the width. It would detect light in ultraviolet, visible and near-infrared wavelengths, and be able to discover objects of astrophysical interest ranging from habitable planets to violent black holes. It would cost around $11 billion and launch in the early 2040s.

Second and third would be missions detecting X-rays, a sector of the electromagnetic spectrum in which some of the most powerful astrophysical phenomena can be observed, and far-infrared radiation, which can penetrate the shrouds of dust around newborn stars. These missions would cost $3 billion to $5 billion each, and a decision on whether to build them would be made five years after the start of the first Hubble-like mission.

Lurking behind these ambitious spacecraft is the spectre of previous space missions whose budgets have blown out of control. For instance, the James Webb Space Telescope, the leading recommendation in the 2000 survey, is set to launch on 18 December, years later than intended, at a cost of nearly $10 billion — well above its original budget.

"We've learned a lot in the course of the last 10–20 years about how to do large missions," says Gaudi. "For me, it's almost inconceivable that we couldn't do better the next time, because we've learned from our past mistakes."

A human endeavour

Astro2020 also attempts to grapple with the importance of equity and inclusion to the health of US astronomy. "Astrophysics is done by humans," says Jane Rigby, an astrophysicist at the Goddard centre. "How these humans treat each other, how they are led, how they hold each other accountable, what the policies and the systems are that they're working in — this makes so much of a difference to the quality of the science that gets done."

US astronomy has found itself at the forefront of many social issues, including the ethics of doing science on Maunakea and other lands seized from Indigenous groups.

The report lays out some recommendations for reducing the systemic barriers that block many people from entering and staying in science. They include increasing federal funding for student and early-career researchers, making diversity a criterion in awarding grants, and gathering data to better track the lack of equity in funding.

"Racial/ethnic diversity among astronomy faculty remains, in a word, abysmal," the report says.

Attention will now turn to how the survey's recommendations might become reality. Pandemic-related delays in the report's release mean that the NSF, NASA and the DOE have already missed their chance to incorporate the findings into the budgets they are drawing up for the 2023 fiscal year. As a result, *Astro2020* priorities will not start receiving funding until 2024 at the earliest.

SPONGE CELLS HINT AT ORIGINS OF NERVOUS SYSTEM

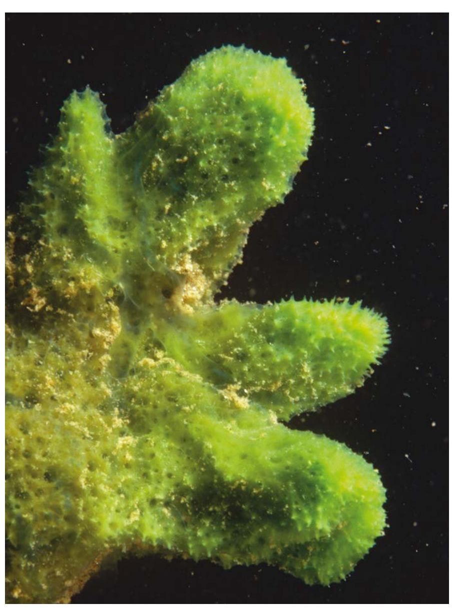
Synapse genes help cells to communicate in the digestive chambers of sponges.

By Max Kozlov

Sponges are simple creatures, yet they are expert filter feeders, straining tens of thousands of litres of water through their bodies every day. Their mastery of this process is all the more remarkable because they have no brain or neurons.

A study published on 4 November in *Science* now reveals that sponges use an intricate cell communication system to regulate their feeding and potentially to weed out invading bacteria (J. M. Musser *et al. Science* https://doi.org/g4xt; 2021). The findings could help researchers to understand how animals' nervous systems evolved, says Casey Dunn, an evolutionary biologist at Yale University in New Haven, Connecticut. "This is a really exciting study that allows us to see sponges in a new light," he says.

Cells frequently communicate with one another, and neurons do so by passing signals through connections called synapses. Previous research has found that sponges possess genes encoding proteins that typically help synapses to function, despite the animals' lack of neurons (M. Srivastava *et al. Nature* **466**, 720–726; 2010).



Freshwater sponges might hold clues about the evolution of the nervous system.

WILLEM KOLVOORT/NATURE PICTURE LIBRARY

To discover which cells were expressing these genes, Detlev Arendt, an evolutionary biologist at the European Molecular Biology Laboratory (EMBL) in Heidelberg, Germany, and colleagues sequenced the RNA in various individual cells from a freshwater sponge (*Spongilla lacustris*). They found that the sponge has 18 distinct cell types. Synaptic genes were active in a few of these types, which were clustered around the sponge's digestive chambers. This suggests that some form of cellular communication might coordinate the animal's filter-feeding behaviour.

The researchers then used X-ray imaging and electron microscopy to study one of these cell types, which they called secretory neuroid cells. The scans revealed that neuroids send out long arms to reach choanocytes, cells with hair-like protrusions that drive sponges' water-flow systems and capture most of their food.

On the basis of the proximity of the two cell types and the expression of genes that might allow for the secretion of chemicals, the researchers think that these arms enable neuroids to communicate with choanocytes, so that they can pause the water-flow system and clear out any debris or foreign microbes. However, these neuroid cells are not nerves, and there is no sign of synapses. Instead, this cell type might represent an evolutionary precursor to a true nervous system, says Jacob Musser, an evolutionary biologist at EMBL, who co-authored the study. "We're at an intermediate point, where you've gone from having all these independent pieces to bringing them together more broadly, but you haven't gotten all the interconnectivity needed to create a fast synapse," he says.

Some scientists say that calling these cells a precursor to a nervous system is a stretch. "It's tantalizing, but it's hardly definitive," says Linda Holland, an evolutionary developmental biologist at the University of California, San Diego. She says it will be difficult to prove whether nervous systems evolved from this cellular communication system or arose earlier or even multiple times, as some groups have proposed.

April Hill, a developmental geneticist at Bates College in Lewiston, Maine, hopes that scientists will use this study and its methods as a "launchpad" for further investigation of this ubiquitous sponge.