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AP/IB Bio P. 3

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AP/IB Biology Summer Reading

Discussion Questions:

Chapter 1: Finding Your Inner Fish:

1. The author chooses to look at 375mya rocks and fossils b/c approximately 365 mya, there was the general transition from creatures that lived in the ocean to living on land (6). In order to breathe on land, the structure of the head needed to change, and so the author was looking for evidence of such a change, in the form of a "fish with a flat head" (4). He travels to Ellesmere Island, 80 degrees north in the frozen Artic of that horrendously could next door neighbor, Canada. He specifically looks at rocks in a layer-cake arrangement, that would allow to relatively date the fossils as well as see a general transition from one type of life form to another. Specifically, he looks at sedimentary rocks, which are ideal for the preservation of fossils as well as being a good layer-cake arrangement rock.
2. Tiktaalik is an animal w/ fish like characteristics such as "scales on its back and fins...", but also with land-living characteristics such as "a flat head and a leg" in addition to bones for arm development (23). This fish is significant because it was found in the right place (environment), the right time period (375 mya rocks), and the right characteristics (transitory forms). The key would be that the fish embodies both characteristics of a water-living animal *as well as* a land-living animal!

3. Tiktaalik has something to do with our own bodies because by looking at these ancestors, we can understand where our own body comes from. Because of how the minute differences in this fish result in the bipedal, distinctive structure of a human, by examining the fish we can learn about how we came to be. Therefore, this fish is what once was inside ourselves, and if we were able to thoroughly understand it, we would be able to have a glimpse into our long, long past.

Chapter 2: Getting a Grip

1. Sir Richard Owen was an anatomist who was able to observe and explore skeletons of all sorts of species. In that manner, he was able to see all creatures with limbs/arms had the same basic structure: "one bone, ... articulates with two bones, which attach to a series of small blobs, which connect with the fingers ..." (30). Through all of the different animals he studied, he repetitively saw this same "divine order" repeated, with the variations not being in the blueprint, but instead, the specific length/shape/size of the bones (30). The structure was the same throughout!
2. Darwin's theory for why there were these "exceptional similarities" is because they came from the same ancestor; all animals who had limbs originated from some kind of animal that began sprouting limbs (32). Because everything comes from that basic structure, that original animal created this blueprint of one bone - two bone - blobby bones - fingers, and all the other animals only adapted on this kind of design. Therefore, the idea of a fundamental design is thus explained.
3. A further examination of the Tiktaalik fossil reveals that it is a fish that does pushups. Specifically, it had evolved wrist bones as well as a "one bone - two bone" structure

that allowed it lift its flat head above the water in order to look for predators. This structure eventually evolves into the "structures of our own limbs" (41).

Chapter 3: Handy Genes

1. One of these experiments dealt with the "Zone of Polarizing Activity", or the ZPA, which seemed to control the formation of digits in a chicken embryo (49). By injecting Vitamin A into the right area, scientists would be able to create "mirror-image duplication" within chicken hands (50). In addition, Summerbell found in 1970 that by blocking the ZPA, it was possible to prevent the formation of digits altogether, or at least seriously mutate them. The significance of this finding was that it would lead to scientists to search for the cause of the ZPA within the genetic material of chickens!
2. The "hedgehog" gene is a gene that controls the formation of digits, similar to that of the ZPA. Significantly, the "sonic hedgehog" gene was first identified within chickens, and mutations within it either resulted with fewer or more badly formed digits. However, scientists later discovered the "sonic hedgehog" in every animal that did have limbs! Later, in an experiment by Randy, he investigated the "sonic hedgehog" gene in sharks and skates, animals that do have limbs but instead of hands, possess fingers. Through the stimulation of the gene, he first found that stimulation of the gene resulted in "mirror-image duplication", as found through the stimulation of chicken embryos (57). However, more interestingly, he inserted mouse DNA into that region, and resulted in a shark with fin-digits that were separate and distinct! This experiment allowed scientists to see how central were these genes, and that in

addition to having the same structure, our ancestors had the same tools to create the structures in our DNA.

