Joe Tardigrada:

Trundlers in Time

. . . An evolutionary adventure

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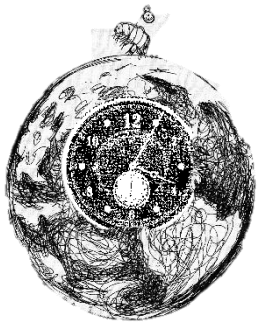
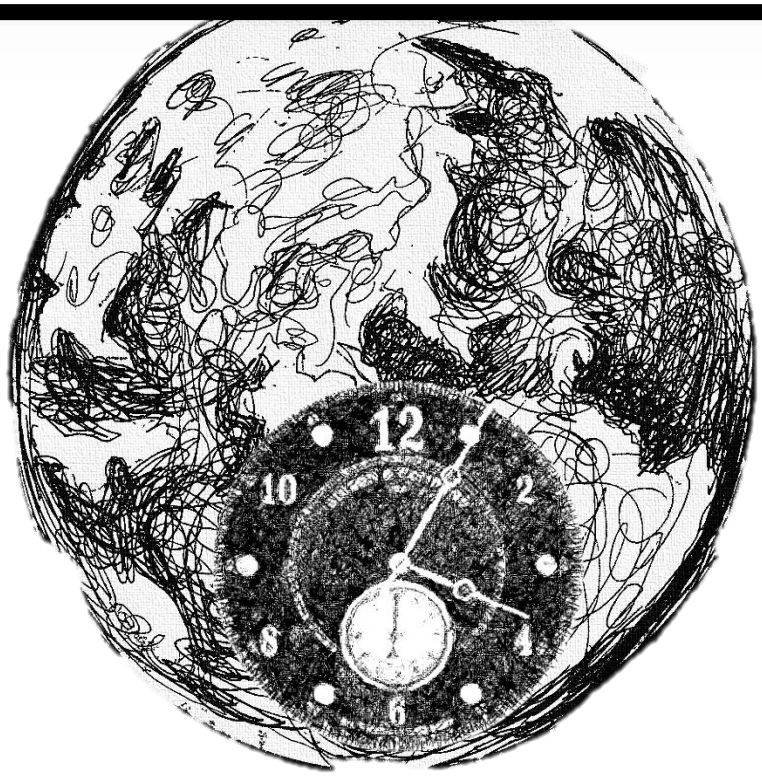
This Workbook belongs
To

Date



Tardigradas

Trundlers in Time



Lesson Plans in the Master Narrative

Tadigrada: Trundlers in Time
A Lesson Plan in Tardigrada Evolution
Experiences in:
Coloring
Drawing
TTOL & the Master Narrative

"If I had my life to live over again, I would have made a rule to read some poetry and listen to some music at least once every week."
Charles Darwin

