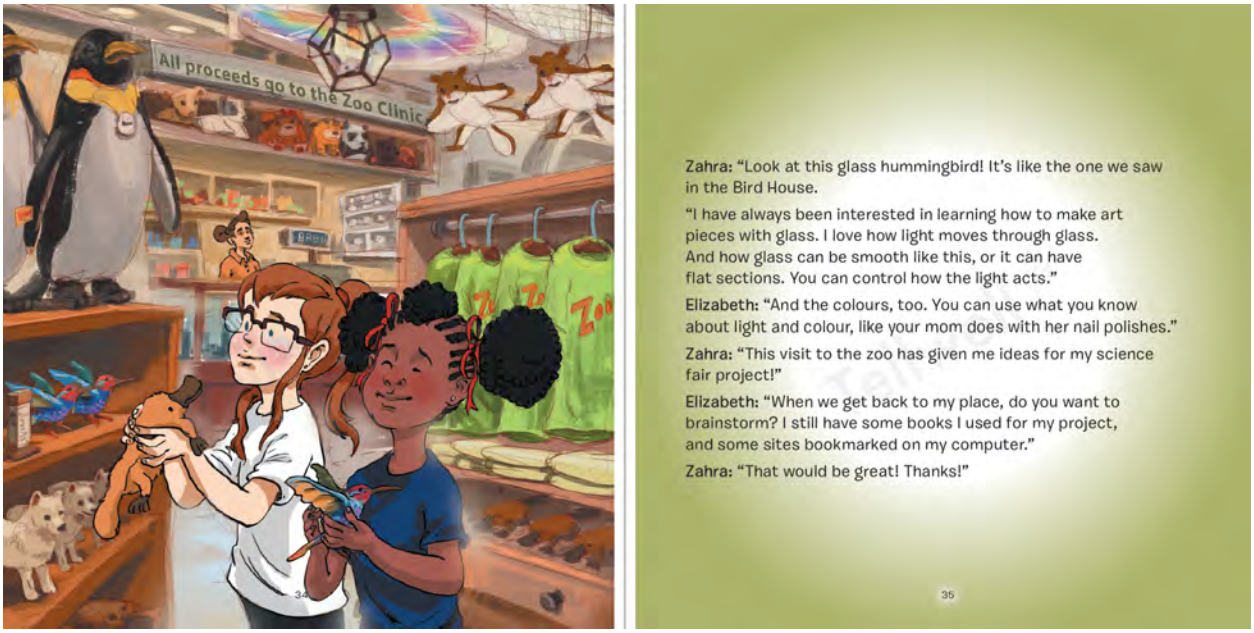
Pages 34 and 35



Students studying light know that white light is made up of all the colours. In this illustration, there is a light fixture with a glass, prism-like shade that shows the colours of the rainbow on the ceiling.

Zahra chooses a glass hummingbird as a memento of their visit to the zoo. She wants to work with light as an artist someday. She has become excited about everything she learned about light at the zoo. She plans to do her science fair project on something related to what she learned.

The sky is the limit for science fair projects related to light: fluorescence, biofluorescence, refraction, the many technologies that use light, an artistic use of colour and light in glass art, such as stained glass, and so much more.

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Career artist

Pages 36 and 37

Both Elizabeth and Zahra have become inspired by what they saw at the zoo today: Zahra is intrigued with the flying squirrels and biofluorescence, and Elizabeth wants to modify the alarm system she saw and use it at home.

Rigel also has ideas: She wants Zahra to do her science fair project on how dogs see.

See Light-Related Ideas for Activities and Science Fair Projects on page 22.

