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HUMAN HEALTH
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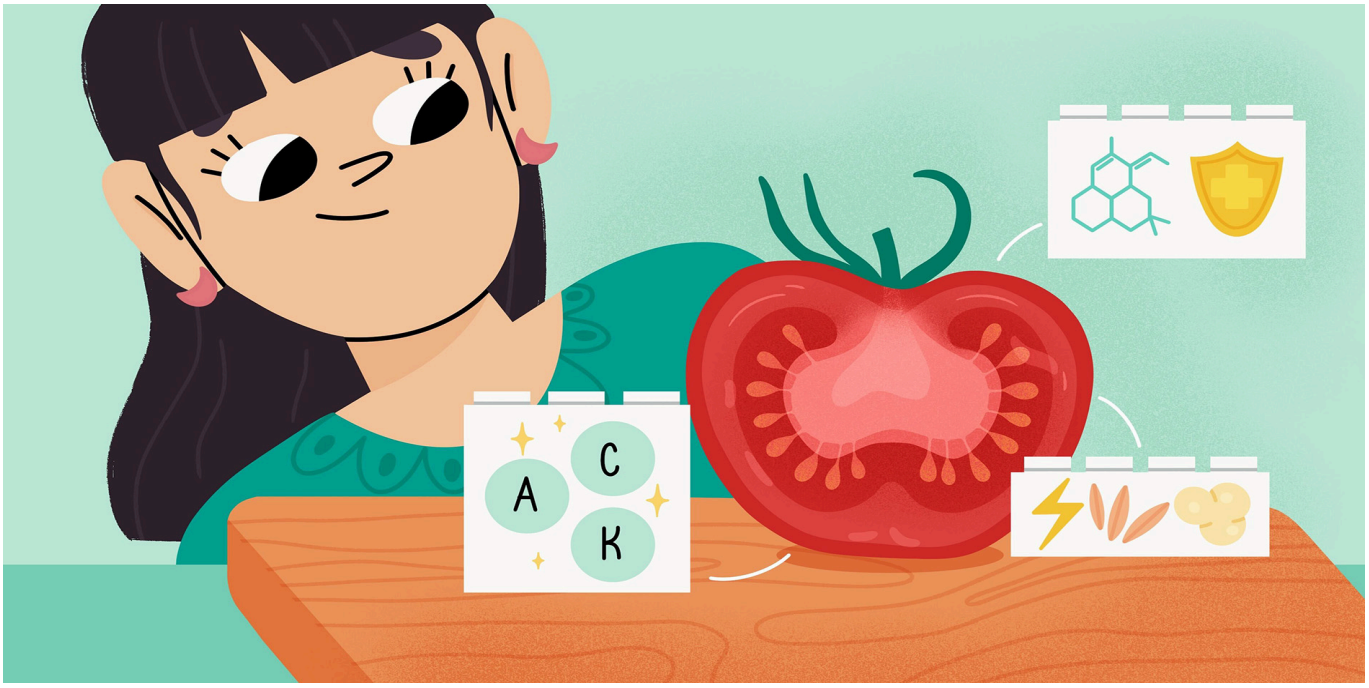

WHAT IS IN A TOMATO? MAPPING THE BUILDING BLOCKS OF FOOD

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When you bite into a tomato, what exactly are you eating? Join us for a tour of tomatoes, as we learn about the building blocks of food, known as biomolecules. Our tour explores the thousands of biomolecules in food, many of which play important roles in nutrition and health. An examination of tomatoes from various farms tells us that not all tomatoes have the same biomolecules. Lots of

things affect the amounts and types of biomolecules in tomatoes, including their genetics, where and how they are grown, and even how they are stored and cooked. Our tour ends with a peek into a lab where scientists work on a global project to map all the biomolecules in foods. Welcome to an exciting frontier of science, where discoveries can lead to big improvements in the health of people and the planet.

While eating, have you ever thought, "what exactly is this food made of?" If this thought has ever crossed your mind, you were asking an important question that scientists are still trying to answer.

To find out what our foods are made of, join us on a tour of one of the most commonly eaten fruits in the world: the tomato. Yes, even though many people think tomatoes are veggies, they are actually fruits! If a food contains seeds, scientists consider it a fruit. Maybe you eat tomatoes sliced on a burger, diced in tacos, mixed into a salsa, or freshly plucked from the garden. Or perhaps you enjoy tomatoes cooked in sauces, soups, and curries. No matter how you eat tomatoes, they can tell us a lot about the building blocks of food.

