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BIODIVERSITY
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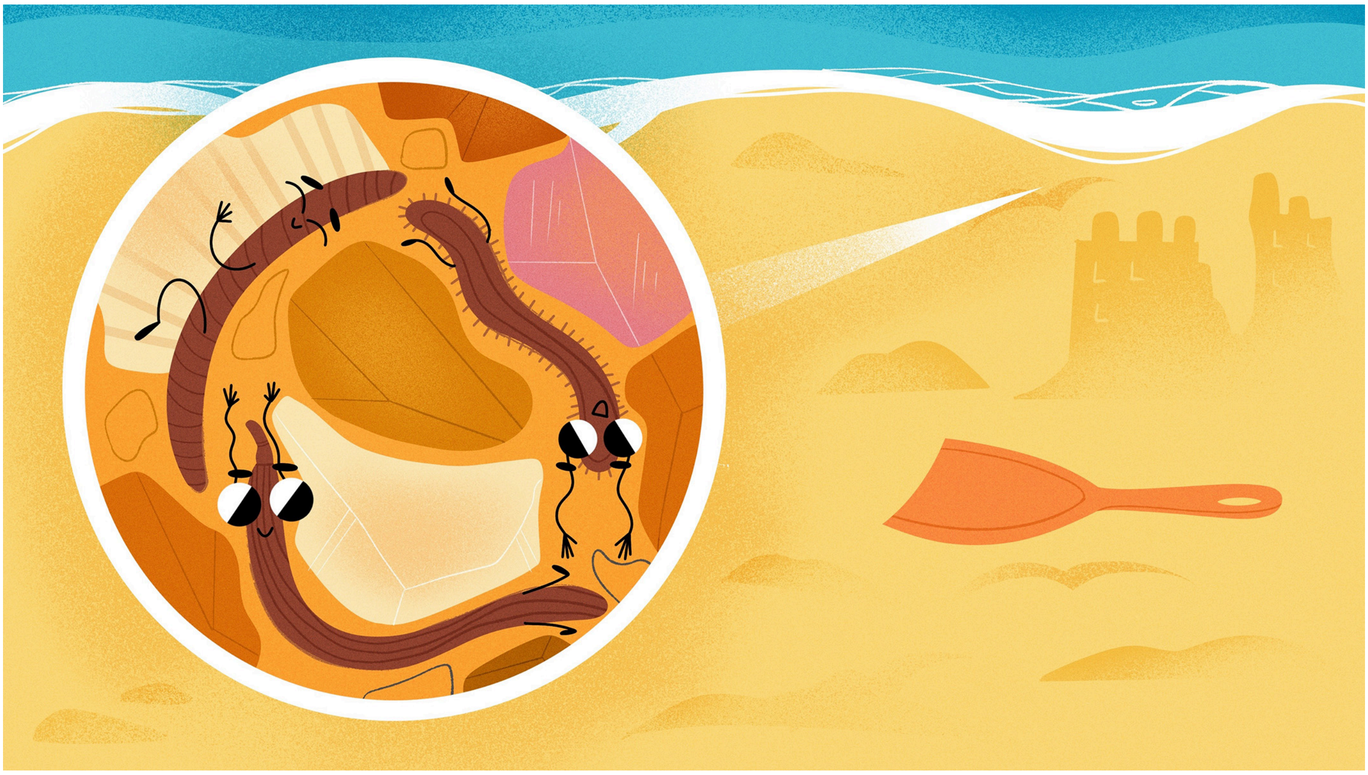

LIFE AMONG THE SAND GRAINS

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YOUNG REVIEWERS:


ANNAMEKA
AGE: 14

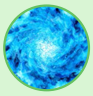

GURSHAAN
AGE: 14


MANHEER
AGE: 13


PRISHA
AGE: 13

Have you ever played with sand at the beach? Did you know you were also playing with thousands of tiny animals? The sand in the ocean is home to many small creatures called meiofauna, but you can only see them under a magnifying glass or microscope. Meiofauna are so tiny that sand grains seem like boulders to them. Meiofauna are too small to move these boulders, so they wriggle through spaces between them. Living in such tight spaces has led them to evolve long, skinny body shapes like worms. They also have special body parts to grip sand grains and avoid being washed away. Meiofauna are small, but they still play a big role in the ocean, feeding larger animals and recycling waste on the ocean floor. There are tens of thousands


RAFSAN
AGE: 15


RITVIK
AGE: 13


TANISH
AGE: 14

of species of meiofauna worldwide, and many more are waiting to be discovered.

