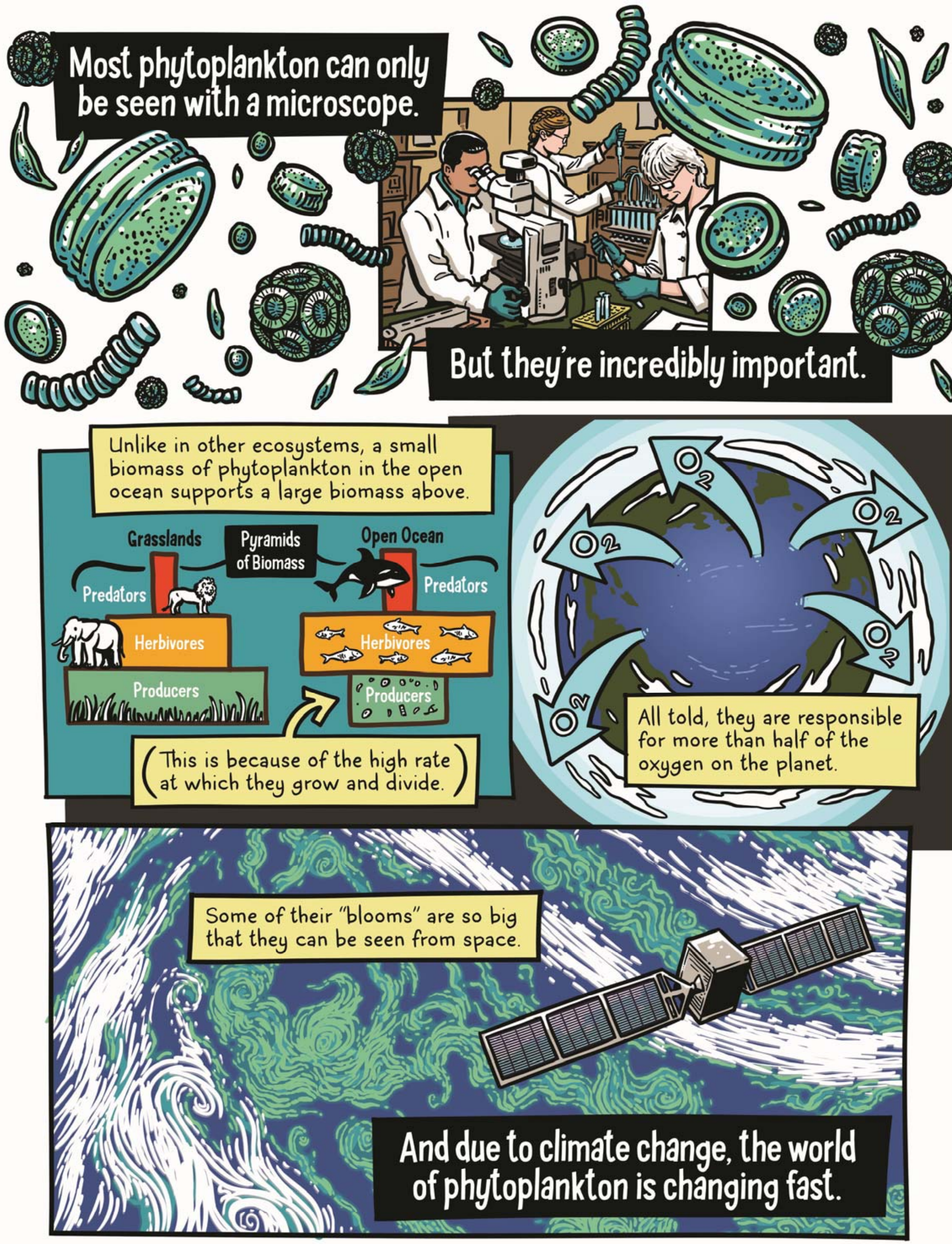
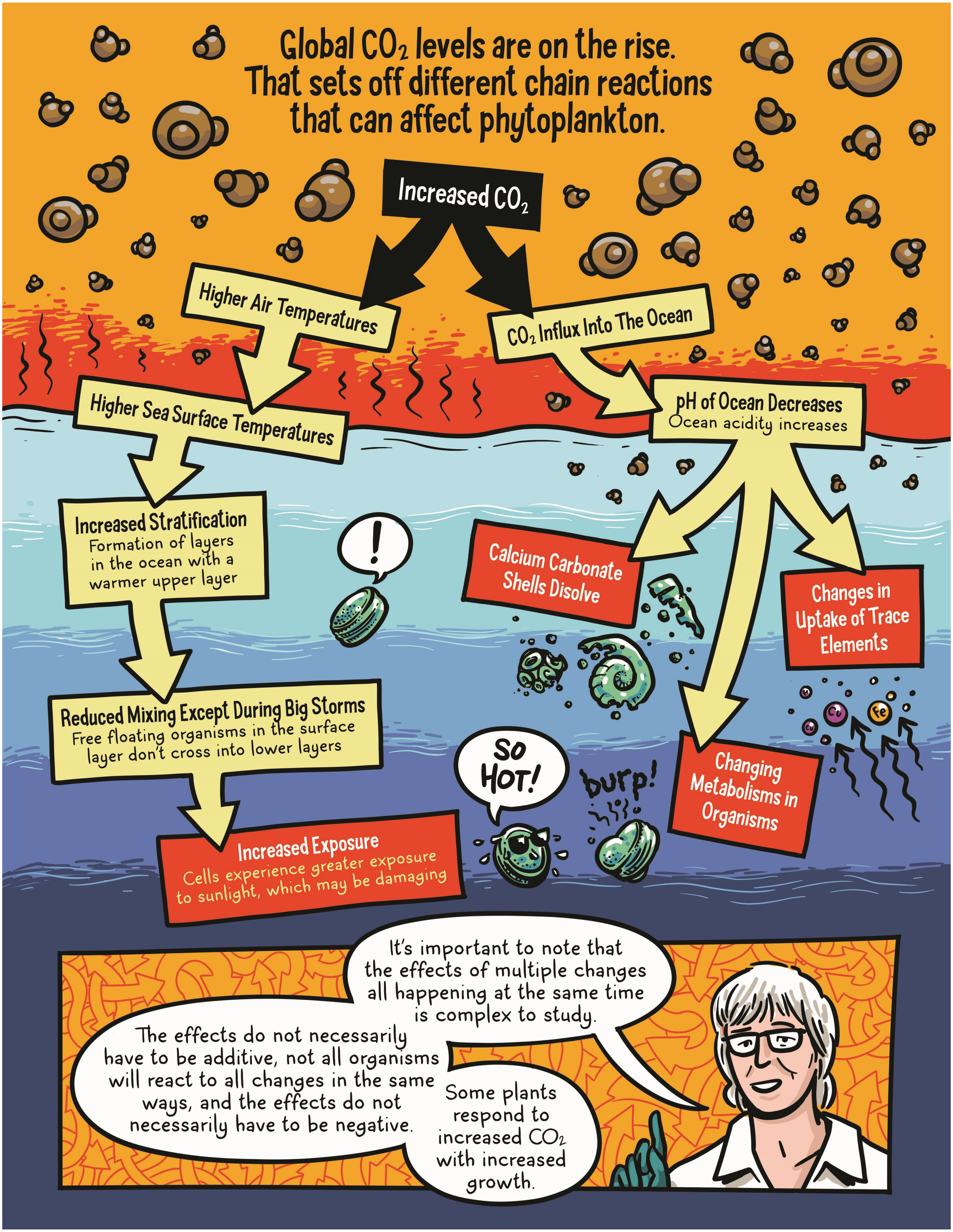
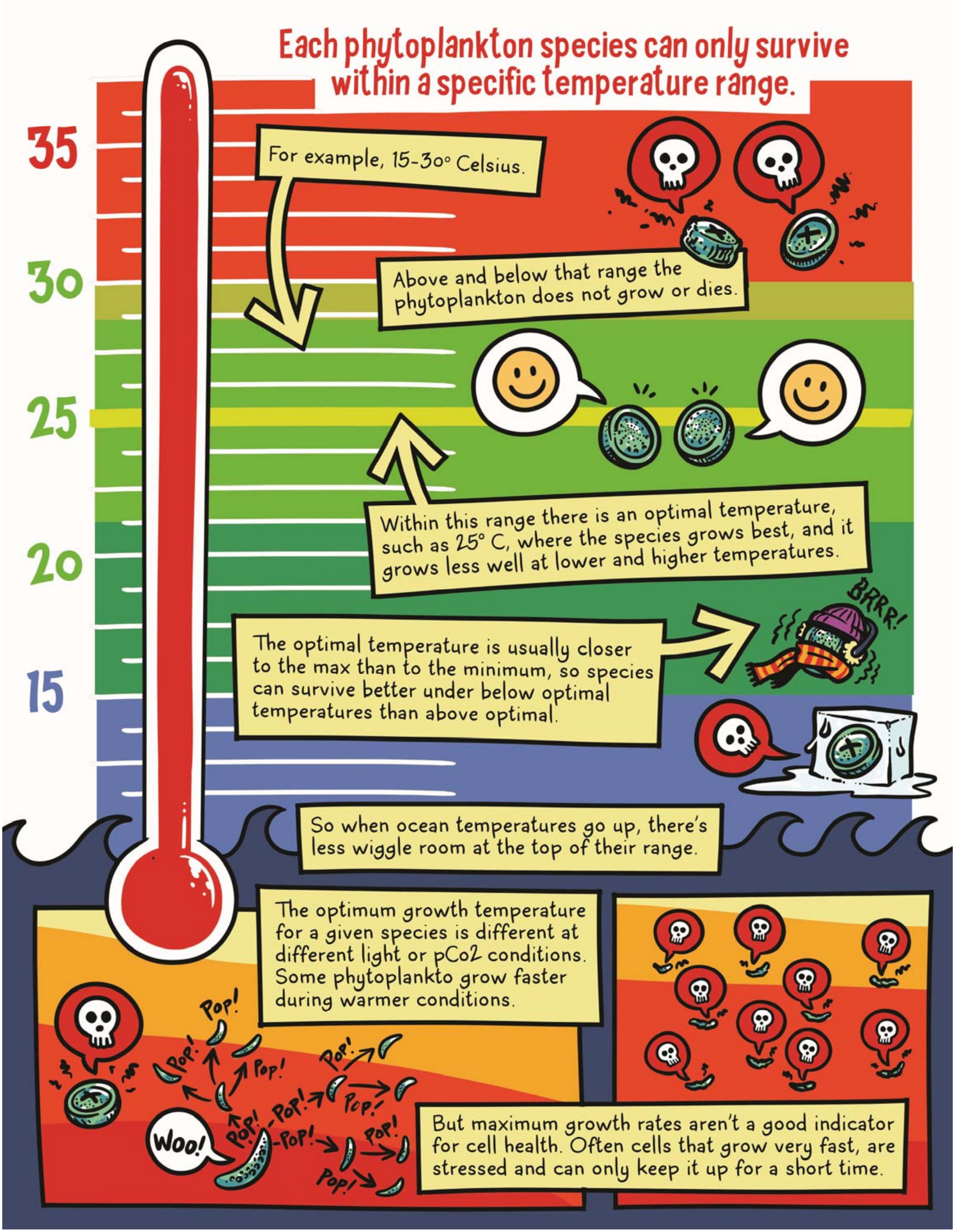


Most phytoplankton can only be seen with a microscope.
But they're incredibly important.
Unlike in other ecosystems, a small biomass of phytoplankton in the open ocean supports a large biomass above.
Grasslands
Pyramids of Biomass
Open Ocean
Predators
Herbivores
Producers
Predators
Herbivores
Producers
(This is because of the high rate at which they grow and divide.)
O2
All told, they are responsible for more than half of the oxygen on the planet.
Some of their "blooms" are so big that they can be seen from space.
And due to climate change, the world of phytoplankton is changing fast.

