If you are a student that **HAS** access to technology, this is not the packet for you. This packet is for students who pick up and drop off their work at the front office every week. If you have access to technology, please go back to your teacher's website and complete the correct assignment.

Name: ______________________________ Period: _________ Teacher: ___________

Assignment 8.1 – The Study of Ocean Acidification

→ Use the following excerpts from '***STUDYING ACIDIFICATION'*** in the NOAA Ocean Acidification Website to **Answer these questions:**

Part I. → Soil Cores Revealing Past Ocean Acidification

Geologists study the potential effects of acidification by digging into Earth's past when ocean carbon dioxide and temperature were similar to conditions found today. One way is to study **cores**, soil and rock samples taken from the surface to deep in the Earth's crust, with layers that go back 65 million years. The chemical composition of fossils in cores from the deep ocean show that it's been 35 million years since the Earth last experienced today's high levels of atmospheric carbon dioxide. But to predict the future—what the Earth might look like at the end of the century—geologists have to look back another 20 million years.

Some 55.8 million years ago, massive amounts of carbon dioxide were released into the atmosphere, and temperatures rose by about 9°F (5°C), a period known as the Paleocene-Eocene Thermal Maximum. Scientists don't yet know why this happened, but there are several possibilities: intense volcanic activity, breakdown of ocean sediments, or widespread fires that burned forests, peat, and coal. Like today, the pH of the deep ocean dropped quickly as carbon dioxide rapidly rose, causing a sudden "dissolution event" in which so much of the shelled sea life disappeared that the sediment changed from primarily white calcium carbonate "chalk" to red-brown mud.

Looking even farther back—about 300 million years—geologists see a number of changes that share many of the characteristics of today's human-driven ocean acidification, including the near-disappearance of coral reefs. However, no past event perfectly mimics the conditions we're seeing today. The main difference is that, today, CO_2 levels are rising at an unprecedented rate—**even faster than during the Paleocene-Eocene Thermal Maximum**.

1. 35 million years ago, soil cores show that the Earth has high levels of ____________________ - just like today!!!
2. During this Paleocene-Eocene Thermal Maximum time, how much did Earth's temperature raise? _______
3. What are 3 possible reasons that could have caused the high CO_2 levels?
   a.
   b.
   c.
4. What happened to the shelled sea-life during this time period?

5. What is different about how fast CO_2 levels are rising compared to those in the Paleocene-Eocene Thermal Maximum period? __________________________

Part II. → Lab Experiments on Ocean Acidification

Another way to study how marine organisms in today's ocean might respond to more acidic seawater is to perform controlled laboratory experiments. Researchers will often place organisms in tanks of water with different pH levels to see how they fare and whether they adapt to the conditions. They're not just looking for shell-building ability; researchers also study their behavior, energy use, immune response and reproductive success. They also look at different life stages of the same species because sometimes an adult will easily adapt, but young larvae will not—or vice versa. Studying the effects of acidification with other stressors such as warming and pollution, is also important, since acidification is not the only way that humans are changing the oceans.

In the wild, however, those algae, plants, and animals are not living in isolation: they're part of communities of many organisms. So some researchers have looked at the effects of acidification on the interactions between species in the lab, often between prey and predator. Results can be complex. In more acidic seawater, a snail called the common periwinkle (*Littorina littorea*) **builds a weaker shell** and avoids crab predators—but in the process, may also spend less time looking for food. **Boring sponges drill** into coral skeletons and scallop shells more quickly. And the late-stage larvae of black-finned clownfish **lose their ability to smell** the difference between predators and non-predators, even becoming attracted to predators.

Although the current rate of ocean acidification is higher than during past (natural) events, it's still not happening all at once. So short-term studies of acidification's effects might not uncover the potential for some populations or species to acclimate to or adapt to decreasing ocean pH. For example, the deepwater coral *Lophelia pertusa* shows a significant decline in its ability to maintain its calcium-carbonate skeleton during the first week of exposure to decreased pH. But after six months in acidified seawater, the coral had **adjusted to the new conditions** and returned to a normal growth rate.

1. Name 5 marine organism functions that lab researchers study when they experiment with different pH salt water.
    a.
    b.
    c.
    d.
    e.

2. What are two different stressors on marine organisms besides acidification?
    a. b.
3. The good news is that, although ocean acidification is happening faster than any time in recorded history, some species and populations have learned to adapt and acclimate to (increasing/decreasing) ___________ pH since it doesn't happen all at once.

Part III → Natural Variation

There are places scattered throughout the ocean where cool CO_2-rich water bubbles from volcanic vents, lowering the pH in surrounding waters. Scientists study these unusual communities for clues to what an acidified ocean will look like.

