Creating Science – Trace Fossils, Evolution, and life on earth.

Are there any animals that once lived on earth but don't anymore?

*Basic concepts of evolution can also be introduced **if desired**. #CreatingScienceTraceFossils*

Please note: While I recognise that many folks, for philosophical and religious reasons, do "not believe the theory of evolution", I have included it here because;

- *The theory of evolution works, whether it's right, or wrong, or not yet in its final form. Because science uses the theory of evolution I believe it's important for us to understand, even if we don't believe it. As the ancient philosopher Aristotle taught: "It is the mark of an educated mind to be able to entertain a thought without accepting it."*[1]
- *Many philosophers believe that people do not have to choose between evolutionary theory and a belief in the divine. Thus saying, 'We believe in science, not god,' is philosophically unsatisfying, scientifically untestable, and at best; ill-informed.*
- *Fossils are real, and you can still learn about trace fossils without covering evolutionary theory.*
- *Personally, I believe science must be allowed to do its thing, without being forced to change for personal, religious or moral reasons – scientific knowledge changes, in an ideal case, only when the evidence forces it to. We've still so much to learn about science and evolution, and for this reason it is fair to say; "Science isn't finished". If truth remains to be found, I have faith science will eventually find it, but only if it's allowed to **be science**.*

Having said, you can still learn about trace fossils without mentioning Evolution at all. Life on earth has been here for a long time, and it has left evidence of its passing. We are exploring that evidence today.

Suggested Outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Biological Sciences 1: Living things live in different places where their needs are met.
- Biological Sciences 4: Living things, including plants and animals, depend on each other and the environment to survive.
- Biological Sciences 5: Living things have structural features and adaptations that help them to survive in their environment.

[1] *Read more at: https://www.brainyquote.com/quotes/aristotle_100584*

Science as a human endeavour

- Nature and development of science 5-6: Important contributions to the advancement of science have been made by people from a range of cultures.
- Nature and development of science 7-8: Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world.

Science inquiry skills

- Processing and analysing data and information 7: Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships in data using digital technologies as appropriate (ACSIS129).

Science vocabulary words

Tier 3 (Specialised vocabulary)

- Trace fossil – evidence of a living being from long ago that does not include any direct evidence, such as footprints or scars on other animals, as opposed to actual bones or skin.
- Imprint fossil – a kind of trace fossil where the life form left a shape we can recognise as belonging to something that was once alive, such as a footprint or body cavity.

Warning

- Air drying clay is pretty safe, but can be dangerous if misused. Please manage appropriately.
- Evolutionary theory is still very upsetting to some parents and students. Please manage appropriately.
- Fossils, evolutionary theory and general discussions of life inevitably involve covering those two most sensitive of classroom topics: Death and Sex. Be prepared to cover those topics with sensitivity and professionalism.

Preparation

- Prepare to create your very own trace fossils, using sponges or potatoes.
- Bring along some fossils, or model dinosaurs.

Disposal

- The fossil you make is supposed to last centuries, if not millennia. If you don't wish to display it proudly on your shelf, burry it somewhere on your property or keep it in a time capsule to help the future know you were here.

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students' questions can and should guide student learning, more material is presented for you convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

This activity is well suited to this age group, but Evolutionary Theory is generally too complex. Focus on trace fossils as evidence of life on earth that is no longer around.

Middle:

Some discussion on evolution theory may be helpful here, but you are at liberty to focus on fossils and how they indicate that there has been life on earth for a very long time.

Teen:

This age group is often ready to ask the hard questions about life, earth, and competing philosophical perspectives. Students can gain a lot from the controversy and their own personal resolution.

Learning Intent (student friendly)

'We are learning to' (WALT) – understand about trace fossils.

Success criteria

'What I'm looking for' (WILF) – a trace fossil to keep, and an appreciation of fossils in general.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as 'make fossil evidence of my life that could potentially last millennia', or 'understand how evolution works'.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations?

- Student can explain how scientific knowledge changes over time as new evidence becomes available, and can draw on the evolving theory of evolution to support their claim.
- Students can explain what a fossil is, including trace fossils, and how they help us know what once lived on earth but no longer lives here.
- Students can make a trace fossil and present it, discussing what they think future scientists might think of the fossil if they find it.

Engage

Play "rumours": students sit in a circle, and one student is selected to whisper a phrase to the student next to them. This rumour is passed along until the final student, who announces the message, and everyone compares it to the original phrase. Perhaps you could try, "Evolution requires natural selection."

Explore

Bring along some fossils or toy dinosaurs. Ask where students think these things came from, and what the world was like long before people.

Explain

Engage students in the following story:

One of the oldest questions in science is, 'Where does life on earth come from?' For millennia, people thought that the animals we see today have always been around. Then we began to find the bones of animals that clearly aren't around anymore. Even the ancient Romans knew about triceratops fossils, and wondered where they came from. So we needed a new explanation, in other words, a new theory.

Many scientists were trying to come up with that theory. One theory was that things that weren't alive could become alive – called biogenesis. For example, old meat left out would turn into flies. Old socks left too long would turn into rats. What do you think of this theory? Was it eventually proven incorrect?