A genomic portrait of Joe Tardigrada

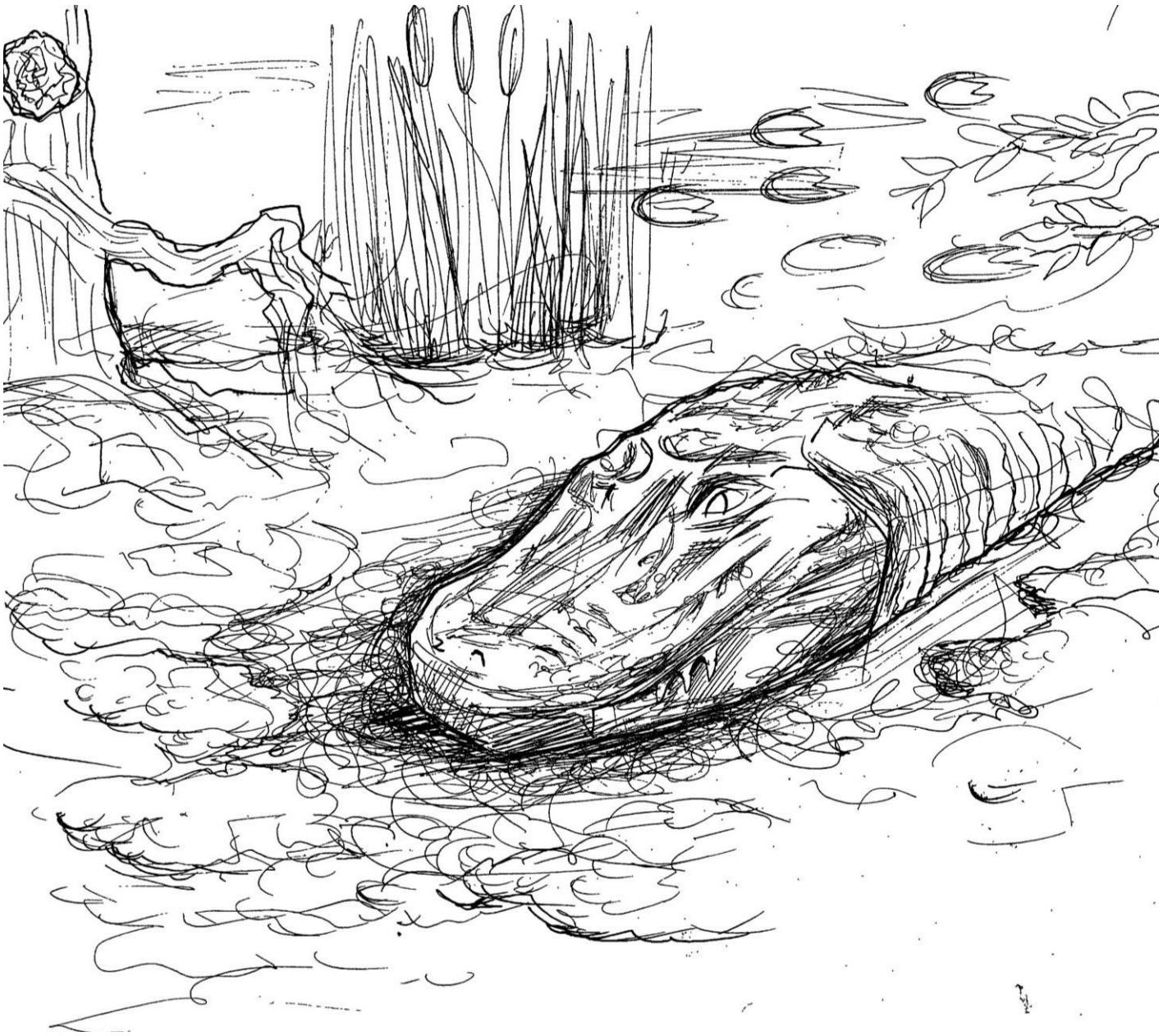
Introduction

Phylum Tardigrade, affectionately known as "water bears," or "moss piglets," Were named by the naturalist Joh Goeze who in the 1770's described them as "Little bears in water." The magical excitement of seeing living things under the microscope had just emerged. Microscopic worlds suddenly revealed another dimension of life in the most common of places. Water bears are on the many amazing microscopic life forms. They are found almost everywhere in Nature. Extremely ubiquitous and well-traveled, Tardigrades offer a glimpse into the power of a small world and into evolutionary processes. Tardigrade have indeed traveled far and wide, with beginnings 600 million years ago in the Precambrian and with a resume of biological innovation that makes modern technology look cumbersome and silly. We are going to time travel with Tardigrades to explore a little of their biology and discover some of the origins and relationships that surround them. The Water bear's story and genome is a story locked in the geological time machine of the Earth as all life stories are. Water bears, desiccating for at least 100 years are pond water time travelers. The adventures of being little and ubiquitous in Nature and with Nature, have shaped our Tardigrade friends into very unique invertebrates, they, along with us, and all life are changing and continually defining themselves. Tardigrades have taken their genome across the globe to diverse ecosystems and biomes, aquatic and terrestrial- maybe *extra-terrestrial*. For Tardigrades, the vortex of chance events in the Universe and on Earth created alterations in an ancient genome within a population, "selecting for" and producing populations that are better adapted to the new conditions that surrounded them. This process of natural Selection, a concept also known as "survival of the fittest," posited by Charles Darwin, keeps life forms in step, splitting and diverging with the biogeochemistry of their space and time.

So, let's meet the "little water bear," Joe Tardigrade (you can name him/her whatever you would like), we like to call him "Joe." Let's find out about his life, where he lives, his anatomy, his incredible adaptability to stress, and how he might have evolved his special powers. We also introduce to you, if you have not experienced it in class or at home, the Time tree of life, where you can search for relationships, build phylogenetic trees, and get a better picture of your organism of interest as the TTOL is a database that puts the organism in context with other organisms and with Earth cycles and Environments in time.

An evolutionary narrative, is Nature's Master narrative, setting the stage for on-going scenes, characters, impromptu changes, and big picture perspective that shapes us and all life on Earth.

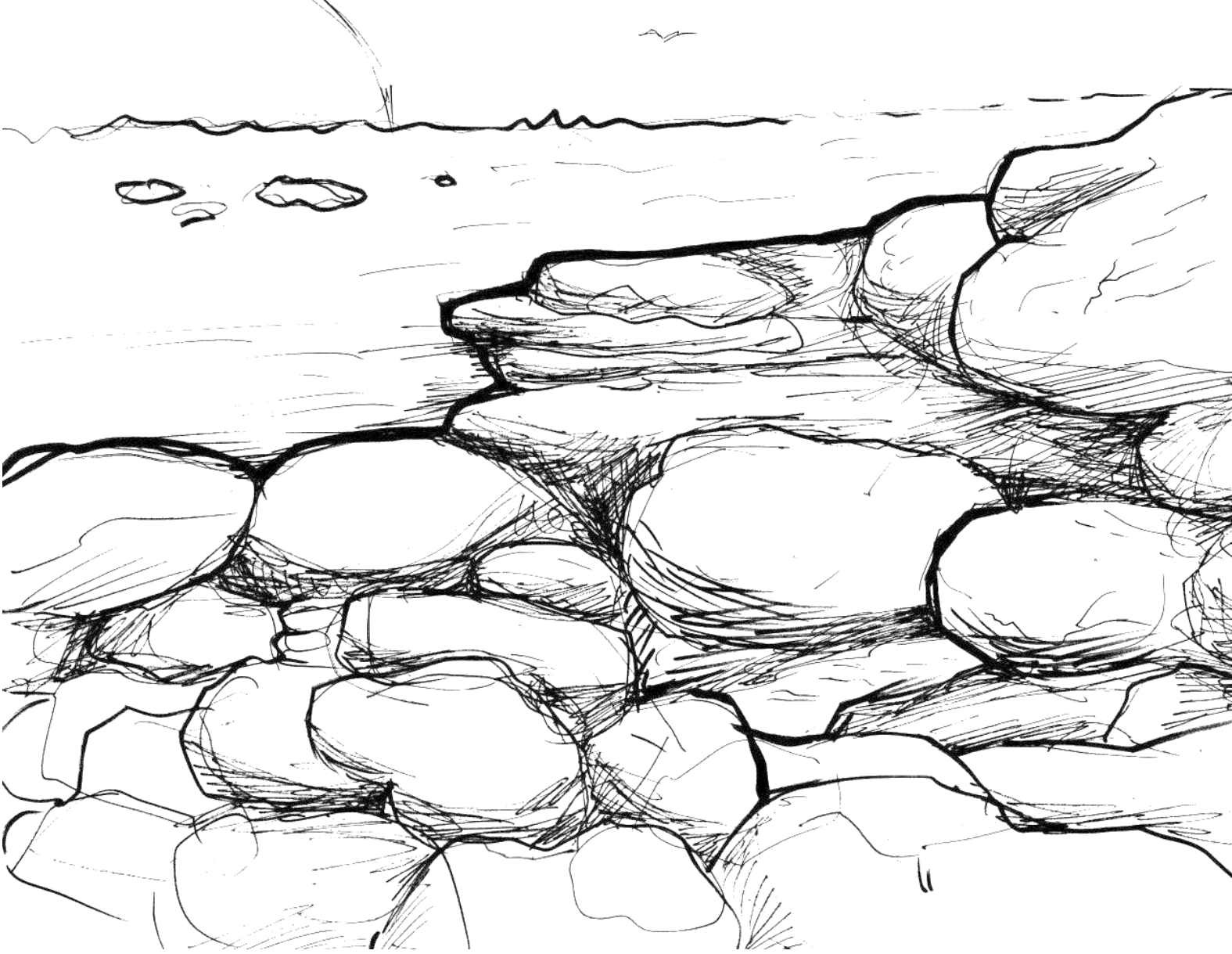
For Tardigrades, also known as moss piglets, our story, our stage, can start in any moist area, or it can start in dried up leaf litter, but anywhere there is water, Joe Tardigrade was probably there. Hygrophilous micro metazoans need water as we all do but are adapted to live without it for incredible lengths of time. They are invertebrate animals that are *sort of* related to arthropods, and yet some say they are related to nematodes, and possibly even annelids. Being micro metazoans, they could be found in the Mangrove forests of the Florida Everglades, right under an alligator's tail...