LIFE IN THE SAND

Life comes in all sizes! There are things we can see, like ladybugs, whale sharks, and strawberries, but there are also microscopic organisms that we cannot see with just our eyes, like bacteria and mold spores. However, there is also a realm between these two worlds. Thousands, if not millions, of different kinds of animals about the size of a pencil tip or smaller, live between the grains of **sediment** found in oceans, lakes, rivers, and caves. These animals are called meiofauna.

SEDIMENT

Tiny pieces of dirt, sand, rocks, and organic matter that settle at the bottom of rivers, lakes, or oceans.

MEIOFAUNA ARE DIVERSE

Meiofauna are extremely diverse, with tens of thousands of different species from branches across the tree of life [1]. Most groups of animals including crabs (crustaceans), snails and clams (mollusks), and worms (annelids) have meiofaunal species too. These species have evolved many times from their larger-bodied relatives. In addition, juvenile (young) stages of some larger animals can be small enough to live among sand grains. These young animals are called temporary meiofauna. Temporary meiofauna have complex life cycles with **adaptations** to survive life as a larva in the water, as a meiofaunal juvenile in the sediment, and then as a larger adult. There are other animals, like mud dragons (kinorhynchs) and hairy bellied worms (gastrotrichs) that only exist as meiofauna. Most permanent meiofauna hatch as a miniature version of their parents and live their entire lives between grains of sand.

ADAPTATION

A change in a plant or animal that makes it better able to live in a particular place or situation.

Although meiofauna can be seen with the naked eye, you need a magnifying glass or microscope to tell them apart. Once you get a closer look, it is remarkable how complex and diverse these tiny animals can be (Figure 1)! Some meiofauna are covered in spines, others have many hairy legs. Some have tails that make sticky glue, and others have mouthparts that extend far out of their bodies and are used like a harpoon to collect food. These are just some of the diverse adaptations that help meiofauna live in a world where sand grains are the size of boulders.

WHAT DO MEIOFAUNA HAVE IN COMMON?

Meiofauna must squeeze through tight spaces, dodge predators, and avoid being washed away in storms or being crushed by moving sand grains. To do all this, meiofauna have become highly adapted to their environment. Many have worm-like bodies that allow them

