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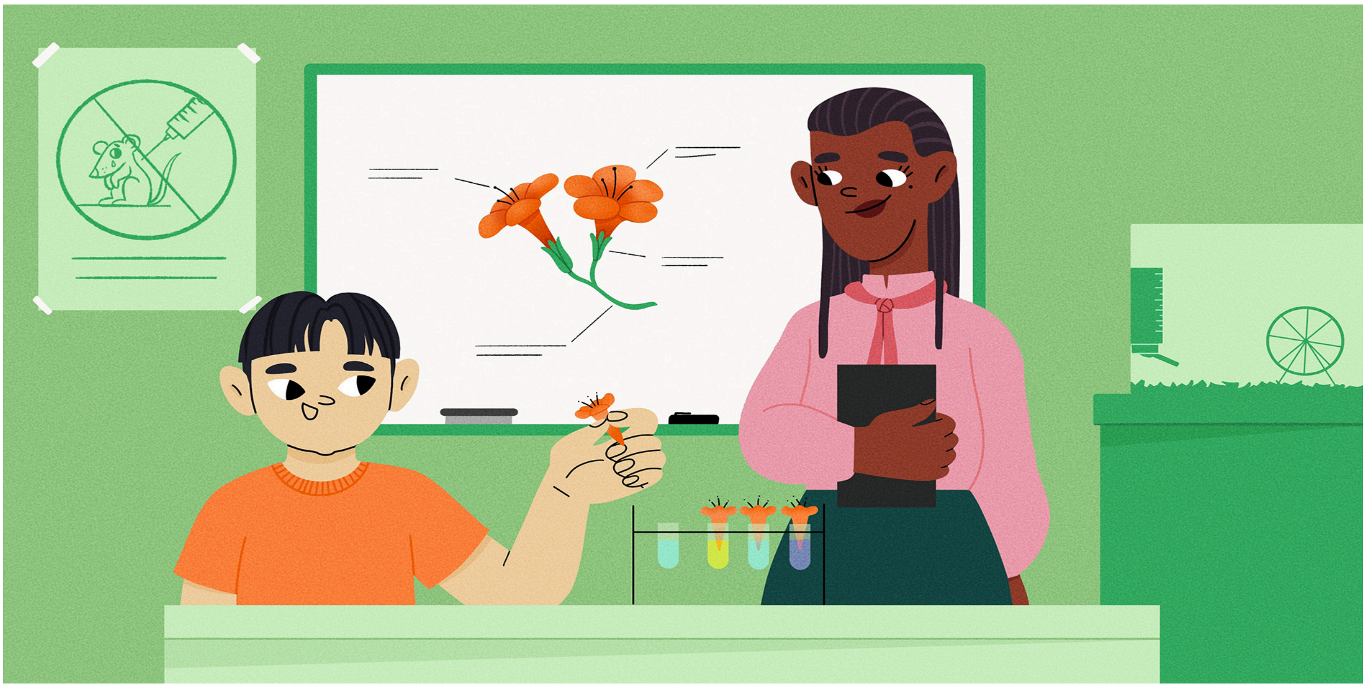

THE LIFESAVING POWER OF FLOWERS: EXPERIMENTS ANYONE CAN DO

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YOUNG REVIEWERS:

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Biomaterials are materials made to be put inside human bodies. To make sure that these materials are safe for our bodies, they are first tested on animals. Reducing the number of animals used in research is an important goal, however, and scientists have been searching for other ways to test biomaterials in living organisms. In this article, we describe an experiment for measuring the properties of biomaterials using flowers. Such flower models can provide a good measure of how compatible a potential biomaterial is with the human body. Most importantly, these models are child-friendly and a great way for children to learn more about the fascinating world of biomaterials.

WHAT ARE BIOMATERIALS?

Humans become frail as they grow old. To illustrate this, many poets have compared humans to flowers. "Alas, young man! your days can never be long, in flower of age you perish for a song!" said Alexander Pope [1]. Like flowers, one day we blossom from a bud, and the next

BIOMATERIAL

A material developed for a direct interface with the human tissues, usually to fulfill a medical goal, either as a therapeutic or as a diagnostic.