In the 1820's a new theory was thought up by a young scientist called Charles Darwin. Even he knew at the time it would not be a popular theory in some social groups! His idea was this:

Remember last week we discussed how some animals can change over time in order to adapt to their environment? Well, Darwin wondered if this could not be taken a little further, and given enough time might actually turn one kind of creature into a very different kind of creature. Why, given millions of years, this might help account for every kind of life on earth, all beginning at simple forms of life over 4 billion years ago!

(High school groups) His logic ran thus:

- Every species has more babies then they need to replace the parents.
- Every baby is different.
- Those babies better able to survive and have babies of their own could be considered more 'fit'. Those that weren't as good at surviving wouldn't live long enough to pass their 'unfit' differences on to the next generation. Thus, over MANY generations (and NOT in one individual) changes could take place. These changes were called 'evolution' by Darwin.

His theory needed a few things:

- The world to be very old. Millions of years in fact. At the time people weren't so sure the world was more than a few thousand years old. Now we've found evidence to convince us the world is not only thousands, and not only millions, but even billions of years old!
- The theory of evolution needed a mechanism to carry the qualities of a successful parent to the next generation. Darwin had no idea, but we have since discovered genetic code, which does indeed pass from parent to child.
- There would be evidence of animals changing over time. He knew about fossils, and we have even more now. And they tend to confirm a story of life existing on earth for billions of years, starting with simple, single-celled life and gradually becoming more complex, changing at times dramatically along the way.

Now most scientists feel there is LOADS of evidence to support the theory of evolution by natural selection. It is used in sciences as diverse as from biology to medicine.

Points to ponder

- Evolution has no end goal. Humanity isn't the 'crowning achievement', but just the best at surviving in their own niche. Arguably, there are more successful lifeforms:
    - Ants outnumber every other animal species by weight.
    - Bacteria have populated more of the world than humans have.
    - Sharks haven't changed in billions of years (because there's nothing better at being a shark than a shark perhaps?)
- Evolution can only work with what it has, not starting from scratch. I.e., things adapt, but don't suddenly develop something entirely new.
    - For example, creatures need to adapt to survive in cold areas. Fish generally don't have hair, so they won't up and evolve a fur coat. They will have to adapt something they already have – making thicker skin and a layer of fat.
- There are no mesoforms, or 'half forms'. Each point in a species evolution must have a purpose, or be too unimportant to remove. For instance, there aren't any half-way wings in bats. Only hands, followed by webbed hands for gliding, and eventually after millions of years, wings that can produce flight.
- On the other hand, sometimes qualities aren't important enough for a species to get rid of them either. This is called 'residual organs'.
    - For example, we have an arm muscle in common with tree climbing monkeys, but it doesn't get used in humans any more. Yet we've found a way so that it doesn't go completely to waste; it can be used in muscle replacement surgery.
- Evolution has no sense of right and wrong, it only cares about what survives to breed (this amoral view is repulsive to many).
    - Thus, benevolence can be explained as simply another tool to perpetuate your own genetic material by making allies and winning friends.

To be scientific, a theory must make predictions that can be tested. However, there isn't enough time (or the right technologies) to test whether species can change over millions of years directly – we can't go back and simply look! So we look at the fossil evidence. Of course, there are gaps in that evidence. Huge gaps. Not one in every million creatures ever becomes a fossil, and we've not yet found one in every million fossils. There are *going* to be gaps. What do those gaps mean? Will we one day find a gap that can only be explained by some outside force imposing order? Or will those gaps, too, eventually be filled in with more mundane explanations? That is a philosophical question only time will answer.

- ⇨ Illustrate one way we know about animals of the past, even though we cannot see them, is from their imprints and fossils. Footprints placed down, even millions of years ago, under special conditions can be preserved even until today. We can illustrate this by making some trace fossils of our very own (See Activity – trace fossils)

Elaborate

Explain – this activity illustrates the basic idea of Evolution, one of the most influential and successful theories of science.

- It was first suggested by English naturalist Charles Darwin in 1830. He was at first very nervous about sharing his idea, he knew some people would think it contradicted their religious beliefs. He kept his ideas to himself for about ten years, till another scientist, Wallace, wrote to him with basically the same idea. Darwin, instead of replying, didn't wait another minute for another scientist to take the credit for this great idea and published right away. Wallace wasn't too happy about that (and probably still isn't ;)

Activities:

- ⇨ Invite students to research evolution, and share their opinion on it.
- ⇨ Research Charles Darwin and how he came up with his theory. Do you know where he went on his famous journey that convinced him his ideas were supported by evidence?

Commit to further research into the likely survival of Mellits (from the Adaptation lesson) in each of the areas discussed. This activity is just the beginning of what a species will need to survive in a certain area, but it illustrates the point that environmental factors influence structure and function. Many other factors can influence the development of a species over time:

- Another key to survival is to find a source of food which, hopefully, no one else wants or can get to. This is one reason why giraffes have such long necks, to eat the leaves no one else can reach. In the Galapagos Islands, several species of finches have evolved entirely different beaks so that each can get to only a certain kind of seeds. Did I mention that those islands have emperor penguins in the tropics? As you can guess, they are shorter, thinner, and much less dark, as their species has adapted to their new home.