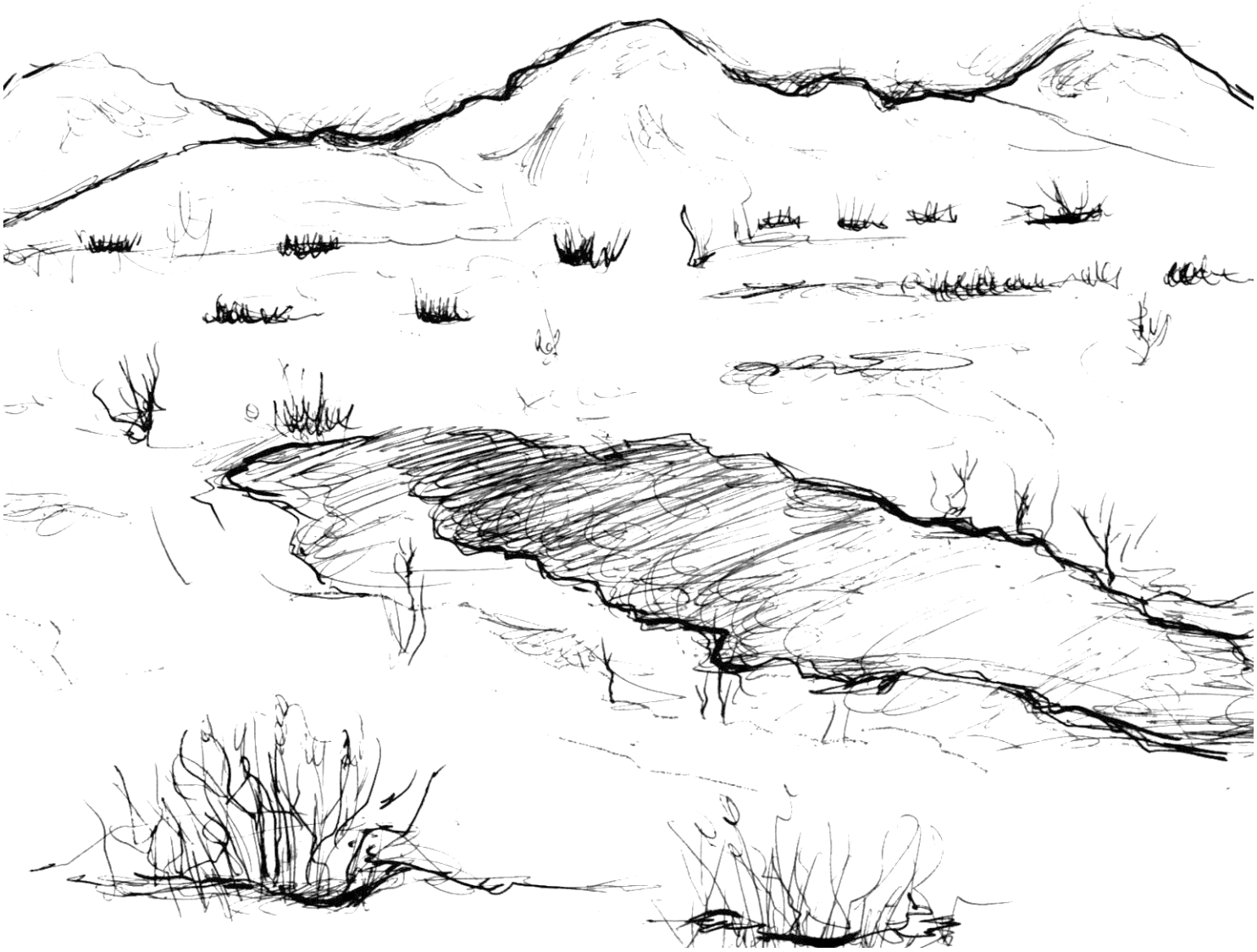
They can also be found in freshwater like that of the Great Lakes

Tardigrades can be found in deep thermal vents with temperatures as high as 120 Celsius…