BIOCOMPATIBILITY

The ability of a biomaterial to coexist at an interface with the human tissue without provoking adverse effects, neither locally nor systemically.

BIOINERTNESS

The property of a biocompatible biomaterial referring to its lack of engaging in union with the tissue adjacent to it.

BIOLOGICAL MODEL

A protocol involving experimental organisms as proxies to assess the safety or efficacy of a particular physical or chemical stimulus.

IN VITRO

Latin phrase used to denote that a process involves cultured cells or microorganisms, taking place in a laboratory setting, outside of a living organism.

EX VIVO

Latin phrase used to denote that a process involves organs or tissues removed from a living organism.

IN VIVO

Latin phrase meaning "inside a living system."

day we amaze the world with our flowery beauty [2]. But then, in what seems like no time, we begin to wither and crumble our petals back into the Earth. To slow down this circle of life, science has been working on a solution: a means of repairing our bodies using complex materials and technologies. Indeed, in the last century, many materials were created to help keep our frail bodies from failing until they grow very, very old. Engineered materials that come into direct contact with our cells and tissues to help us live healthier, happier and longer are called **biomaterials**.

Biomaterials can be made from many kinds of materials, including metals, alloys, ceramics, and polymers. Titanium, for example, is a metal you can find not only in bicycle frames, shoes and tennis racquets, but also in prosthetic implants like artificial hips or bionic arms. Stainless steel, an alloy that spoons, forks, bridges and airplanes are made of, can also be used to make little tubes that keep collapsing blood vessels open or screws that tie broken bone together. Silicate glass is a ceramic that windows and mirrors are made of, but with just a slightly changed composition it can be used to fill bone defects. As for polymers, the same polyethylene materials that make up artificial grass or the packaging for popsicles can be used to make implants for joints.

BIOCOMPATIBILITY AND MODELS TO ASSESS IT

However, not all materials can be put inside our bodies safely. Sometimes the body thinks biomaterials are foreign objects, and it starts a series of reactions to reject them. In these cases, we say that the material is not **biocompatible**. At other times, the material does not form an intimate bond with human tissues, but it still safely sits in its newly found place within the body. These materials are called **bioinert**. Still other times, the material forms very tight bonds with the tissues, almost as if they were hugging each other. In these cases, the biomaterials can help heal the tissues—this is what every biomaterials scientist loves to see.

Science is all about making good predictions. Random materials cannot be picked off the shelf and put inside the human body. Rather, the selection of a material must be scientifically justified. For this to happen, scientists use **biological models**—laboratory systems in which to test the materials before they are used in humans. In the case of biomaterials, other organisms serve as models (Figure 1). This could be a bunch of cells grown in a dish, which is called an ***in vitro*** model. It could also be an organ separated from an animal, like a liver taken from a mouse—this is called an ***ex vivo*** model. Finally, it could be a living animal—this is called an ***in vivo*** model [3]. Scientists generally prefer using animals that are similar to humans as models for testing biomaterials. They often test their materials in vivo immediately, without any prior experiments in non-animal models. However, this decision does not always consider that experimental animals have feelings. They have their own moms and dads and siblings and can feel the pain and should have the right for a good life, just like we, humans do.

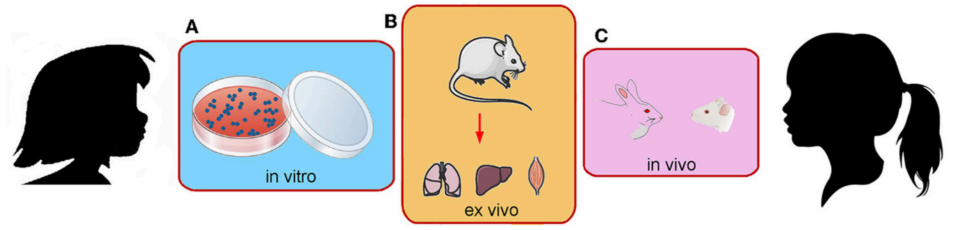

Figure 1

Figure 1

(A) Models for measuring the response to biomaterials are called *in vitro* if they are performed using cells grown in the lab. **(B)** Models are called *ex vivo* if they are performed using tissues or organs isolated from animals. **(C)** Models are called *in vivo* if they are performed using living organisms, typically mammals like rabbits or mice.