- One BIG ONE we didn't cover was the selection of mates. What qualities are the females looking for before they choose a mate (or vice versa)? One reason birds have such intricate calls may be because choosing a male with a strong and interesting song may actually be choosing a male that is healthy and clever. It's the same with whales. This will increase the chance of having 'fit' offspring (i.e., kids who survive long enough to have kids of their own.)

Evaluate

⇨ Review with students what the felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Display and explain your trace fossil, including a picture of what the animal that made them might have looked like.

Success criteria

⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

- Did you achieve your learning goal?
- What did you learn?
- What worked to help you achieve it?
- What might you do better next time?
- (If needed) Where can you go for extra help or information?

Assessment

Prior learning:

Focus on the outcomes – how can we create the BEST scientific knowledge?

Take time to focus on planned content material during the engage phase, for example,

- What are fossils?
- What does the theory of evolution mean?
- Of all the species of animals that have ever lived on earth, how many are alive today?

Be sure to watch out for the following common alternative conceptions:

- Individual animals don't evolve – it takes an entire species to evolve.
- Evolution rarely takes dramatic steps, such as a new individual with an entirely new colour pelt (or scintillating blue scales, to pick a random, nonspecific example) that everyone in their species loves and wants to mate with.

- Remember, the word theory in science means 'explanation', not 'guess'. **Every** idea in science is a theory. This means all ideas in science are open to change, once *compelling evidence* is found that no longer supports the theory – but not before!

Formative:

As students are learning, help them self-monitor their own learning and achievements.

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

- Display their trace fossils, and explain how they made them, how long they think they'll last, and what they hope future archaeologists in a million years' time might think if they find it.

So what?

- Creatures adapt to survive in certain environments.
- These adaptions, over many millions of years, has helped lead to the species we see on earth today.

Creating science

Science understanding

As we learnt about fossils, we saw that;

- Biological Sciences: Life on earth can leave evidence of its passing.

Science inquiry skills

As we made our own trace fossils to discuss and explore, and presented them in a report or discussion, we had the chance to;

- Processing and analysing data and information 7: Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships in data using digital technologies as appropriate (ACSIS129) – as we make trace fossils and present them for others to explore.

Science as a human endeavour

As we learnt about the history of fossils and evolutionary theory, we;

- Important contributions to the advancement of science have been made by people from a range of cultures, i.e., Charles Darwin was English, but the theory is so popular and widespread scientists from around the world contribute to it.
- Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world, ie, the theory of evolution by natural selection.

Appendix

On morality

One interesting point of evolution is that it doesn't ask what is right or wrong, it only asks what succeeds. It isn't nice when young animals die, but perhaps we can have hope that the entire species will continue to survive because those that do survive are the best suited for the challenges of their environment.

- As a fact, if humans' intervene too much in the natural process of death they can end up making a species particularly weak. Farmers learned long ago that if they only kill and eat the biggest and best animals, the smaller and weaker ones will be the only ones that have children and the entire species will eventually become smaller and weaker.
- This, of course, is the key to selective breeding that has given us many useful breeds of animals, such as horses. Some are bred for racing, for farming, or as gentle and helpful pets. Once again, evolution doesn't make those moral decision or right or wrong. It only 'cares' about what works.

On redundancy

There are a lot of facets to the contemporary description of how evolution works. Once interesting point is that if an animal possesses a characteristic (or even, for example, a broken gene that doesn't work anymore), but if that characteristic doesn't lessen the chances of the creature's survival and reproduction, the characteristic tends to just hang around. (It's more than that, but that's just for starters).

- We certainly don't need a set of three muscles that can wiggle our ears, but our ancestors might have in much the same way as rabbits did. But they don't effect survival or reproduction, so we keep them anyway, much to the entertainment of the grandkids.
- Hair on the little toe, indeed, the little toe itself.
- All that remains of our ancestors' third eyelid is a tiny section at the inner part of the eye.
- Paranasal sinuses may have been used by the ancestors of humans to heighten their sense of smell, but they don't appear to have that, or any particularly useful function, at all.
- The coccyx, which in other mammals forms a tail, isn't needed in humans at all, but it's still there, waiting to be broken at inopportune times.
- Huge tracts of our DNA don't appear to have any role at all.
- Nipples in men fall in this same category, but that might be because (genetically speaking) it's more effort to delete an unused characteristic in half the population than to keep it around for the other half that uses it. So too the tiny vestigial vas on the ovaries of women (in men, the vas carry the sperm from the testicles).

Of course, we may change our science on any or all of these one day too as scientific knowledge grows and develops – the appendix is a good example, once thought redundant, it now appears to have a role in helping the bowels recover from illness. Perhaps there are good evolutionary and

survival reasons to have some or all of these characteristics. Do they carry information of which we are unaware? Are they still important to mate selection, or perform some function we have not yet explored? **Science isn't finished**, and we are still learning, but most of these apparent redundancies appear to serve no other useful function in humans.

Making an imprint fossil on air drying clay – will this evidence of your life last another million years?