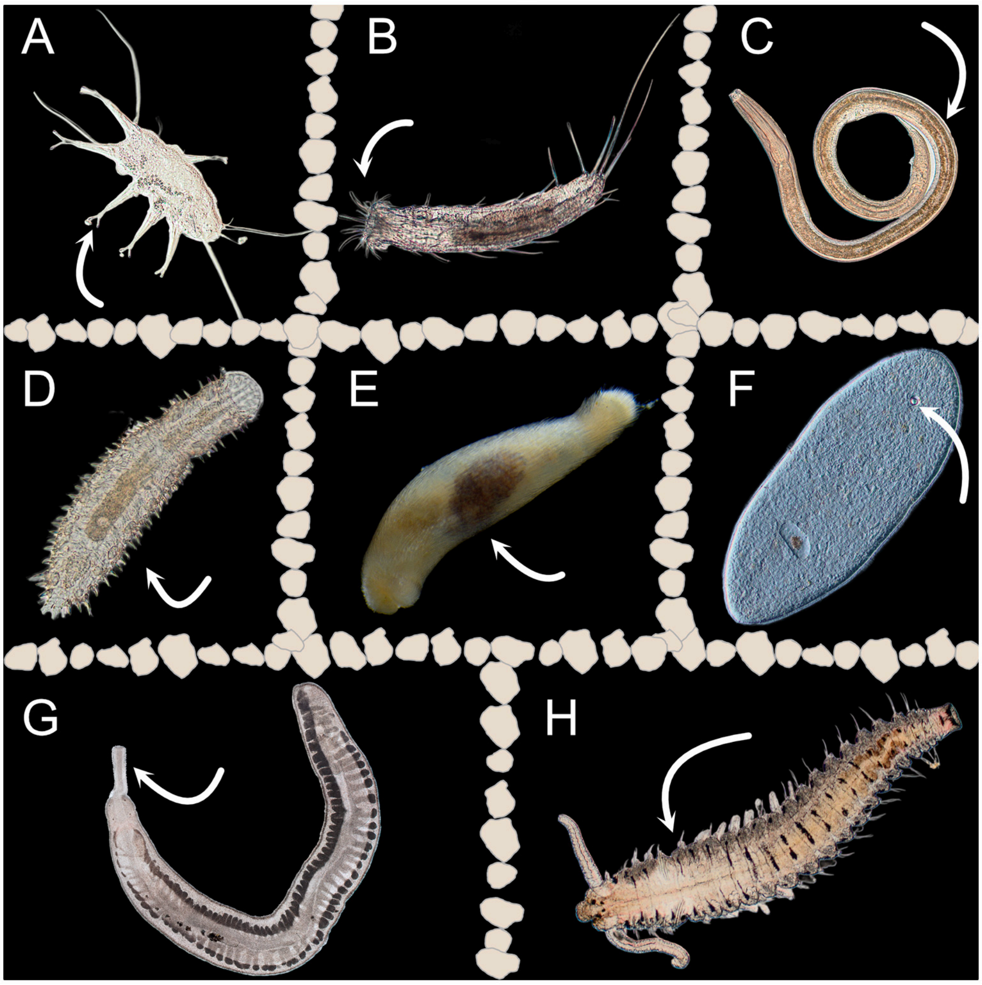


Figure 1

Figure 1

(A) Tardigrades have sticky toes for gripping sand grains. **(B)** Kinorhynchs have spines extending from their mouths, bodies, and tails. **(C)** Nematodes are small, skinny worms that slide between sand grains. **(D)** Gastrotrichs are covered in sticky tubes that help them stick to and move among sand grains. **(E)** Aplacophoran mollusks cover their bodies in armor made of thousands of spines. **(F)** Aceol worms have a statocyst that helps sense which way is up and down. **(G)** Nemerteans have a long tongue-like structure that captures prey. **(H)** Spionid worms are temporary meiofauna and only live between sand grains as juveniles.

to wriggle through tight spaces. To prevent being washed away, they have ways to stick to sediment, like producing mucus or having specialized sticky structures called **adhesive glands**. Because sand is constantly shifting, meiofauna need protection from being crushed by the sand-grain boulders. Many meiofauna have either internal or external protective structures that can act like armor. Some even have spines for defense.

ADHESIVE GLANDS

An adhesive gland is a special structure on the surface of the animal that produces special glue that helps meiofauna stick to sand grains.

Because life in the sand tends to be dark, many meiofauna rely on specialized structures to sense the world around them. Meiofaunal annelid worms, for example, have tentacle-like structures near their heads. They use these tentacles to feel around ahead of themselves. Other meiofauna have a gravity-sensing organ called a **statocyst**—a small, fluid-filled chamber that holds a tiny, rock-like ball called a statolith. When the animal moves, the statolith rolls around and touches sensory cells in the chamber. These cells send signals to the animal, helping it figure out which way is up or down in the darkness.

STATOCYST

A tiny organ in some animals, like jellyfish or crabs, that helps them sense balance and know which way is up or down.