And pressures of 1000 atmospheres

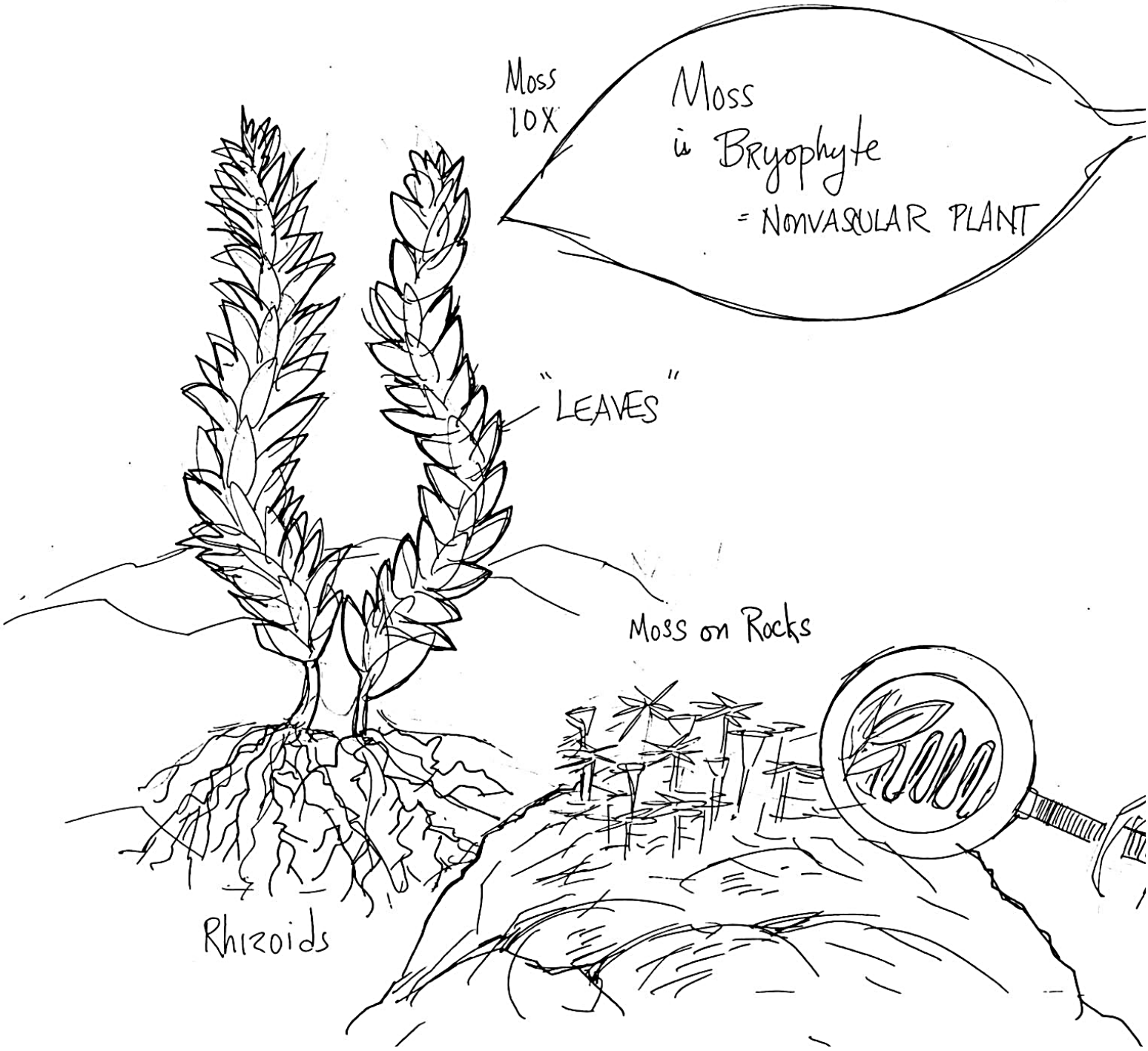


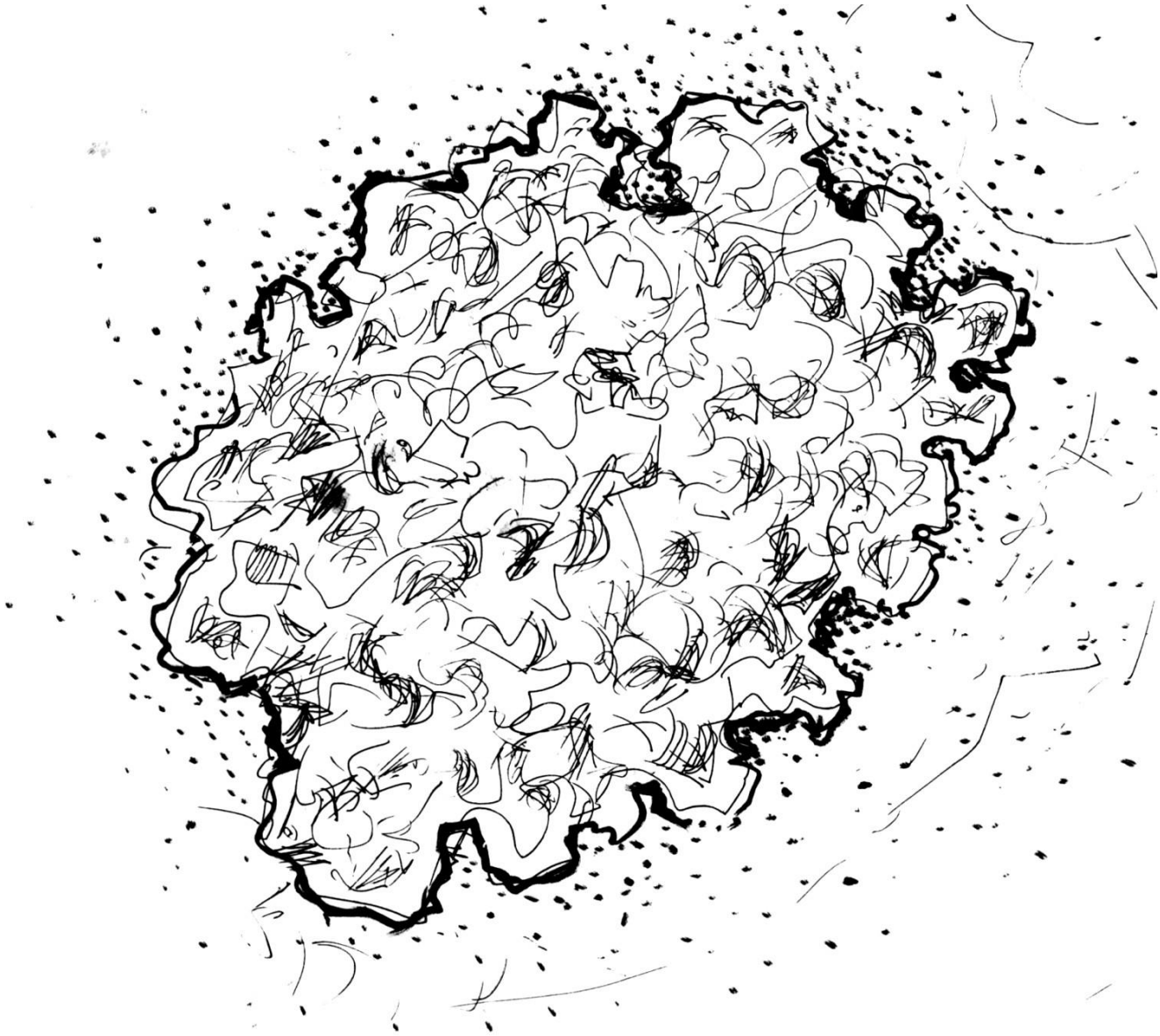
They can be found in tidal pools in Maine or Salem Massachusetts…