Chapter 4: Teeth Everywhere

1. Teeth are the hardest parts of the body, "hard as rocks", because the "enamel includes a high proportion of the mineral hydroxyapatite", a mineral that is responsible for the toughness of bones (61). This mineral is responsible for the toughness in our enamel, as well as the layered structure of the tooth. Conodonts are spiky enigmas that were questioned for many years before being realized as the teeth of lampreys. By looking at the fossil imprints of lampreys, ancient jawless fish, scientists were able to make this conclusion.
2. The key to the formation of a tooth is that " two layers come together, fold, and secrete proteins" (78). However, this formation pattern is not limited to a tooth; it is actually identical to the formation of scales, feathers, breasts, and sweat glands! Therefore, discovering how our early ancestors were able to create teeth is an insight into how we gained this capability to develop all of these things. Without the capability, our bodies would not have had the tools in order to create hair, or other bodily features.

Chapter 5: Getting Ahead

1. These nerves, the trigeminal cranial nerve, which controls the muscles in the mouth and within the year, and the facial cranial nerve, which controls the facial muscles (duh), are very much intertwined inside the head, leading to "almost crisscross[ing]"

through the brain (85). The author compares the development of these muscles to the jerry rigging of an old office building: Originally, these muscles/wires were not needed, but as the body evolved, they had to be inserted somehow. Therefore, they were essentially squeezed into any possible place, resulting in the jumbled mess that we have today.

2. The first arch tissue forms the "upper and lower jaws, two tiny ear bones, and all supporting vessels/muscles. The second arch bone forms the third small ear bone, a tiny throat bone, and most of facial expression muscles. The third arch bone forms bones in the throat for swallowing purposes, while the fourth arch bone forms the deepest parts of the throat, including parts of the larynx and surrounding muscles/vessels (87).
3. Hox genes are essential to the development of each of the arches listed above, and essentially defines each one. In experiments, it was found in frogs that by interchanging the Hox sequence within the first and second arches during the embryonic stage, making them the same, the frog ended up having two jaws! (sorry frog) (93). They are very important because they make up the basic design of the head, and therefore, having control of them results in having control of anybody's head. Amphoxus is a very basic invertebrate worm that is unique for having a nerve cord down its back. A jelly-like substance fills this cord, named the notochord, and is the cause of much of the pain in modern humans who may have a ruptured disk in their spine. We share this notochord, and therefore we share bits of ourselves with these boneless, icky, worms.

Chapter 6: The Best Laid (Body) Plans

1. A germ layer is what Karl Ernst von Baer identified in the 1800s, as one of three fundamental layers that resulted in the formation area for every single organ in the human body. It was later found that in every single embryo of every single embryo, the same germ layers allowed the rise of the same organs at the same times within development. The outmost layer is the ectoderm, which forms the outer body (skin), as well as the nervous system. The middle layer, the mesoderm, forms tissue between the guts and skin, including skeletons and muscle. Finally, the inner most layer, the endoderm, forms the inner structures of the body, including the digestive track and associated glands (101-102).
2. The blastocyst itself is a ball of cells, similar to a "fluid-filled balloon", which then travels through the fallopian tubes into the uterus. Assuming a proper implantation, the blastocyst stage later turns into a flattened disk, which then becomes the entirety of the human body! This is because the blastocyst stage later becomes those three germ layers, where the rest of our body emerges from (100-101).
3. The "Onotogeny recapitulates phylogeny" idea comes from Ernst Haeckel, who attempted to claim that each stage within our embryonic stage mirrored an adult stage of the evolutionary path of humans. Therefore, our embryos first behaved like adult fish, then like adult reptiles, and finally adult mammals (103). However, later evidence proved that Von Baer's original observation, that merely every embryo from all species looked similar, was more correct. One could not compare embryos to adults.

4. Before Harland's Noggin gene was Hilde Magold's Organizer patch. She discovered that there was a patch within the embryo that, if implanted properly, would "organize" the body to develop another entire body plan. Therefore, an embryo with an additionally grafted organizer could become like conjoined twins. However, it took some time for scientists to isolate the DNA that was responsible for such action, and thus, the Noggin gene. This gene was active in the organizer region of the embryo, but was not the sole gene to regulate body development. Instead, it corresponded with several other genes in order to play a role in the development of the body axis ... and other organs" (111). It essentially functioned as a switch for another gene, the *BMP-4* gene which created the bottom of an embryo, and when activated, the Noggin gene would turn BMP-4 off. This simple on-off relationship allows for the formation of the entire body.
5. Sea anemones have similar body plans to humans because of axis of symmetry within its body structure. Even though it seems to have radial symmetry, when one chops up a sea anemone, one could find that the inside organs are organized in two distinct sides, which corresponds to that of a human's "belly-back" axis. In addition, there is a "head-anus" symmetrical axis in the form of an "oral aboral" axis. Notwithstanding physical differences, scientists have also found many startling similarities within the genetic code of both humans and sea anemones, which give birth to these axis. These genes, labeled as the Hox genes, are essentially interchangeable between species such that a sea anemone hox gene would cause the same reaction within a frog as an additional injection of the frog Hox gene!