Adaptations like a worm-shaped body, adhesive organs, and statocysts can be found in meiofauna that are not closely related, and distantly related species can look similar. When two species from unrelated groups evolve similar adaptations or features, it is called **convergent evolution**. For example, the reason birds, bats, and butterflies all have wings is because they help the animals do the same thing—fly. Convergent evolution can also occur when animals live in similar habitats. Many meiofauna that might not be closely related look similar because they evolved to live between the grains of sand.

CONVERGENT EVOLUTION

When different animals or plants evolve to look or behave similarly, even though they are not related.

HOW AND WHY DO SCIENTISTS STUDY MEIOFAUNA?

Scientists are still discovering and describing new species of meiofauna, and there are likely tens of thousands of species yet to be described. The scientists who identify and catalog new species of organisms are called **taxonomists**. Taxonomists also study how different species are related, to better understand the diversity of life. They often travel all over the world to find new species.

TAXONOMIST

A scientist who names and classifies living things into groups.

The first challenge taxonomists face when studying meiofauna is separating animals from the sand. Because the animals and sand grains are the same size, meiofauna can't be filtered out with a net or a sieve. Instead, scientists use the difference in density to separate the relatively light animals from the heavier particles of sand. You can try this method too, by following the directions in Figure 2 the next time you are at the beach.

Once the meiofauna have been separated from the sediment, scientists use microscopes to get a closer look (Figure 3). Taxonomists examine their anatomy (what body parts and organs they have) to identify species and describe new ones. Another challenge in studying meiofauna is that distinguishing differences between animals is more difficult when animals are very small. Because meiofauna often have shared characteristics, they can be difficult to tell apart from each other.

Sometimes scientists use **DNA** to tell similar meiofauna apart. DNA is like a blueprint for building an animal, studying DNA can help answer a lot of questions about how and where meiofauna have evolved. Comparing DNA among different animals helps taxonomists determine how closely related they are and identify new species. However, getting enough DNA from small animals like meiofauna is hard. Scientists have been improving methods to extract DNA and determine the information encoded in the DNA. Thanks to advances in technology, scientists today can sequence DNA from a single meiofaunal animal. Sometimes scientists find meiofaunal animals from two or more far-away places that look identical but, when they study their DNA, they find the species are more genetically different

DNA

Deoxyribonucleic acid, is a molecule inside cells that carries the instructions for how living things grow, develop, and function. It acts like a blueprint for building our bodies.