Or in the permafrost, which is melting, in the Tundra in Siberia…

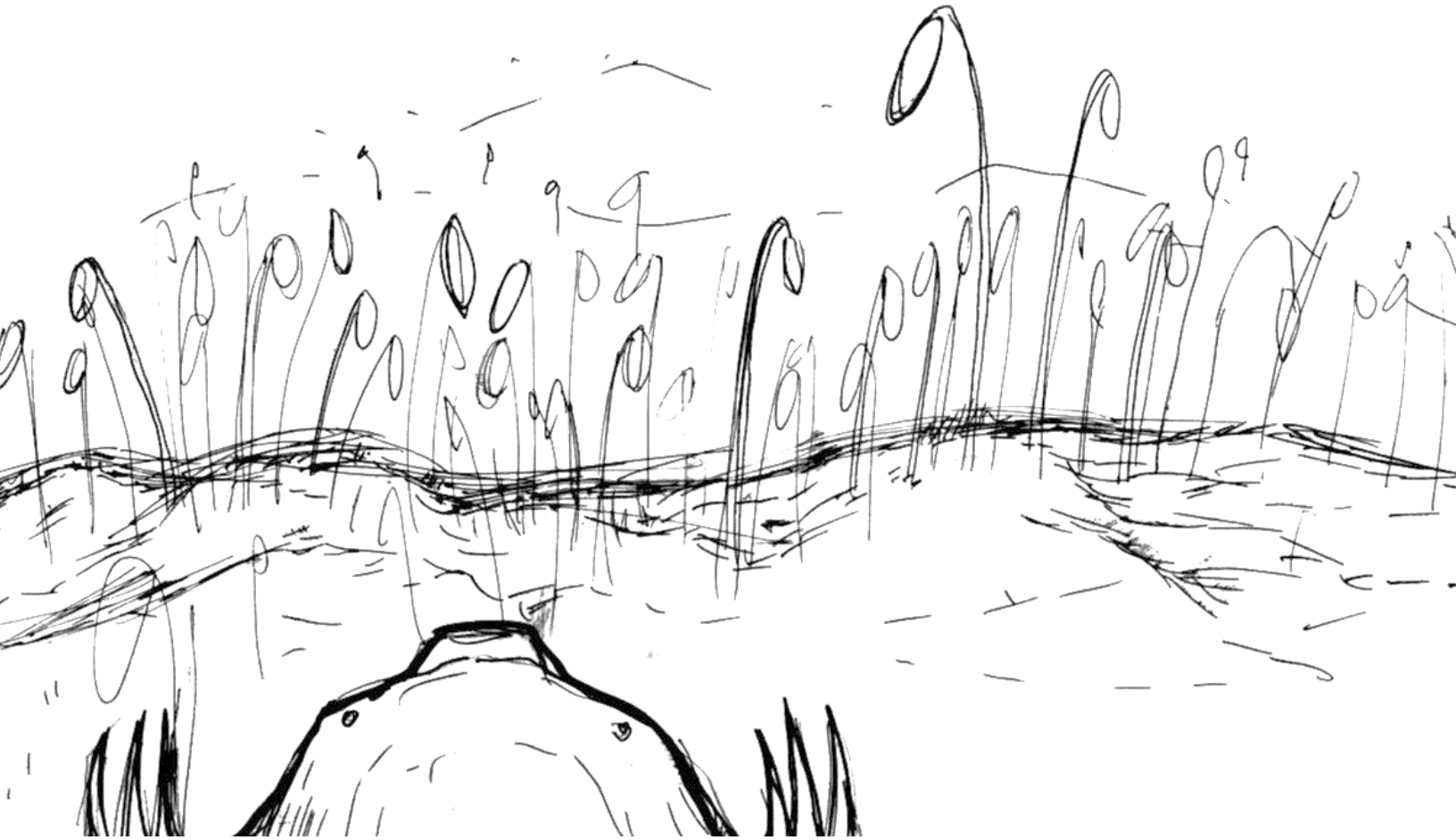
The Earth's hydrological cycle is a necessity of a living metabolism…and when plants encounter water, they expand, and so does Joe Tardigrade. Without water, desiccated in a suspended state, water can't freeze, fracture or rupture cells- a big advantage for Tardigrades. Metabolism on hold is an important stratagem in changing seasons and in the ebb and flow of natural systems. In this case drying out evokes a non-living state that keeps Joe alive for the future- a state of suspended animation…


Moss
10X
Moss
is Bryophyte
= NONVASCULAR PLANT
"LEAVES"
Moss on Rocks
Rhizoids



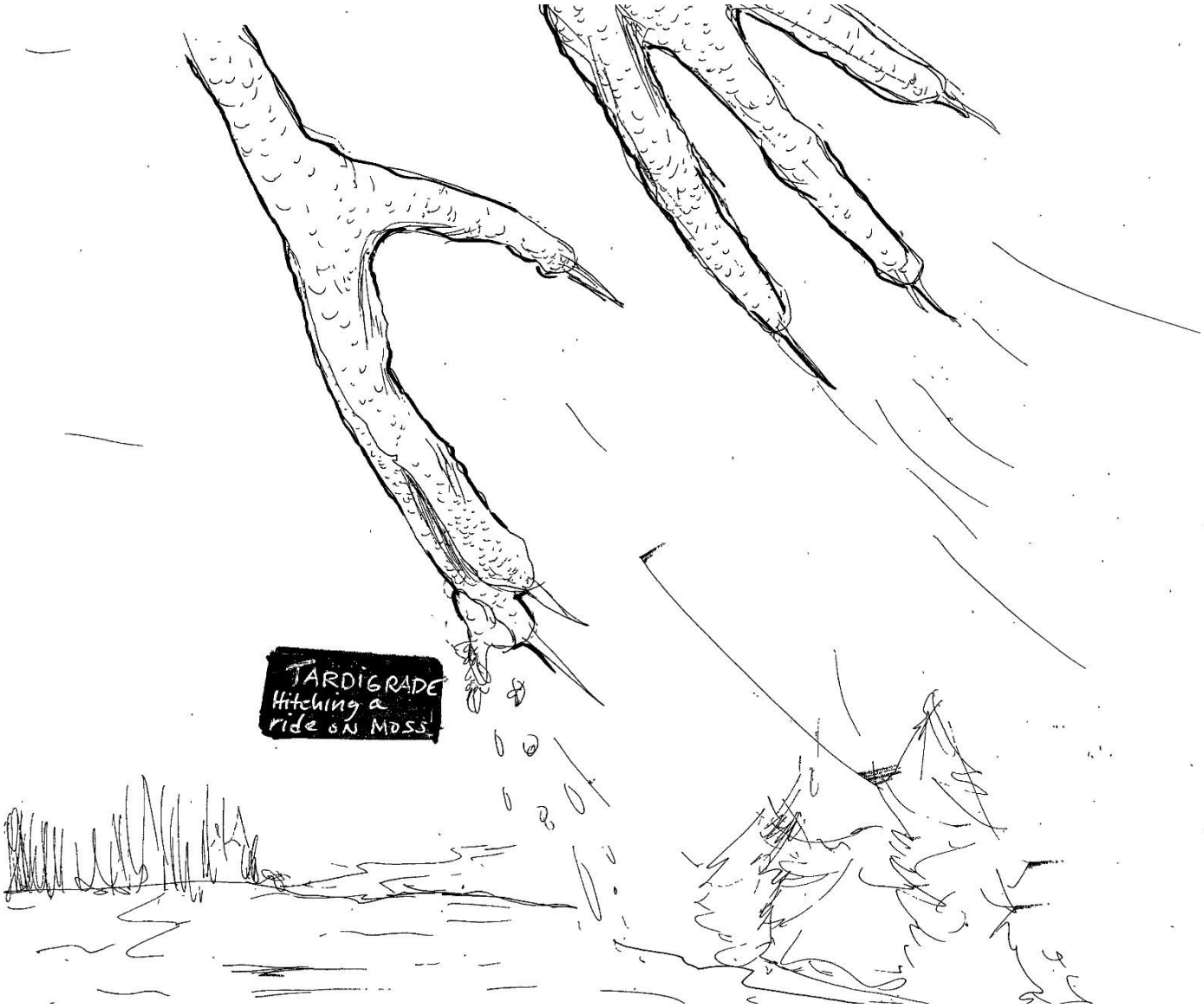
As you pass by a Lichen on a tree, you may forget that Tardigrades are making their niche in symbiotic interface of algae and fungi…