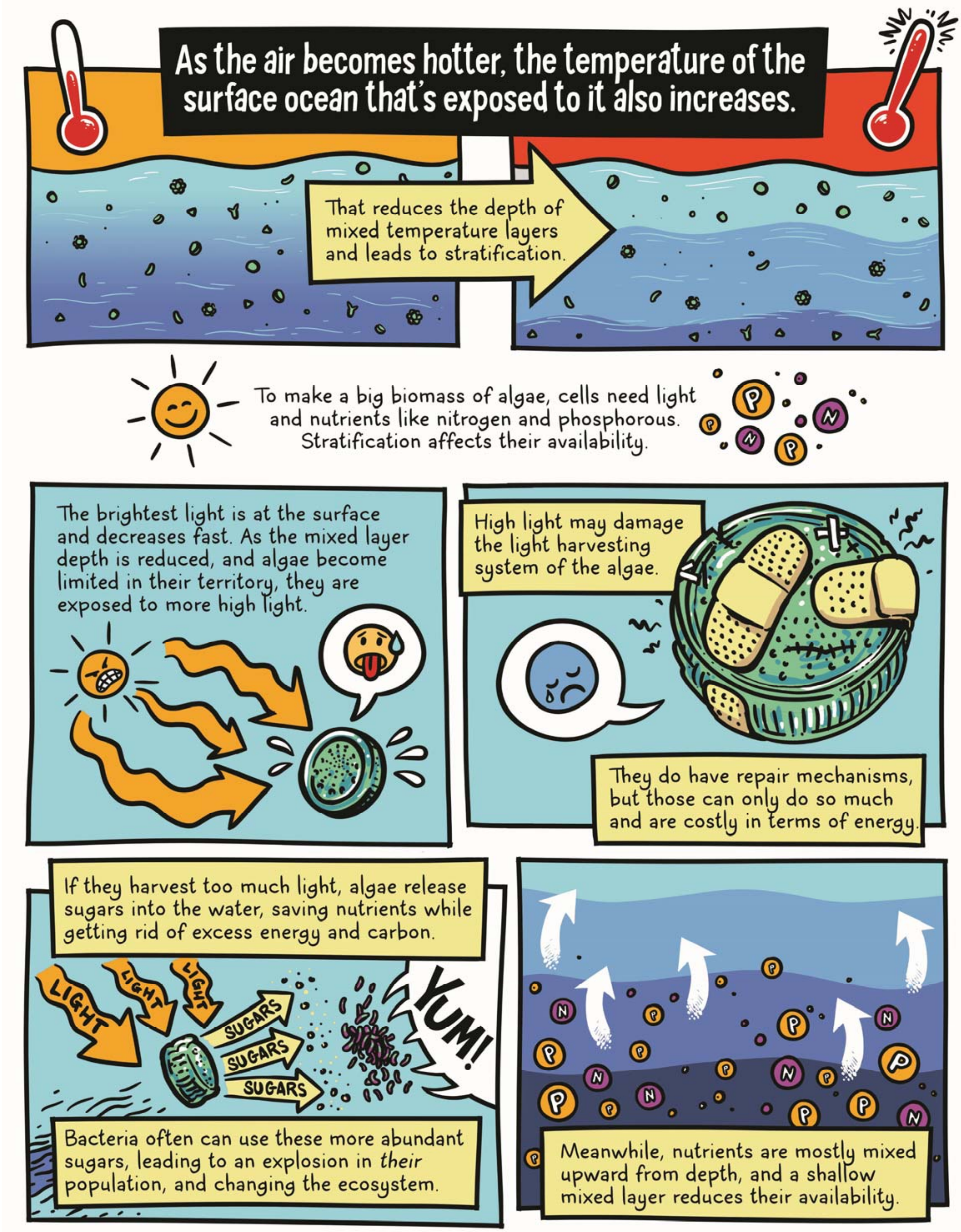


Global CO_2 levels are on the rise. That sets off different chain reactions that can affect phytoplankton.
Increased CO_2
Higher Air Temperatures
CO_2 Influx Into The Ocean
Higher Sea Surface Temperatures
pH of Ocean Decreases
Ocean acidity increases
Increased Stratification
Formation of layers in the ocean with a warmer upper layer
!
Calcium Carbonate Shells Disolve
Changes in Uptake of Trace Elements
Cu
Fe
Reduced Mixing Except During Big Storms
Free floating organisms in the surface layer don't cross into lower layers
SO HOT!
burp!