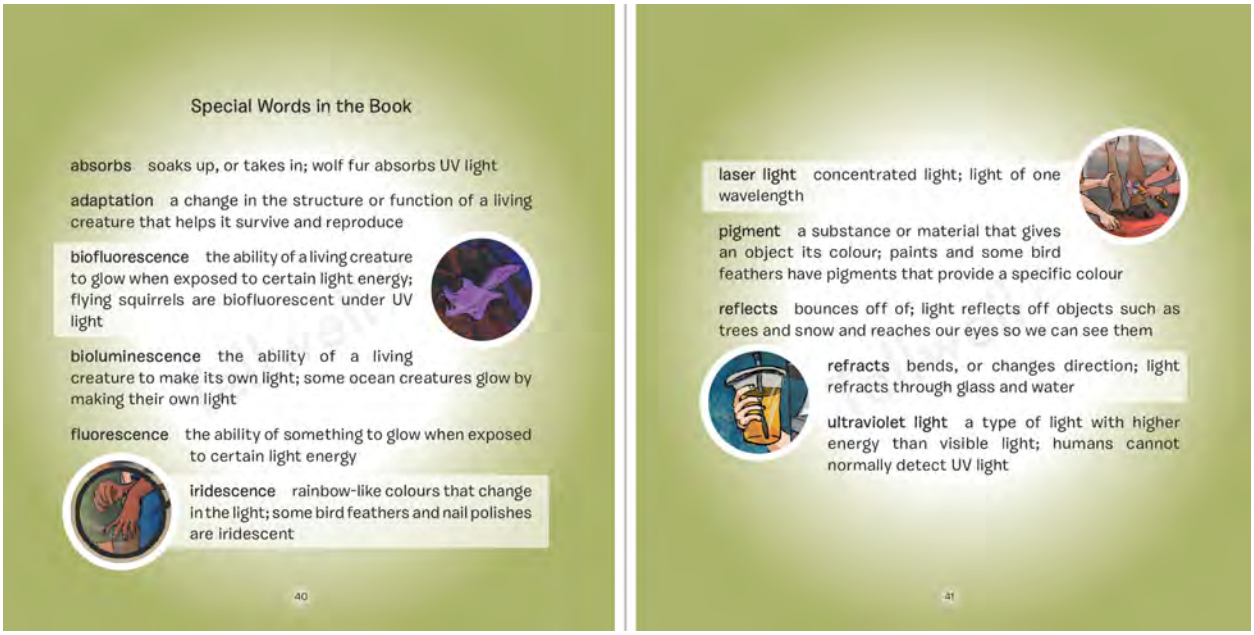
Grade 4: Understanding Matter and Energy, Light and Sound
1.2 assess the impacts on society and the environment of light and/or sound energy produced by different technologies, taking different perspectives into account
3.1 identify a variety of natural light sources and artificial light sources
3.2 distinguish between objects that emit their own light and those that reflect light from other sources
3.6 describe how different objects and materials interact with light and sound energy
3.8 identify devices that make use of the properties of light and sound

Pages 38 and 39

A fun activity might be to imagine the colours of nail polish that Dalia might design, and then name the designs. The names could be based on the animal or insect that inspired them. See the suggested activity in the Worksheet with Sample Answers file. See, also, Light-Related Ideas for Activities and Science Fair Projects on page 22.

Grade 4: Understanding Matter and Energy, Light and Sound
Career nail polish designer

Pages 40 and 41



The glossary, or Special Words in the Book, is a new feature in the Elizabeth series. I hope it adds something for the readers!

Light-Related Ideas for Activities and Science Fair Projects

Refraction

- how light refracts in different substances, such as water, air, glass, lenses (plastic or glass), minerals, a variety of oils
- using light to make art, such as with UV light or glass
- light and eyesight, in people, different animals, different insects

Reflection

- Pepper's Ghost (ideas turn up with an Internet search for this)
- controlling the direction of light
- making a cellphone "hologram" (not really a hologram, but a reflection; search "cellphone hologram"; see, also, https://bettyrrobinson.ca/blog/reflection-and-making-a-cellphone-hologram/)
- make a kaleidoscope

Fluorescence

- shining UV light on different household pantry items to see how they fluoresce (e.g., compare rock salt, olive oil, and canola oil, tonic water)
- researching which plants fluoresce to attract bees or other insects

Temperature

- comparing temperatures of objects in the Sun and in the shade