Mountains, marine environments, deep pressure of 5 miles down, floating on the surface, in boiling geysers, sneaking up upon moss, recently revived by a midnight rainfall…



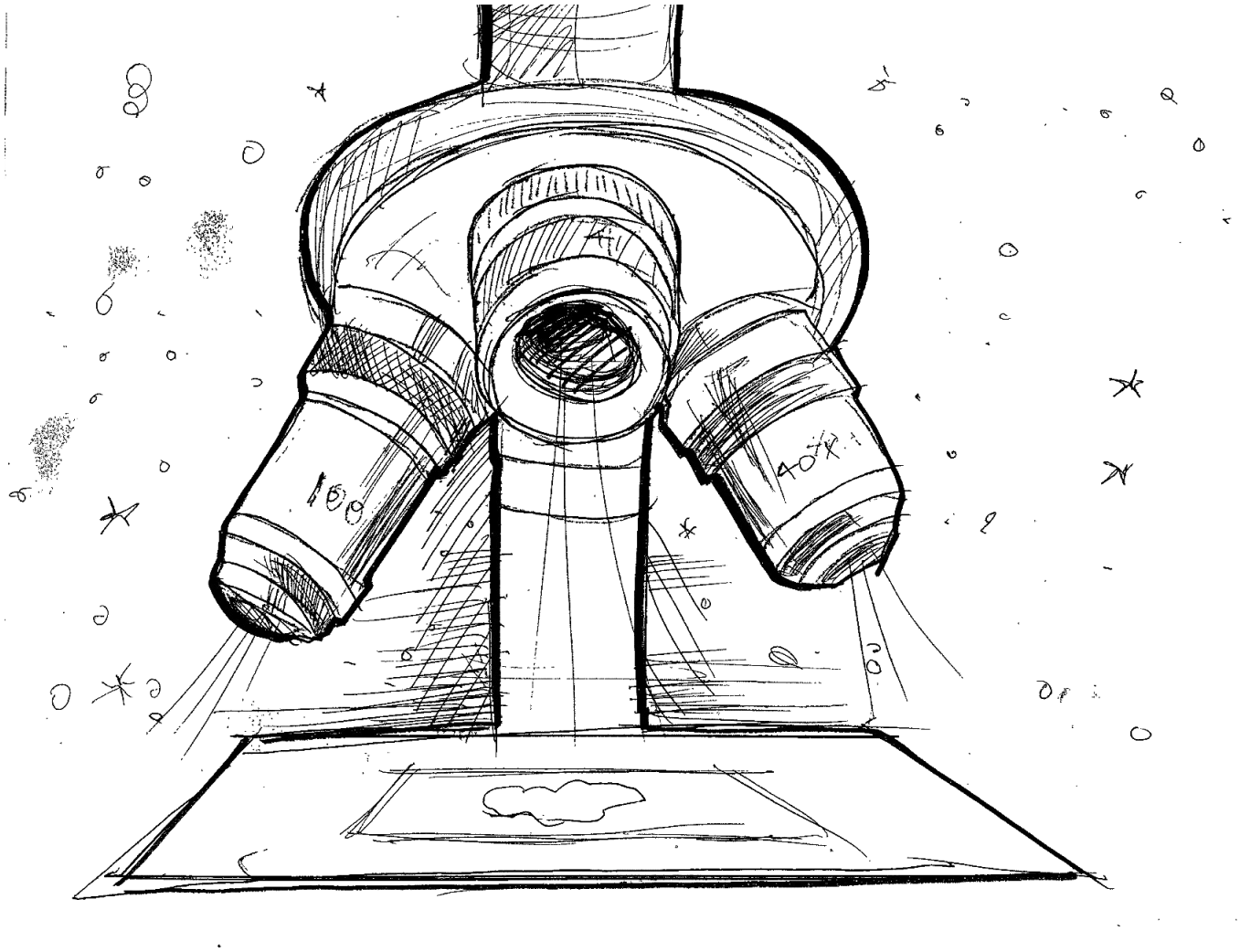
Tardigrades evolve like everything else alive as the planet shifts, some events can encourage a more rapid adaption to a more rapid change. You might be in leaf litter one day or fresh water algae and end up on a sandy beach months later…

Tardigrades can move by the winds, on floating plants, or clinging a bird's feet as they migrate or move to other ecosystems.



Maybe thousands of miles away…


If someone could just develop an algorithm to predict my ancestral protein sequence they could make a model and they might understand me a little better, I'm really a pretty badass organism.



But the fascinating story of the Tardigrades (for humans) starts under the microscope. If you squeezed some wet moss, you probably squeezed out a bunch of moss mingelers, including Joe Tardigrada, as many organisms make their homes in moss, including bacteria, fungi, nematodes, rotifers, other little arthropods, and protozoa.