Researchers working off the Italian coast **compared the ability of 79 species of bottom-dwelling invertebrates** to settle in areas at different distances from CO_2 vents. For most species, including worms, mollusks, and crustaceans, the closer to the vent (and the more acidic the water), the fewer the number of individuals that were able to colonize or survive. Algae and animals that need abundant calcium-carbonate, like reef-building corals, snails, barnacles, sea urchins, and coralline algae, were absent or much less abundant in acidified water, which were dominated by dense stands of sea grass and brown algae. Only one species, the polychaete worm *Syllis prolifers*, was more abundant in lower pH water. The **effects of carbon dioxide seeps on a coral reef** in Papua New Guinea were also dramatic, with large boulder corals replacing complex branching forms and, in some places, with sand, rubble and algae beds replacing corals entirely.

All of these studies provide strong evidence that an acidified ocean will look quite different from today's ocean. Some species will soldier on while others will decrease or go extinct—and altogether the ocean's various habitats will no longer provide the diversity we depend on.

1. At underwater volcanic vents there are lots of carbon dioxide bubbles released which (raise/lower) ________ the pH.
2. When scientists studied species at these vents, they noticed less organisms that required calcium carbonate for their skeletons/shells and noticed more of which organisms? ____

Part IV → Field Experiments

One challenge of studying acidification in the lab is that you can only really look at a couple species at a time. To study whole ecosystems—including the many other environmental effects beyond acidification, including warming, pollution, and overfishing—scientists need to do it in the field.

The biggest field experiment underway studying acidification is the **Biological Impacts of Ocean Acidification (BIOACID)** project. Scientists from five European countries built ten mesocosms—essentially giant test tubes 60-feet deep that hold almost 15,000 gallons of water—and placed them in the Swedish Gullmar Fjord. After letting plankton and other tiny organisms drift or swim in, the researchers sealed the test tubes and decreased the pH to 7.8, the expected acidity for 2100, in half of them. Now they are **waiting to see how the organisms will react**, and whether they're able to adapt. If this experiment, one of the first of its kind, is successful, it can be repeated in different ocean areas around the world.

1. If To study the effects of lower pH on populations of ocean organisms in their habitat, scientists created 10 huge tubes holding about 15,000 gallons of water each in a project called 'Biological Impacts of Ocean Acidification'. They lowered the pH of the water in these tubes to ____ in order to simulate predicted ocean pH levels in the year 2100.
2. Does this experiment accurately simulate what may happen in the oceans as pH decreases? ___
3. Explain why OR why not. (no correct answer…what do you think?)

Part V → Looking into the Future for Solutions

If the amount of carbon dioxide in the atmosphere stabilizes, eventually buffering (or neutralizing) will occur and pH will return to normal. This is why there are periods in the past with much higher levels of carbon dioxide but no evidence of ocean acidification: the rate of carbon dioxide increase was slower, so the ocean had time to buffer and adapt. But this time, pH is dropping too quickly. Buffering will take thousands of years, which is way too long a period of time for the ocean organisms affected now and in the near future.

So far, the signs of acidification visible to humans are few. But they will only increase as more carbon dioxide dissolves into seawater over time. What can we do to stop it?

Cut Carbon Emissions

In 2013, carbon dioxide in the atmosphere **passed 400 parts per million (ppm)**—higher than at any time in the last one million years (and maybe even 25 million years). The "safe" level of carbon dioxide is around 350 ppm, a milestone we passed in 1988. Without ocean absorption, atmospheric carbon dioxide would be even higher—closer to 475 ppm.

The most realistic way to lower this number—or to keep it from getting astronomically higher—would be to reduce our carbon emissions by burning less fossil fuels and finding more carbon sinks, such as regrowing **mangroves**, **seagrass beds**, and marshes, known as **blue carbon**. If we did, over hundreds of thousands of years, carbon dioxide in the atmosphere and ocean would stabilize again.

Even if we stopped emitting all carbon right now, ocean acidification would not end immediately. This is because there is a lag between changing our emissions and when we start to feel the effects. It's kind of like making a short stop while driving a car: even if you slam the brakes, the car will still move for tens or hundreds of feet before coming to a halt. The same thing happens with emissions, but instead of stopping a moving vehicle, the climate will continue to change, the atmosphere will continue to warm and the ocean will continue to acidify. Carbon dioxide typically lasts in the atmosphere for hundreds of years; in the ocean, this effect is amplified further as more acidic ocean waters mix with deep water over a cycle that **also lasts hundreds of years**.