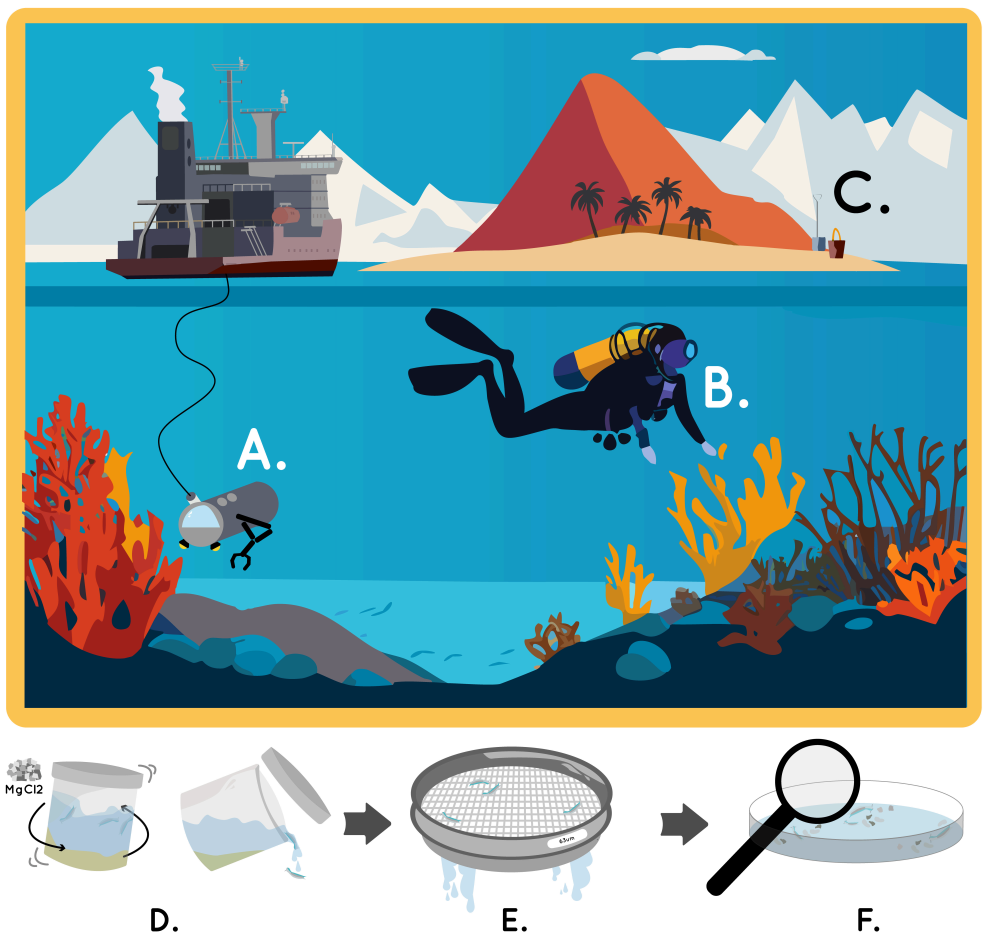


Figure 2

Figure 2

Meiofauna can be found all over the world. **(A)** In the deep sea, scientists use special equipment like advanced nets and manned drones to collect sediment. **(B)** Scientists collect meiofauna from the sand formed from dead coral around coral reefs. **(C)** Most groups of meiofauna can be found just feet from the shore. **(D)** To collect meiofauna, scientists collect sand, swirl it well, and pour the liquid through a sieve or coffee filter. **(E)** Meiofauna are too large to pass through the filter, so they get stuck. **(F)** A magnifying glass or a microscope can be used to look for meiofauna.

than humans and chimpanzees. These similar-looking but genetically different species are called **cryptic species**.

CRYPTIC SPECIES

Different species that look almost identical but are not the same.

Scientists also study meiofaunal behavior, such as how the animals move and eat. These researchers use very small, specialized tools. For example, to catch and move these tiny animals, scientists use small sticks with eyelashes or cat hairs attached. Scientists put meiofauna in clear sand and have even built tiny treadmills to observe how they respond to water flowing through the sand (Figure 3B) [2].

Figuring out how many species of meiofauna there are, how to identify them, how they are related, and how they behave is important for understanding the whole ocean. In some parts of the ocean, you can find thousands of meiofauna in a single teaspoon of sand. These animals grow very quickly, from babies to adults in just a few months. Because they are abundant and grow quickly, meiofauna are important players in moving nutrients through ecosystems. When organisms in the ocean die, they eventually sink to the sea floor. Many meiofauna eat these leftovers, recycling their nutrients back into the food web. After eating this material, meiofauna themselves become important food for young fish and crabs. Meiofauna help keep the seafloor