FLOWERS AS NON-ANIMAL *IN VIVO* MODELS

Here is where the bulb of discovery lights up and an interesting idea comes our way. It tells us this: what if, instead of animals, we could use flowers to test biomaterials? What if some flowers could predict the fate of biomaterials in the human body just as accurately as animals can? If the material is unhealthy for humans, flowers may wither or their growth may be stunted; and if the material is good for humans, it may improve the growth of flowers. If this idea works, it would both decrease the use of laboratory animals and speed up the creation and testing of biomaterials, because flowers can be grown and tested in greater numbers than animals can. Of course, flowers cannot yet fully replace animals in biomaterials testing, but for now, doing as much as we can to limit the testing of biomaterials on animals is a good goal.

But you say, how can flowers be a good option for a model? People are not tulips, so how can a flower tell us how a human body would behave? Well, flowers and plants have similar cellular architecture to animals, although some functions are specialized in plants and others in animals. Still, animal cells and flower cells all produce proteins, all move cellular cargo in a similar way, and all contribute to maintaining the life of the organism.

FLOWER EXPERIMENTS ARE CHILD-FRIENDLY

Not all scientific experiments can safely be performed by children. Many involve dangerous chemicals or require the use of highly complicated instruments. Some experiments even require researchers to stay in the desert for months to excavate dinosaur bones with a toothpick—and eat armadillos for dinner! But using flowers to measure the biocompatibility of materials can be a very child-friendly experiment. In fact, for one of these experiments, one 4-year-old and one 6-year-old assisted in plucking the flowers, placing them in little tubes, watering them, and measuring their drooping petals with a ruler (Figure 2) [4].