Changing Metabolisms in Organisms
Increased Exposure
Cells experience greater exposure to sunlight, which may be damaging
It's important to note that the effects of multiple changes all happening at the same time is complex to study.
The effects do not necessarily have to be additive, not all organisms will react to all changes in the same ways, and the effects do not necessarily have to be negative.
Some plants respond to increased CO_2 with increased growth.

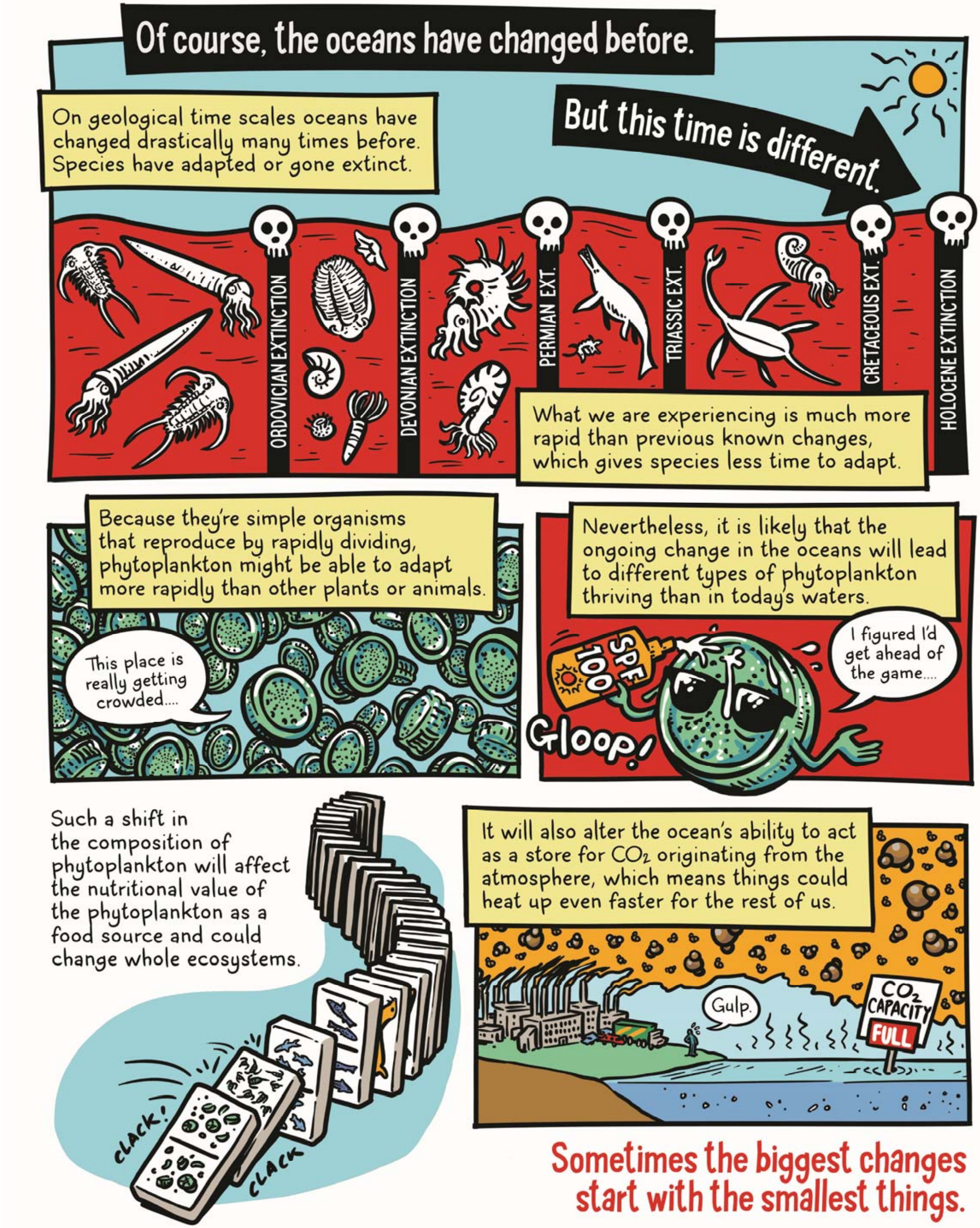


Each phytoplankton species can only survive within a specific temperature range.