BIOMOLECULES

Substances that are made and stored in the cells of plants and animals, and that play important roles in growth and survival. Biomolecules are the building blocks of food.

MACRONUTRIENTS

Biomolecules that are required in large amounts by living organisms, for their growth and survival. Macronutrients include carbohydrates, lipids, and proteins.

MICRONUTRIENTS

Biomolecules that are essential in small amounts, for the growth and survival of living organisms. Micronutrients include minerals and vitamins.

SPECIALIZED METABOLITES

Biomolecules that organisms make to support their survival, including for defense and communication. In plants, specialized metabolites include alkaloids, carotenoids, flavonoids, and terpenoids.

BITING INTO A TOMATO: THE BUILDING BLOCKS OF FOOD

Fruits, vegetables, and meats are made up of thousands of tiny building blocks known as **biomolecules**. Biomolecules are substances made by plants and animals that play important roles in their physical structure, growth, and survival. We can imagine biomolecules like tiny Legos, used to make thousands of new shapes that have unique roles.

There are three main types of biomolecules naturally produced by tomatoes and other edible plants: **macronutrients** (carbohydrates, lipids, and proteins), **micronutrients** (minerals and vitamins), and **specialized metabolites** (chemicals like alkaloids, carotenoids, flavonoids, and terpenoids; Figure 1). Each of these building blocks can be grouped into more specific types, based on their structures and roles. Identifying and grouping biomolecules helps us understand the inspiring diversity of food. Let us take a closer look at these blocks and the roles they play in "building" a tomato.

Macronutrients are the largest of a food's building blocks. They are required by all plants and animals in relatively large amounts daily, for growth and survival. The three types of macronutrients in food are carbohydrates, fats, and proteins. Carbohydrates include starches, sugars, and fiber. The sugars in tomatoes make them sweet, while the fiber provides texture and gives a slight crunch. Tomatoes also contain extremely small amount of several types of fats.

Figure 1

What is in a tomato? Tomatoes contain biomolecules naturally found in plants, and extra stuff that enters the fruit through farming, storage, processing, and cooking.

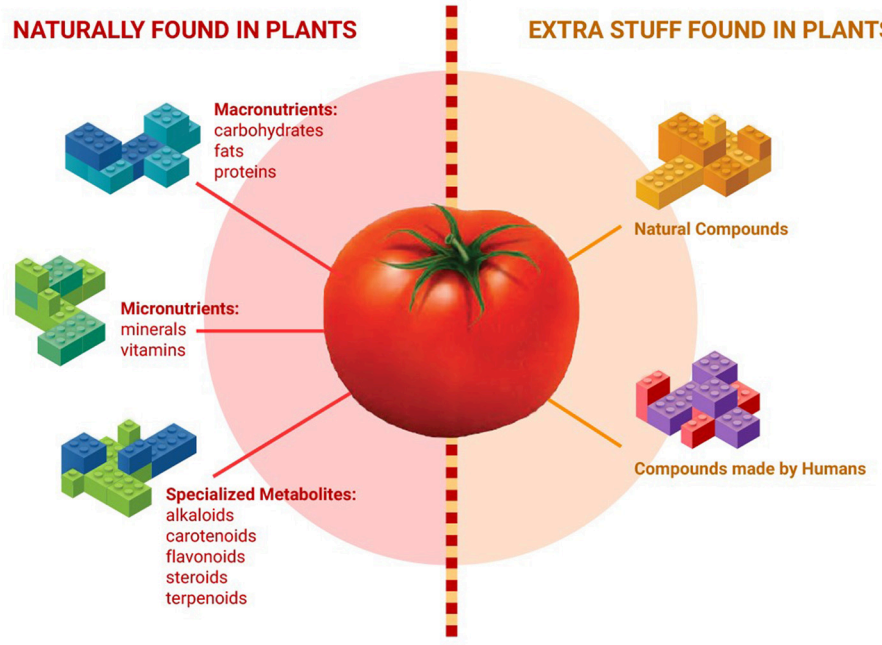

Figure 1

Micronutrients are smaller building blocks of edible plants, but they are no less important. They include minerals and vitamins required by plants and humans in relatively small amounts, but that are still essential for growth and survival. The key minerals we get from food are calcium, phosphorus, iron, potassium, magnesium, manganese, selenium, zinc, and copper. The key vitamins we get from food are A, B complex, C, E, and K. Tomatoes are a fantastic source of vitamins A, C, and K.