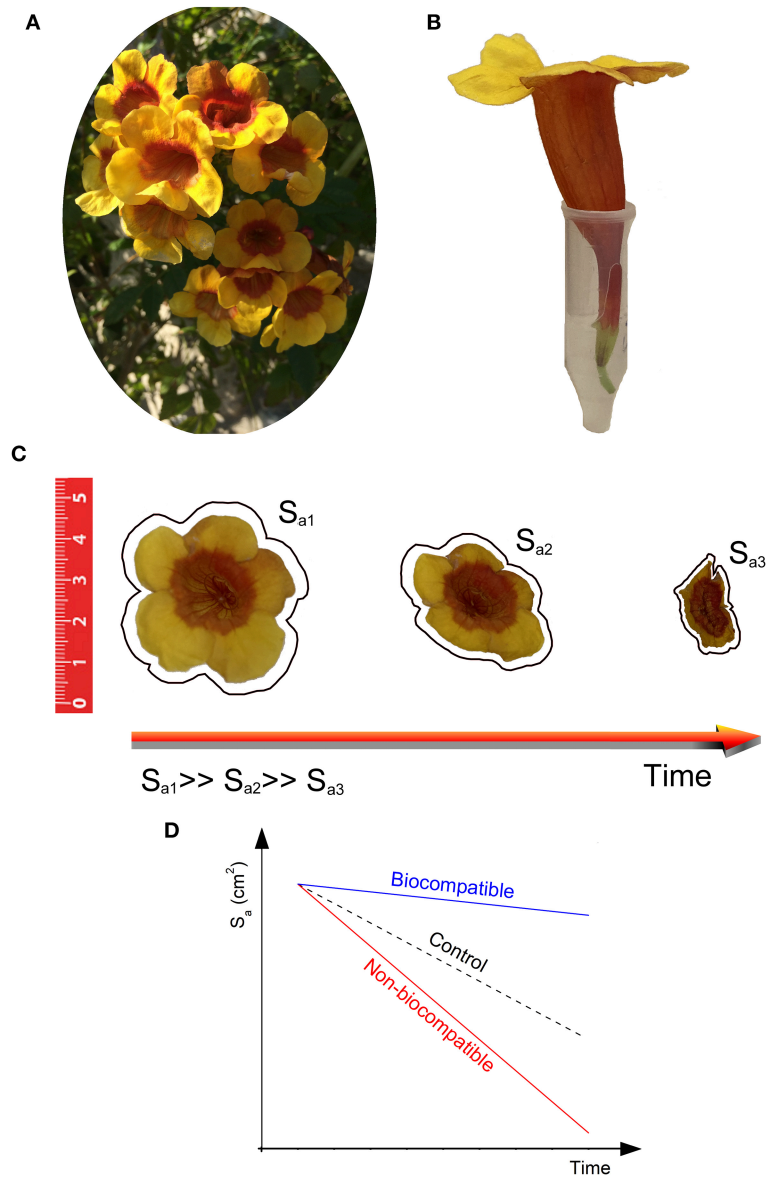

Figure 2

Figure 2

Flowers can be used as a model to measure the biocompatibility of materials. **(A)** Flowers, in this case orange jubilees, are plucked in clusters. **(B)** The flowers are exposed to biomaterials added to their tubes of water. **(C)** We can measure changes in the surface area of the perimeter (S_a) of the flower, as indicated by the black line, over time. **(D)** A trend in the change in this surface area over time correlates with the biocompatibility of the material. A material that is not biocompatible will cause the flower to shrink faster (red line), and one that is biocompatible can extend the life of the flower (blue line) as compared to the control flower exposed to no material whatsoever (dashed line).

These two young scientists learned early on that not all flowers are good models for biomaterials. Some flowers give a very quirky and unreliable response, even if we use large numbers of them in an experiment and mathematical tools called statistics to measure their responses. Some flowers wilt too quickly, and some too slowly. For a flower to be a good model, its process of falling apart, which biologists call **senescence**, should be optimal—neither too slow nor too fast. Senescence should proceed gradually, at as steady a pace as possible. This helps researchers—young or old—to spot the effects of the biomaterial and convert those effects into numbers.

SENESCENCE

The aging-related process of deterioration of normal functions of a living organism and its cellular components.

WHAT THE FLOWER MODELS CAN TELL US

These experiments with flowers could tell us how biocompatible a material is. For example, a material that speeds up the wilting of a flower after being sprinkled into the tube of water would not be considered biocompatible. In contrast, a material that extends the life of the flower might be biocompatible. Other properties can be measured, too. For example, flowers wilt when the xylems, the tiny channels through which the flower "drinks" water, become clogged. This clogging is often caused by tiny microorganisms that feed off the sugars contained in the flowers. Therefore, if a material extends the life of the flower, it is likely to have antimicrobial properties—properties that prevent microorganisms from growing. Antimicrobial properties are also important for biomaterials because humans often develop infections after biomaterials are implanted into their bodies [5]. A biomaterial forming tight bonds with the tissue and also stopping the growth of microorganisms accidentally introduced into the body is, however, an extremely rare event that most scientists only dream about.

CONCLUSION

To sum up, this article described a discovery that could inspire future researchers, including you, Frontiers for Young Minds readers. One interesting thing about this model is that nature, especially in the spring and the summer, is filled with flowers. And really, how cool is it that scientists, who usually bury their heads in labs and in their notebooks when searching for new ideas, can find a useful model in nature, right in front of their noses? Beside a couple of containers, some water, a ruler to measure the petals, and a notepad in which to write down the results, nothing more is needed. You *do* need enthusiasm, creativity, and joy—and those things are often the hardest to reach. But once you do reach them, hold them gently and gingerly, on the palms of your hands, and then share them abundantly. Never forget: in everything around you, something might be hiding—something that can save a life. It is up to you now to discover where, what, and how. Good luck in your research!

ORIGINAL SOURCE ARTICLE

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CONFLICT OF INTEREST: VU and VW are the founders and chief executives of TardigradeNano.

YOUNG REVIEWERS

JÚLIA, AGE: 15

Hi, I am Júlia and I am 15 years old. I love spending my time discovering new curiosities about everything, and also I love reading. One of my passions is volleyball, and I am addicted to music, series, and movies.

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Vuk Uskoković, Ph.D., is a scientist and educator with a long history of innovative research in natural sciences, primarily in the field of medical devices. He is currently a co-founder of TardigradeNano, a biotech startup and think tank based in Orange County, California, and a lecturer in engineering at San Diego

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