Geoengineering

It's possible that we will develop technologies that can help us reduce atmospheric carbon dioxide or the acidity of the ocean more quickly or without needing to cut carbon emissions very drastically. Because such solutions would require us to deliberately manipulate planetary systems and the biosphere (whether through the atmosphere, ocean, or other natural systems), such solutions are grouped under the title "geoengineering."

The main effect of increasing carbon dioxide that weighs on people's minds is the warming of the planet. Some geoengineering proposals address this through various ways of reflecting sunlight—and thus excess heat—back into space from the atmosphere. This could be done by **releasing particles into the high atmosphere**, which act like tiny, reflecting mirrors, or even by putting giant reflecting mirrors in orbit! However, this solution does nothing to remove carbon dioxide from the atmosphere, and this carbon dioxide would continue to dissolve into the ocean and cause acidification.

Another idea is to remove carbon dioxide from the atmosphere by growing more of the organisms that use it up: phytoplankton. **Adding iron or other fertilizers to the ocean** could cause man-made phytoplankton blooms. This phytoplankton would then absorb carbon dioxide from the atmosphere, and then, after death, sink down and trap it in the deep sea. However, it's unknown how this would affect marine food webs that depend on phytoplankton, or whether this would just cause the deep sea to become more acidic itself.

What You Can Do

Even though the ocean may seem far away from your front door, there are things you can do in your life and in your home that can help to slow ocean acidification and carbon dioxide emissions.

The best thing you can do is to try and lower how much carbon dioxide you use every day. Try to reduce your energy use at home by recycling, turning off unused lights, walking or biking short distances instead of driving, using public transportation, and supporting clean energy, such as solar, wind, and geothermal power. Even the simple act of checking your tire pressure (or asking your parents to check theirs) can lower gas consumption and reduce your carbon footprint. (**Calculate your carbon footprint here**.)

One of the most important things you can do is to tell your friends and family about ocean acidification. Because scientists only noticed what a big problem it is fairly recently, a lot of people still don't know it is happening. So talk about it! Educate your classmates, coworkers and friends about how acidification will affect the amazing ocean animals that provide food, income, and beauty to billions of people around the world.

1. If humans cut carbon emissions immediately, what would happen to ocean acidification? ___________How long would the carbon dioxide stay in the atmosphere and oceans? ________
2. What affect on global temperature do scientists think would happen if they released tiny particles into the high atmosphere? ________ Would this change ocean acidification? _________
3. Why are scientists considering adding iron or other fertilizers to the ocean? _______________ Would this change be a CERTAIN fix for ocean acidification? _________
4. What are 2 things you can do to help reduce ocean acidification?
   a.
   b.

Assignment 8.2: Ocean Acidification - Article Analysis

Week 8 ~Distance Learning ~ May 25th – May 29th

Instructions:

- Read the 'Super Corals of the Red Sea' ocean acidification article.
- As your read, please answer the following questions **in complete sentences**.

1. Why did you choose to read this article?

2. Which marine animal(s) are being affected by ocean acidification in this article?

3. What is one of the problems described by this article?

4. What hope or solution does this article give to the problem?

5. If some ocean species become extinct due to ocean acidity, will it be significant to the world economy and food? _____ Why or why not?

The Super Corals of the Red Sea

By Sunny Fitzgerald - 8th April, 2020 *adapted from BBC Article*

As seas warm and acidify with climate change, corals worldwide are bleaching – but in the north of the Red Sea there is a ray, or rather reef, of hope.

Images of white, skeletal coral reefs are becoming an increasingly bleak, if familiar sight. **Massive coral bleaching events are becoming more common around the world**, as a result of the rapid pace of climate change. In the period from 2014 to 2017, about **75% of the planet's tropical coral reefs suffered heat-induced bleaching during a global ocean heatwave**.

A "bleached" coral is a stressed-out coral that, when triggered by environmental changes such as pollution and warming waters, has evicted its beneficial, energy-producing algae. Without these symbiotic algae, **the coral loses its colour and appears white**. Recovery from bleaching can be possible, but it's not guaranteed. More frequent bleaching events mean less time for the corals to bounce back. Those that don't recover, die – and their ecosystem can collapse with them.

Indeed, **the majority of the world's coral reefs are predicted to die by the end of this century, if not sooner**.

Yet, at the northern end of the Red Sea in the Gulf of Aqaba there is a ray – or, rather, reef – of hope.

Coral reefs in the Gulf of Aqaba appear to be "content" with the increasing temperatures, as Anders Meibom, a geochemist running the Laboratory for Biological Geochemistry at the Ecole Polytechnique Fédérale de Lausanne (EPFL) and Institute of Earth Sciences in Switzerland, puts it.