Chapter 7: Adventures in Bodybuilding

1. The caption captures my surprise: there was such a long period of time where animals did not have any bodies, coming up to somewhere around 700 million years out of a full 4.5 Billion years before bodies developed (121)! It is hard to imagine a world where the only living things were single-celled organisms.
2. One of the most common proteins is the collagen protein, which is a molecule that acts like a rope: Strong when pulled, weak when collapsed (125). This molecule fills up the space between cartilage, the smooth surfaces where our bones glide upon each other and allows for movement. Therefore, the collagen ratio combines and wraps around the proteoglycan, a Jell-O like structure, to form the structure we know as cartilage (126-127).
3. Cells are able to "stick" to each other by "tiny mechanical rivets", which have a wide diversity in the way they work. Some are similar to glue, binding to outside and inside structures, while others are like selective rivets, forming distinct bodily shapes (127-128). This results in the bone and skin structures.
4. Cells are able to communicate with each other by using molecules that move from cell to cell, communicating. These molecules "speak" to the nucleus of a cell, commanding it to turn on or off specific genes, which then impacts the behavior of the cell (128). That micro behavior essentially transfers to the macrobehavior of the human body.
5. Chronoflagellates were cousins of sponges, essentially sharing much of their microbe DNA with sponges, but being single-celled microbes. With their investigation, it was found that the DNA that controlled molecular rivets within large organisms with

bodies were replicated within these single celled choanoflagellates. Therefore, the bodybuilding apparatus was apparent in such a primitive creature!

6. Bodies may have come from a specific time not because of a spontaneous change within the genetic structure of animals, but because how the outside environment had changed to accommodate bodies, as well as predator/prey interactions. For example, the introduction of prey was able to induce the formation of basic 8-celled bodies from a single-celled alga (136-137). Another cause could be from how bodies are quite expensive to have, and required oxygen for its synthesis. Not until several hundred million years ago was oxygen actually abundant on Earth, thus aiding in the developmental cost of a body (137).

Chapter 8: Making Scents

1. A smell is obviously created when our noses detect scent particles in the air, as the particles interact with odor receptors located in an area within the mucous of our nasal passage (141). However, the key to our sense of smell is that not every single chemical maps to a single smell; instead, what we perceive to be a smell is actually a cocktail of many different chemicals that, combined, registers as a singular smell. These signals are then interpreted by our brain, which devotes a very large amount of space and energy to categorizing smells as well as associating them with our memories and other senses. In fact, the "code" for smelling is very deeply embedded within our DNA, as a full 3% is devoted to smelling (144)!
2. Jawless fish are perceived to be our ancestors, in many ways including our smell. As time passed, the sense of smell in more advanced creatures became more and more

pronounced, as random mutations and duplications resulted in a a more diverse gene pool for smells.

Chapter 9: Vision

1. For the same reason why humans share odor genes with jawless fish, it is thought that these old world monkeys were the ancestors for our color vision genes. We share 2 of our receptor making genes, genes critical for how we perceive color, with these monkeys, which implies that our own color vision came from duplication and mutation of those original genes (153). The cause for the Old World Monkey genes comes, interestingly enough, from an evolution within the floral kingdom, as tastier and more nutritious fruits evolved to be more brightly colored, so a color-vision chimp would have a distinct advantage of how to eat over a black-and-white chimp.
2. Eyeless genes, also called the Pax 6 genes in a general term, are genes that control the creation of an eye within an animal. The activation/deactivation of this gene results in either healthy eyes or deformed, mutated, or even missing eyes, hence the name "eyeless". This gene/DNA sequence seems to be universal across all animals who have eyes, as a mouse PAX 6 gene was implanted within a fly, and produced a fly eye (156). Therefore, they can be thought of as an universal trigger for creating eyes.