35
30
25
20
15
For example, 15-30° Celsius.
Above and below that range the phytoplankton does not grow or dies.
Within this range there is an optimal temperature, such as 25° C, where the species grows best, and it grows less well at lower and higher temperatures.
The optimal temperature is usually closer to the max than to the minimum, so species can survive better under below optimal temperatures than above optimal.
BRRR!
So when ocean temperatures go up, there's less wiggle room at the top of their range.
The optimum growth temperature for a given species is different at different light or pCo2 conditions. Some phytoplankto grow faster during warmer conditions.
Pop!
Pop!
Pop!
Pop!
Pop!
Pop!
Pop!
Pop!
Pop!
Pop!
Woo!
But maximum growth rates aren't a good indicator for cell health. Often cells that grow very fast, are stressed and can only keep it up for a short time.


More CO_2 in the air means more CO_2 in the oceans.
CO_2 Time Series in the North Pacific
Seawater CO_2
Seawater pH
Source: NOAA PMEL Carbon Program
1988
1998
2008
2018
This decreases the pH of seawater, making it more acidic and creating a few different stressors for phytoplankton.
Some algae, such as coccolithophores, build shells with calcium carbonate.
In a low pH environment, these shells can dissolve or get harder to generate.
But the further effects of increased CO_2 in oceans are mixed or unclear.
For some species, an increased uptake of CO_2 can actually allow them to compete more efficiently.
However, for algae to grow, the CO_2 uptake and light harvest need to be balanced. Keeping that balance may be tricky and all the physiological implications aren't yet known.
A pH decrease also changes the ionic state of all elements, with mixed results. Iron, which algae need, may become more available. But so will copper, which is toxic in most cases.
Many algae stay afloat by exchanging heavy ions for lighter ones, and it's not yet known if that's altered at lower pH.



As the air becomes hotter, the temperature of the surface ocean that's exposed to it also increases.
That reduces the depth of mixed temperature layers and leads to stratification.
To make a big biomass of algae, cells need light and nutrients like nitrogen and phosphorous. Stratification affects their availability.
P
N
The brightest light is at the surface and decreases fast. As the mixed layer depth is reduced, and algae become limited in their territory, they are exposed to more high light.
High light may damage the light harvesting system of the algae.
They do have repair mechanisms, but those can only do so much and are costly in terms of energy.
If they harvest too much light, algae release sugars into the water, saving nutrients while getting rid of excess energy and carbon.
LIGHT
LIGHT
LIGHT
SUGARS
SUGARS
SUGARS
YUM!
Bacteria often can use these more abundant sugars, leading to an explosion in *their* population, and changing the ecosystem.
Meanwhile, nutrients are mostly mixed upward from depth, and a shallow mixed layer reduces their availability.


Of course, the oceans have changed before.
On geological time scales oceans have changed drastically many times before. Species have adapted or gone extinct.
But this time is different.
ORDOVICIAN EXTINCTION
DEVONIAN EXTINCTION
PERMIAN EXT.
TRIASSIC EXT.
CRETACEOUS EXT.
HOLOCENE EXTINCTION
What we are experiencing is much more rapid than previous known changes, which gives species less time to adapt.
Because they're simple organisms that reproduce by rapidly dividing, phytoplankton might be able to adapt more rapidly than other plants or animals.
This place is really getting crowded....
Nevertheless, it is likely that the ongoing change in the oceans will lead to different types of phytoplankton thriving than in today's waters.
SPF 100
GLOOP!
I figured I'd get ahead of the game....
Such a shift in the composition of phytoplankton will affect the nutritional value of the phytoplankton as a food source and could change whole ecosystems.
CLACK!
CLACK
It will also alter the ocean's ability to act as a store for CO_2 originating from the atmosphere, which means things could heat up even faster for the rest of us.
Gulp.
CO_2 CAPACITY
FULL
Sometimes the biggest changes start with the smallest things.