Maoz Fine, a Bar-Ilan University professor who leads this lab, first noticed that there was something distinctly different about the Red Sea reefs when he returned home to Israel in 2005 after researching reefs in Australia. Fine expected to see more degrading reefs of the kind he was used to there. But what he found in the **Gulf of Aqaba were corals apparently unaffected by ocean acidification and the steadily warming waters**.

In 2010, Fine designed a prototype of what would become the **Red Sea Simulator** (RSS), a large-scale, multiple aquarium system with the ability to simulate future ocean conditions and run experiments that might shed light on what it is that makes the corals here so resilient.

With this system at the Gulf of Aqaba, the team is able to study corals and water from the Gulf, and adjust the acidity and temperature in the tanks according to their experiments. Multiple aquariums mean that more researchers can run experiments simultaneously, in the hope to better understand the physiology and genetics of the reef ecosystems.

Of particular interest, Kleinhaus says, are any important ecological factors in the reefs that "amplify any innate coral resilience or potential to recover from bleaching". These could be particular phases of reduced pollution in the water, or periods of relief from overfishing.

Today, the RSS is 88 aquariums strong. So far, the team has tested about 20 different species of Red Sea corals in the Gulf of Aqaba and found them much more tolerant of increased temperature.

Typically, a 1-2C increase beyond the summer maximum temperature would cause corals to dispel their algae and, often, die. Meibom and Fine's unpublished research suggests that, while resilience varied between the corals they tested, overall, the corals easily withstood 4-5C above the current summer maximum. Some have even survived as much as 7C above the summer maximum.

Not only are these corals proving resilient, but **actually appear to do better in warmer waters**. In some cases, their symbiotic algae doubled the amount of oxygen they produced and showed a 51% increase in primary productivity.

The secret to the Red Sea corals' strength is thought to be a product of their past.

"This population of corals [in the northern part of the Gulf of Aqaba] migrated into the Red Sea system from the south where the temperature of the water is – and always was – high," Meibom says. As you move north, the water temperature drops. Over thousands of years, some of these corals migrated north to where they now live at lower temperatures – today the Gulf of Aqaba is 27-28C.

But, it seems these corals retained their capacity to live at higher temperatures. “They still remember *in their biology* how to live at 33C,” says Meibom. “So if you increase the temperature to 31C, for example, they’re still happy.”

Other corals around the world don’t typically possess the same biological ability to persist. **Given the global climate warming trajectory we are on** – headed for a 2-3C increase or more by the end of the century, only corals that are now living well below their maximum temperature will be able to tolerate that change.

At this rate, the Red Sea reefs could be one of the last standing by the year 2100. “We know of corals in other regions that live in very hot water and survive,” Fine says, “but none that have such a large gap between the summer maxima and their bleaching threshold.”

And as one of the last coral reefs to survive, the Red Sea reefs could potentially “form a refuge where it becomes one of the few remaining reefs with full ecosystem function”, says Grottoli. “It could serve as a model for restoration once climate change stress is mitigated and we start being able to actually reintroduce coral… it could serve as a model for what a normal reef might look like.”

But in order for it to serve as a refuge and possible model in the future, it will need to survive more than the rising temperatures; nutrients and heavy metals from human activity such as unchecked coastal development, agricultural and wastewater runoffs, boats and fish farming could be the super-corals’ kryptonite. When Fine and the team introduce nutrients such as nitrate, ammonium and phosphate into the experiments, the corals’ physiology is compromised and they’re no longer as resilient. “It’s not enough to be resilient to temperature,” Fine says. “If we are to secure the Gulf of Aqaba and the northern Red Sea as a coral reef refuge, we have to remove the local stress.”

But it’s a mission that, if it comes off, could offer insight into the reasons behind the corals’ resilience and a glimpse into their future. “When you move south in the Red Sea, you’re essentially sailing into the future in terms of coral resilience to climate change,” Meibom says, “everything gets warmer and warmer.”

Sara Cannon, a doctoral candidate at the University of British Columbia’s Department of Geography and the Institute for Oceans and Fisheries, believes the Red Sea corals could indeed have the potential to help other corals. “The Red Sea could provide information to help scientists to save reefs in other parts of the world that have not had the same opportunity to adapt, she says.

“And, the sad truth is that even if we could magically stop all greenhouse gas emissions immediately, global temperatures and carbon dioxide will remain high for centuries,” says Cannon. “To save reefs, we need to stop climate change, but we also need to consider how we can help corals adapt given that some effects of climate change have already become unavoidable. Corals in the Red Sea could be invaluable in that research.”