Chpapter 10: Ears

1. The three parts of the ear are the inner ear, the middle ear, and the outer ear, with the middle ear being a unique trait of mammals.

2. The reason that Karl Reichert proposed in 1837 that human ears were the same as the jaws of reptiles was because he traced the development of the year. To his surprise, he found that the bones for the ear within mammals was the same bone as the jaw bones of reptiles (160). Later evidence for this theory was found within embryonic data, as these vastly different bones were derived from the same second arch derivative, but most amazingly was the discovery of "mammal-like reptiles" buried in Africa (161). There, archeologists discovered animals that seemed to be a transition between reptiles and mammals, and within them was a clear sign of how mammals evolved from reptiles, explaining the congruity of the middle ear.
3. The Pax 2 gene is a gene that specifically controls your inner ear, which monitors functions such as the acceleration and velocity of your head and your ability to keep your balance. Like the Pax 6 gene, it is a major gene that if turned off, would result in mutated or missing inner ears. Interestingly, there is an additional connection with the Pax 6 gene, as the common ancestor seems to neither have Pax 6 nor Pax 2. Instead, the box jellyfish seems to have a hybrid of Pax 6 and 2, which is hypothesized to have later split apart into what we know today.

Chapter 11: The Meaning of It All

1. The biological "law of everything" is that every single living organism must have had parents (174). The significance of this seemingly obvious law is that it allows us to trace our minute changes from one another through our parents, going through the genetic code in order to find the areas where we have mutated and branched off. As we mutate into different traits, we can apply a level of classification onto this, as we

are a subgroup of our parents, who may have a particular trait, who are then subgroups of their parents ... we can thus trace ourselves back to the development of the species Homo Sapiens, whose parents could be traced back to different genus's and other animal kingdoms!

2. The author attempts to illustrate with the "bozo" example how a completely different type of creature can evolve from a "regular" person, which is an analogy of how today's creatures came from something that is completely different from them (176). Through the iterative changes, we see how we can trace lineage through what features we see, ass all the bozos who have floppy feet go back to one person while the squeaky noses can be traced back even further.
    a. Obesity can be traced back to our ancestors, who were particularly active and would not have a steady supply of food all the time. Therefore, our taste buds have evolved to crazy high energy content, such as fats and other high energy density food, so that we would know what to eat. In addition, we developed the ability to store that energy for an extended period of time, so that we could use it during times of scarcity. However, as modern middle class Americans clearly do not have a food shortage, the abundance of food clashes with our instinct to be as "greedy" as possible, resulting in rampant obesity (187).
    b. Sleep Apnea comes our throat is rather long, because of our evolution so that we could talk. Because talk requires rather flexible muscles within our throat, and how our muscles become relaxed when we sleep, when we sleep there is a tendency for these flexible muscles to collapse the breathing tube for some

time, resulting in not breathing for some time while sleeping. Of course, this is very dangerous!

c. Hiccups come from our inner fish, as well as our inner tadpole. The fish sense comes from how the nerves within our brain has evolved, because those ancestors required only very short nerves to reach the diaphragm, while us modern descendants require a long distance. Therefore, this "jerry-rigged" nerve situation results in easy obstruction or interference with our breathing nerves. Our connection with the tadpole comes from our glottis, the flap of skin that directs the difference between the food tube and the breathing tube as well as the cause for that rhythmic "hic". This is related to the tadpole, which has a similar glottis to direct water and air around.

Afterward (new findings re: Tiktaalik)

1. Because the fish has lost the use and the actual structure of the operculum, it means that it had had to develop muscles to allow it to entirely breathe with the mouth, unlike other kinds of regular fish. This development once again highlights how much of a change it is from the other species currently known.
2. Having a true neck means that it is able to look around and understand the world around it, without having to reposition its entire body. While a fish's body always exists in three dimensional space, as it is able to position itself in numerous different ways throughout the water, a land creature's body must stay to some degree rooted to the ground. Therefore, being able to use its neck to look around it would have been a large advantage.

3. Tiktaalik lived in this region, but it did not live in this region at this point in time. Instead, it lived in a time where the climate was much warmer, and is only where it is today due to either climate change or shifting of continental plates. Therefore, the skeletons might have been deposited within that rock millions of years ago, when the area that it lived in had a tropical climate, and has only slowly moved into the Arctic tundra that we are familiar with today.