Now imagine the tomato plant as a character in a video game (Figure 2). All the things around the tomato, from the sun and soil to pollinators and plant-eating animals, can be helpful, stressful, or really harmful. Unlike animals that can run away from threats, plants are rooted in place. They use their macronutrient and micronutrient building blocks to build new "super-powered" blocks, to protect themselves from all sorts of threats as well as to communicate. These amazing "super-powered" blocks are called specialized metabolites.

Scientists have found over 2,000 specialized metabolites in tomatoes! The four main types of specialized metabolites in plants are carotenoids, alkaloids, flavonoids, and terpenoids. Each of these main types contain hundreds to thousands of biomolecules with their own properties. For example, terpenoids contribute to the flavor of tomatoes and also protect the juicy fruit from being eaten by bugs. Scientists have found over 400 types of terpenoids in tomatoes!

Along with the biomolecules naturally found in tomatoes, other types of molecules enter the plants through farming and processing,

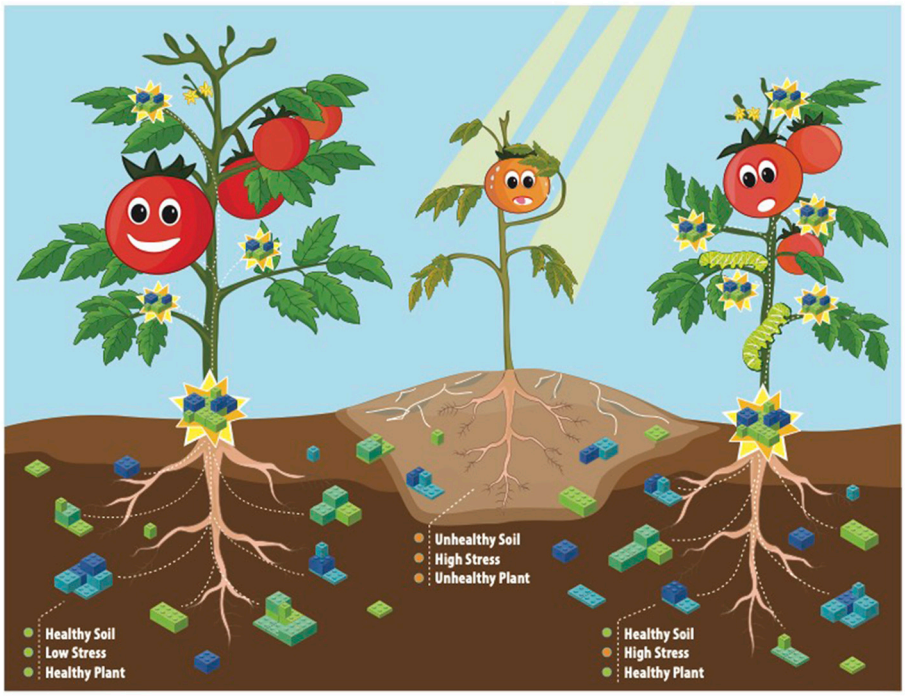

Figure 2

Specialized metabolites help plants protect themselves from stresses and threats, and they vary based on environmental conditions. If the tomato plants were characters in a video game, specialized metabolites would be the superpowers they have to protect themselves and communicate. Here we see three tomato plants with unique amounts of macronutrients, micronutrients, and specialized metabolites, depending on the health of the soil they are growing in and the stresses they face.

as the tomatoes make their way to our tables. You can think of these molecules as the little bits of fuzz, toy marbles, or even crumbs from an old snack that you might find while rummaging in the bottom of your Lego box. These molecules might include pesticides, herbicides, preservatives, and additives. Do you think these human-made molecules are good to eat? Scientists are still working to find the answer.

BUILDING BLOCKS FOR NUTRITION AND HEALTH

As kids grow, their bodies must get everything they need from food. The building blocks of food are also the building blocks for our bodies! The better the building blocks of our diets, the healthier our bodies will be.

We need macronutrients and micronutrients to live, grow, and protect our cells. These biomolecules are considered essential nutrients, since our bodies cannot make them on their own. For example, we get energy from macronutrients, in the form of calories. Vitamins A and C support growth and repair and can even strengthen the immune system. The mineral potassium helps keep the heartbeat regular and bring nutrients into our cells.

Although we do not need every type of biomolecule to survive, scientists are discovering the many ways specialized metabolites can support us, if eaten in the right amounts. For example, lycopene,

a red-colored biomolecule in tomatoes, can help keep our hearts healthy [1].

Since fruits and vegetables have different types of specialized metabolites, we get unique health benefits from each type of food. This is why it is so important to eat a diverse diet. With so many interesting building blocks in food, we need more research to better understand their role in health.