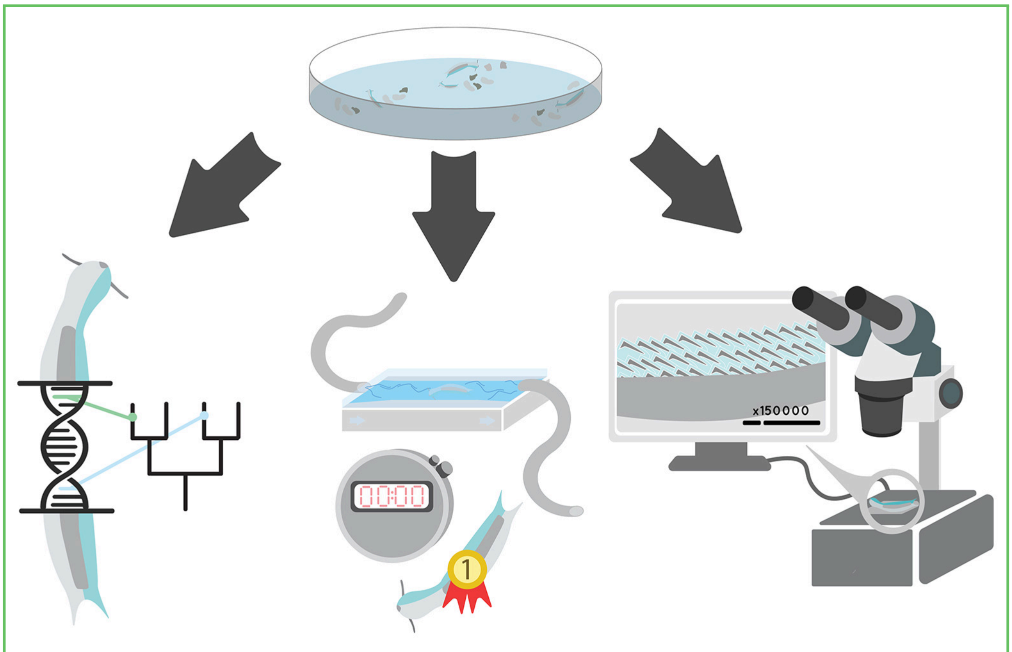


Figure 3

Figure 3

Scientists use a variety of tools to study meiofauna including: **(A)** DNA sequencing, in which organisms are ground up and their genes are analyzed to understand how they live and how they are related to each other. **(B)** Behavioral studies, in which scientists study how meiofauna navigate the complex spaces among sand grains using treadmill flow chambers and clear sand. **(C)** Microscopy, which allows scientists to see and study characteristics that are normally invisible to the naked eye.

healthy by stirring water down into the sediments, bringing oxygen and nutrients to microbes living there, which recycle this material. Without meiofauna, less of this valuable food would be recycled, and the sea floor would be more like a trash can and less like a recycling bin.

Meiofauna can also help scientists understand how healthy an environment is. Because they are small and cannot move very far, meiofauna are used as **bioindicators** for environmental and climate change [3]. Just like a doctor uses a thermometer to help diagnose a sickness, scientists can use meiofauna to diagnose the environment. This can be done by counting the number of each species or by studying DNA and counting the different sequences. The species or sequence counts can be compared to the diversity in samples taken from different places or from the same place at different times. For example, after an oil spill in the Gulf of Mexico, scientists compared the diversity of meiofauna at sites across the region before and after the oil spill, to determine how the oil spill affected the meiofaunal community [4]. They found fewer species of meiofauna after the oil spill, but after a year, the diversity increased again.

BIOINDICATOR

A living thing, like a plant or animal, that shows how healthy the environment is.

MEIOFAUNA MATTER

The seafloor is filled with diverse and interesting meiofauna that live between the grains of sand. Within this secret world of sand, animals of all shapes glide and stick through small spaces, navigating their “meio-scopic” environment. Next time you play in the sand or walk along the beach, remember that you are stepping on thousands of little animals specially adapted to survive in the shifting sands. Figuring out how many species of meiofauna there are, how to identify them, how they are related, and how they behave is important for understanding the whole ocean.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ANNAMEKA, AGE: 14

There are so many things in this world that are just waiting to be revealed. I find pleasure in discovering things I never knew existed and concepts I never delved into explained. For me, science is not "studying" if people do not showcase it to be. This page is important as it allows students like me to learn in a fun way and explore different topics we never knew about.

GURSHAAN, AGE: 14

I love learning about science and enjoy asking questions and finding answers. I am committed to deepening my knowledge and aim to make meaningful contributions to the scientific community.

MANHEER, AGE: 13

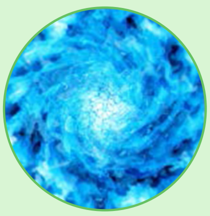
I am a passionate learner with a keen interest in exploring the wonders of science. Fascinated by how the world works, I enjoy diving deep into topics like biology, chemistry, and physics and apply them to real-world challenges.