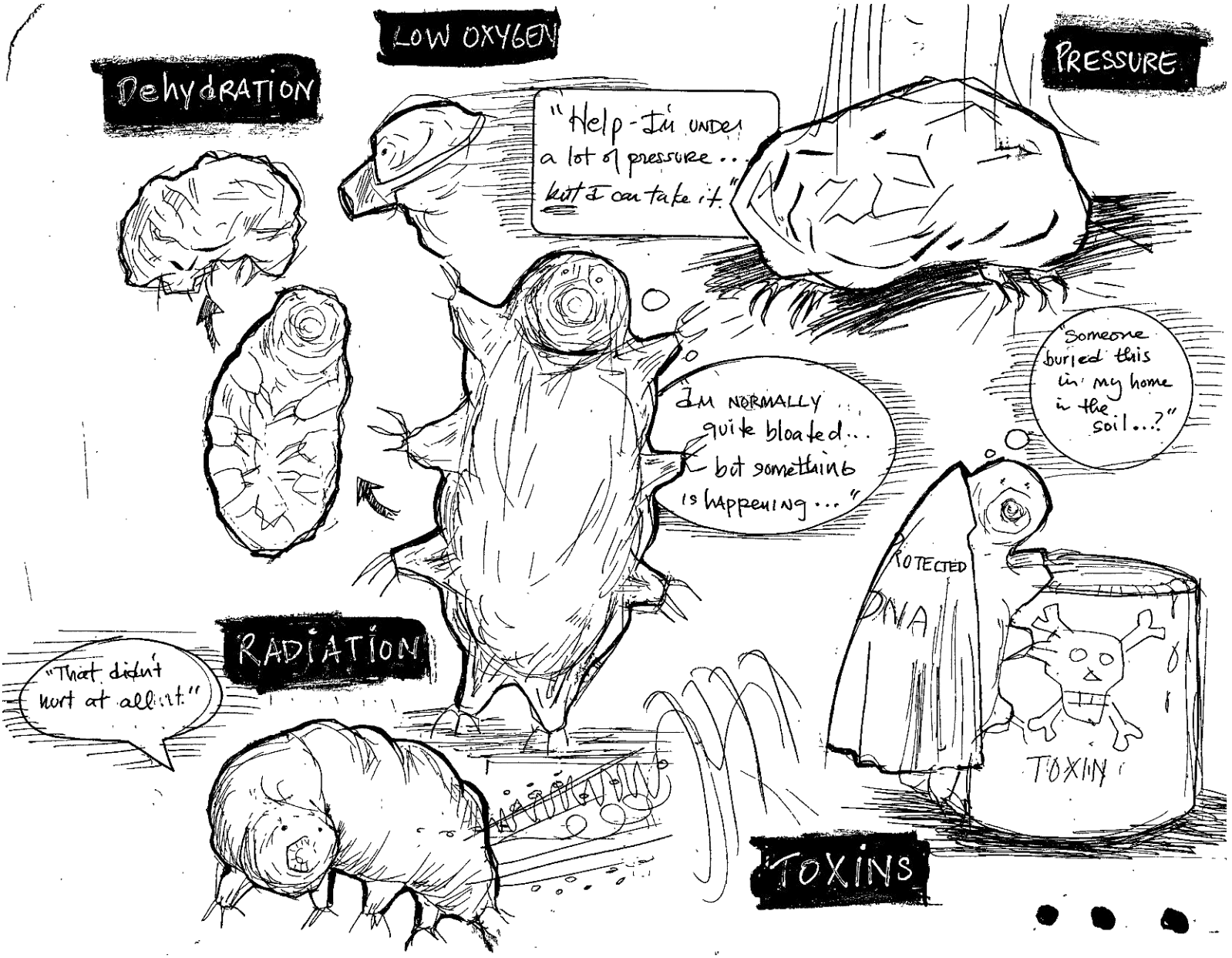
Tardigrades range in size from roughly 1.5 mm (.059 inches) to about 0.1 mm. Of course, we don't really know how many species of Tardigrade are out there in nature so there may be smaller or larger ones. Anytime you collect or look at anything, you are looking at a snapshot of it, a moment in time, so within the life cycle of Tardigrade, you may encounter unfertilized eggs, sperm, fertilized eggs, embryos, instar states, or cryptobiotic states. Stages of development of the Tardigrade appear very similar to the divisions of protostomes. In a pond water community, you might find paramecium (.25 mm), amoeba (.2-.3 mm) and baby Tardigrades (.05 mm). In this way, you can see their comparative size in the community that they live.

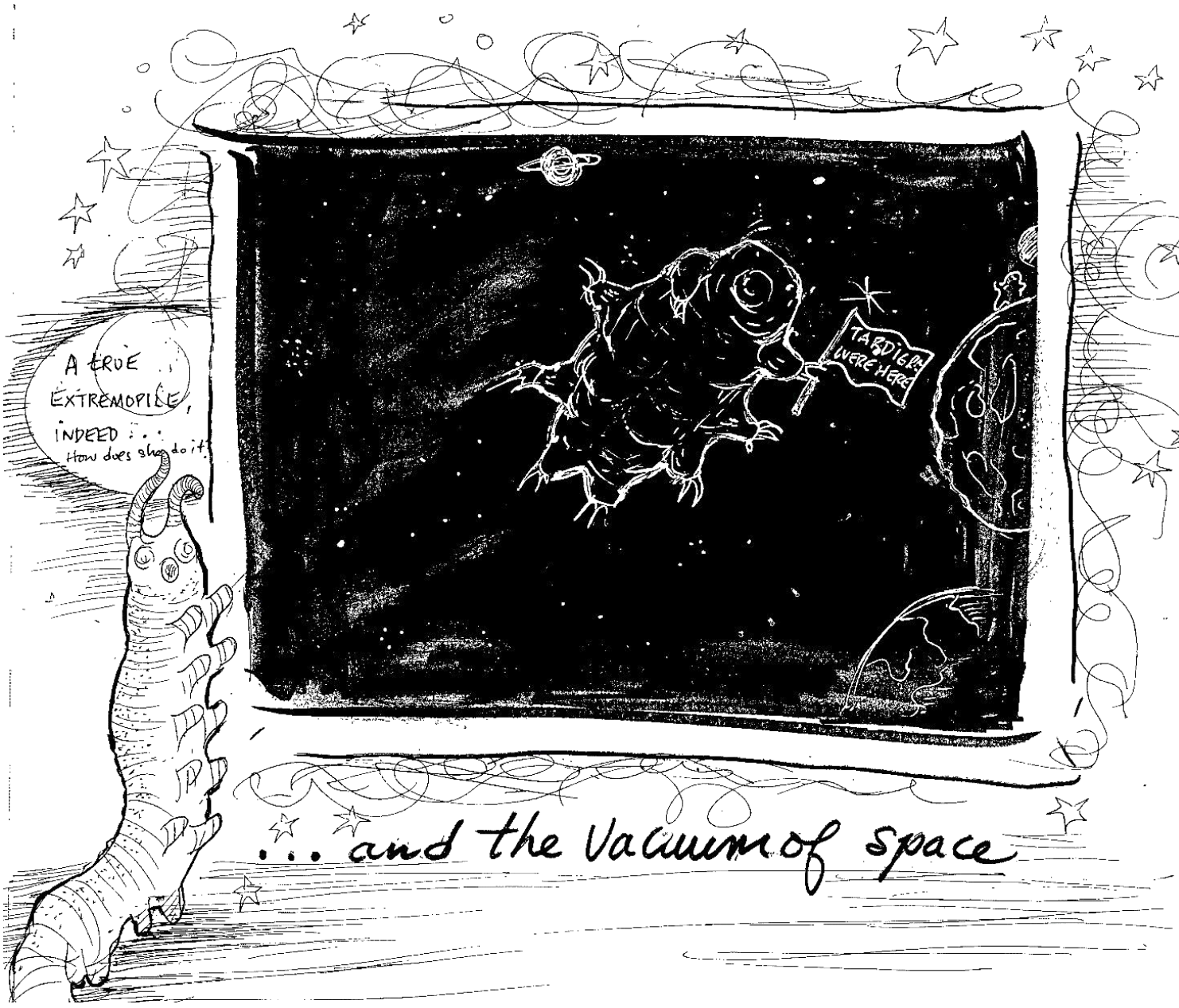
Under the microscope we can see, just as Spallanzani and others did, the anatomy of Joe Tardigrade. As Tardigrades come in many colors often as a result of their food source and the pigments within it, stored in specialized structures, that are visible, as most Tardigrades are transparent. Scanning electron micrographs, scan the surface of structures and organisms, and give the Tardigrade the appearance of a stolid, chubby sort of body. It's kind of like sea monkeys, on the box, they were illustrated as little miniature monkey-like animals, when in fact they were brine shrimp, which in itself is quite interesting, the shrimp just might not be dancing around, riding bikes, and playing tennis.