FARM TOUR: NOT ALL TOMATOES ARE THE SAME

Let us head to the farm! The first tomato plants were grown over 2,500 years ago, in South America, Central America, and Mexico. The Aztecs called the fruit *tomatl* and used them in their cooking. Tomatoes are now grown all over the world. China, the United States, Italy, Turkey, India, and Egypt grow the most tomatoes.

Farmers have selected tomatoes with characteristics that they prefer, and passed down seeds over generations. This has resulted in over 10,000 types of tomatoes with different colors, sizes, tastes, and—you guessed it—biomolecules. While we often think of tomatoes as red, some are green, yellow, pink, or even purple! Some are the size of your fingernail, and others are larger than your fist. Some taste sweet, while others are sour. Some are juicy, while others are crunchy.

Touring from one tomato farm to the next, we are reminded that differences in the environment and genetics impact what ends up in our food, especially those "super power" specialized metabolites. Each environment has its own characteristics, which can trigger plants based on their genetics to produce varying amounts and types of specialized metabolites (Figure 2). This is one reason why the very same type of tomato can taste different from one farm to another, or from one season to the next [2]. This is also another reason to care about climate change—it can change the quality of our food [3].

By keeping farms healthy, we will be able to get the best foods, far into the future. Some farming practices make the soil healthier, so we can grow foods with more desirable biomolecules [4]. Other farming practices can damage the soil, while adding undesirable molecules to foods and releasing greenhouse gases that can cause climate change and damage the planet.

Once tomatoes are harvested, the amounts of the biomolecules they contain change with processing, storage, and cooking. Next time you sit down for a meal, consider the journey that your food took, all the way from the farm. If we had a map of all the building blocks and extra stuff in tomatoes, along with where and how they were grown, stored, and prepared, we could figure out how to get tomatoes that are the

healthiest for people and the planet. Let us head to the lab to see how we might be able to create this map!

LAB TOUR: THE PERIODIC TABLE OF FOOD INITIATIVE

Welcome to the Analytical Chemistry Laboratories at Colorado State University. Scientists in this lab work with other scientists all over the world to map all the biomolecules in foods, for a project known as the Periodic Table of Food Initiative [5].

Scientists use advanced instruments to see the thousands of biomolecules in foods, including macronutrients, micronutrients, and specialized metabolites, as well as those "extra stuff" molecules. One of the main instruments they use to identify biomolecules in foods is a **high-resolution mass spectrometer** (Figure 3). Mass spectrometers are kind of like lasers that zap the molecules in food, to figure out their mass and identity. These scientists see thousands of biomolecules in tomatoes, almost like a map of the galaxy!

HIGH-RESOLUTION MASS SPECTROMETER

An advanced laboratory instrument able to detect known and unknown biomolecules based on their unique characteristics including their mass.

Figure 3

The Analytical Chemistry Laboratories at Colorado State University is mapping all the biomolecules in foods, using advanced instruments such as a high-resolution mass spectrometer, with the goal of improving food quality and the health of people and the planet.

In addition to the known biomolecules in tomatoes, a high-resolution mass spectrometer lets scientists see thousands of *unknown* biomolecules, which are like parts of the galaxy yet to be explored. Would you like to know how these unknown biomolecules impact our health?

SCIENTIFIC FRONTIERS: JOIN US TO MAP FOOD BIOMOLECULES

So now you have taken a deep dive to know the three main types of biomolecules in our food: macronutrients, micronutrients, and specialized metabolites. By taking a farm tour, you understand that plants produce specialized metabolites to help protect themselves from stresses and threats in their environment. Lastly, our lab tour demonstrated the technology used to identify thousands of biomolecules in food.

For the first time in history, we *can* imagine knowing all the biomolecules in food. This knowledge will allow us to eat foods that will build healthier bodies, every day. From the juicy tomato to all other foods, mapping biomolecules is an exciting scientific frontier that can lead to big improvements in the health of people *and* the planet. If this excites you, consider becoming a scientist and joining us on our food-mapping journey!

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CLAUDIA, AGE: 13
Hii, I am Brazilian, I am a 13 years old, and an 8 grade student. I like Science a lot and as my father is a scientist: he inspired me to do these reviews. I also love reading, drawing and listening to music!

EVA, AGE: 10
Eva loves to spend her free time drawing and creating colorful characters that come to life on the page. She has a deep appreciation for all things kawaii and anime. One of her greatest strengths is her kind and caring nature. She is always looking for ways to help people and make a positive impact on the world around her.

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