PRISHA, AGE: 13

I am passionate about maths and science and especially enjoy biology and chemistry. In my free time, I enjoy playing tennis and listening to music. My hobbies also include playing the violin and keyboard, as well as reading a variety of books, especially fantasy and adventure.

RAFSAN, AGE: 15

Hey there! I am Rafsan – a sports enthusiast who loves football, athletics, and chess, with a strong interest in science and a drive to learn and challenge myself.



RITVIK, AGE: 13

I love science and their topics. This mainly fall under astronomy. I am fascinated by astronomy because it is more than just the night sky and stars, it is an expanding area of space. Not only that, but the possible existence of life on other planets. It is so inspiring to see scientists around the world working so hard to discover so valuable information, just so we can learn more about our place in space.

TANISH, AGE: 14

Hi, I am Tanish. I am a curious 14-year-old with a passion for geography, science, and understanding how the world works. Fascinated by maps, I love exploring different countries and cultures, always eager to learn about new places. Science is another big interest, and I enjoy diving into topics like ecosystems, weather patterns, and the natural world. With a big imagination and a knack for asking great questions, I am always on a quest for knowledge, discovering how things fit together to make our planet unique.

AUTHORS

WILL M. BALLENTINE

I am an oceanographer who studies how marine animals interact with their physical environments, and how those interactions affect animal shape and size. I use techniques from fluid dynamics, mechanics, and biology to study how life among sand grains has shaped meiofauna form and function over evolutionary time. I became interested in marine science as an undergraduate when I took a course on marine invertebrate diversity and became fascinated by the hundreds of thousands of species living in our oceans. *willballentine@gmail.com

NICKELLAUS G. ROBERTS

I am a graduate student interested in invertebrate zoology and bioinformatics. I am primarily interested in some of the amazing organisms that inhabit the world's oceans. My primary research involves sequencing the genomes of the world's smallest animals, most <1 mm in size, ranging from microscopic worms at the deepest depths of the ocean to tiny filter-feeding organisms found in tide pools. While I grew up in the desert, I became interested in microscopic invertebrates when I went to college in Santa Barbara, California, and studied the great diversity of organisms off the west coast of the United States. In the future, I hope to continue to study the amazing lives of the world's smallest marine animals.

MEGHAN K. YAP-CHIONGCO

I am an evolutionary biologist interested in how the differences in genomes of marine invertebrates lead to different body shapes and sizes. Growing up in Northern California, my family would often go to the beach, but I was afraid of the ocean until I was in high school. I did not become interested in marine biology until I took a course in college where I fell in love with marine invertebrates. Since then, I have worked toward understanding how organisms can look so different from one another using techniques in genomics, bioinformatics, and morphology.

KENNETH M. HALANYCH

I am a marine evolutionary biologist who has worked on animal diversity in several environments, including extreme environments like Antarctica and hydrothermal vents. My laboratory has used both genetic and morphological tools to study a variety of invertebrates including sponges, sea stars, worms, and clams. My interest in marine biology started when I was in high school and on field trips in the Chesapeake Bay. This led to a career of asking questions about how animals are related and how they have adapted to their environments.

KEVIN M. KOCOT

I am an invertebrate zoologist specializing in the biodiversity and systematics of small-bodied animals that are likely more diverse than currently understood. My research combines traditional and modern approaches to explore the hidden diversity and evolutionary relationships of these fascinating organisms. I am particularly interested in the worm-shaped Aplacophoran molluscs, a group that has many species that have not yet been named. I am passionate about training the next generation of taxonomists in both traditional and modern skills and contributing to our understanding of life's diversity on Earth.

KELLY M. DORGAN

I am an oceanographer and, for over two decades, I have been studying how worms and other animals that live in sediments interact with their environments. I work with engineers to learn their tools and techniques and use them to understand what life is like for worms.