If Joe Tardigrade was your size, he might not be so cute, maybe down right frightening, a little like a giant Mutant Ninja Turtle. At least you could really check out the details of the anatomy though.

Stress- *Yikes!*

We associate stress with unpleasant experiences, events that burden our sympathetic nervous system. Worry, fear, anxiety, which includes taking exams as well as physical extremes cause stress. Our stress of course is no comparison to the stress that Tardigrades can tolerate. It appears that all stages of a Tardigrade's life have some qualities that prevent them from succumbing to stress, it might even be that **encystment** (reacting to slow changes in the environment and drying out) as well as **Anhydrobiotic** (reacting to rapid changes in the environment) might be considered part of their life cycle. Depending upon the ecosystem and conditions, special stages of existence can respond to all sorts of environmental pressures. ***Osmobiosis*** is a Tardigrade's response to salinity changes. You could be living in fresh water and then suddenly end up in Salt Lake! As pressure changes may occur, oxygen levels may fluctuate, ecosystems may have floods and then drought. Tardigrades are equipped to wait out the storm or pressure. It could be boiling, excessive carbon monoxide, hydrogen sulfide, and nitrogen, or human created catastrophes like toxic waste dumps and oil spills. Tardigrades can live in a **cryptobiotic** state for a 100 year or more! Even ionizing radiation and toxins are not sufficient to destroy a Tardigrade's DNA. Tardigrades have been tested in vacuum of space as well and NASA may be drafting unsuspecting Tardigrade's for future space travel. **How did Tardigrades and other organisms end up with Extremophile adaptations?** Some bacteria and viruses can survive these conditions, and nematodes, a relative and food of Tardigrades exhibit some of these qualities. Over billions of years of periodic catastrophes and Earth's growing pains, early ancestral cells and organisms had to adapt. **Could prokaryotic organisms have transferred their genes to Tardigrades? Some say "yes" others "no." What do you think?**


Dehydration
LOW OXYGEN
PRESSURE
"Help - I'm under a lot of pressure... but I can take it."
I'm normally quite bloated... but something is happening..."
Someone buried this in my home in the soil...?"
RADIATION
"That didn't hurt at all!"
PROTECTED DNA
TOXIN
TOXINS


A TRUE EXTREMOPILE, INDEED . . .
How does she do it?
TARDIGRADES WERE HERE
. . . and the vacuum of space

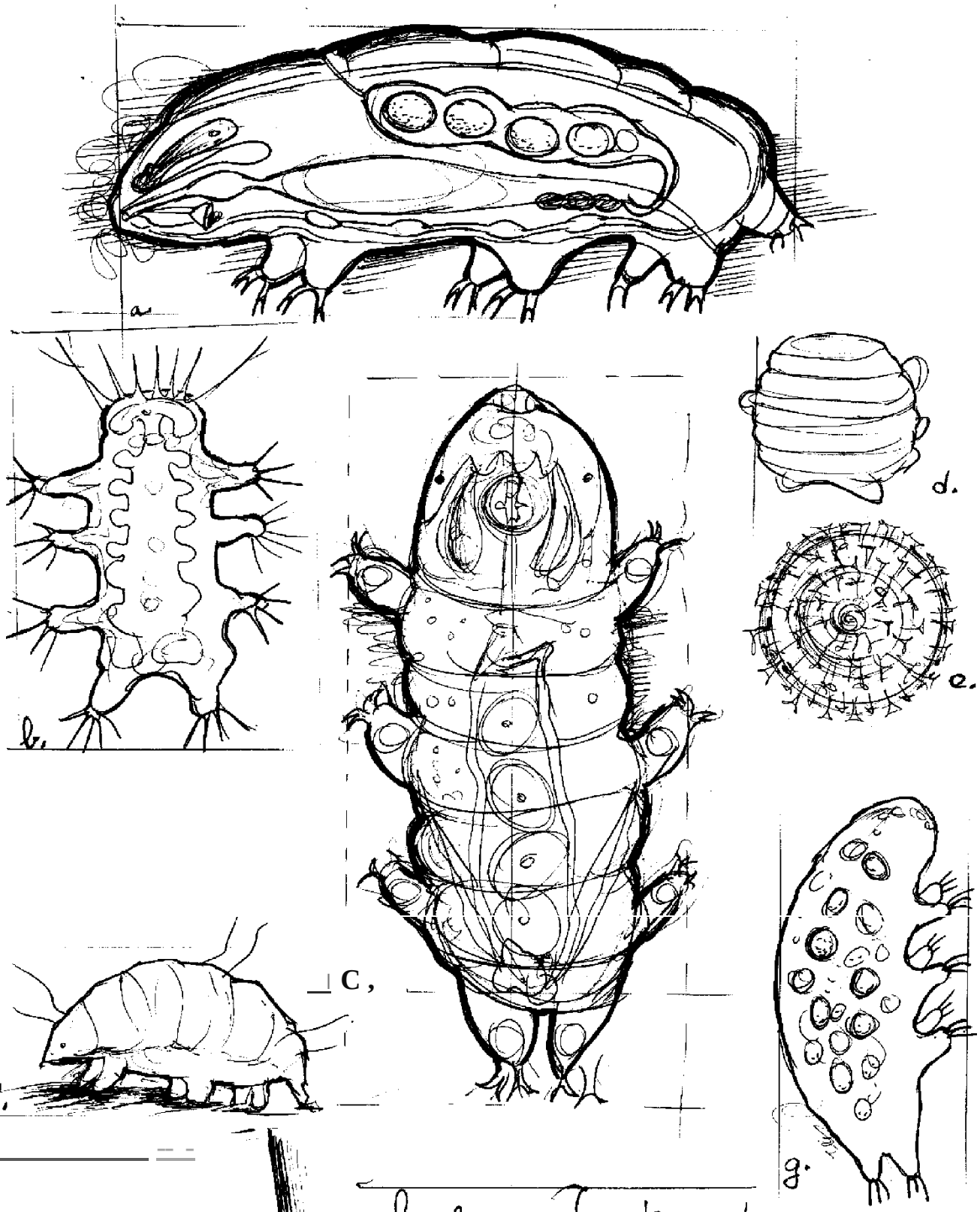
Notes

Got any ideas so far on Tardigradas?

What would happen to DNA under such extreme conditions?

Anatomy

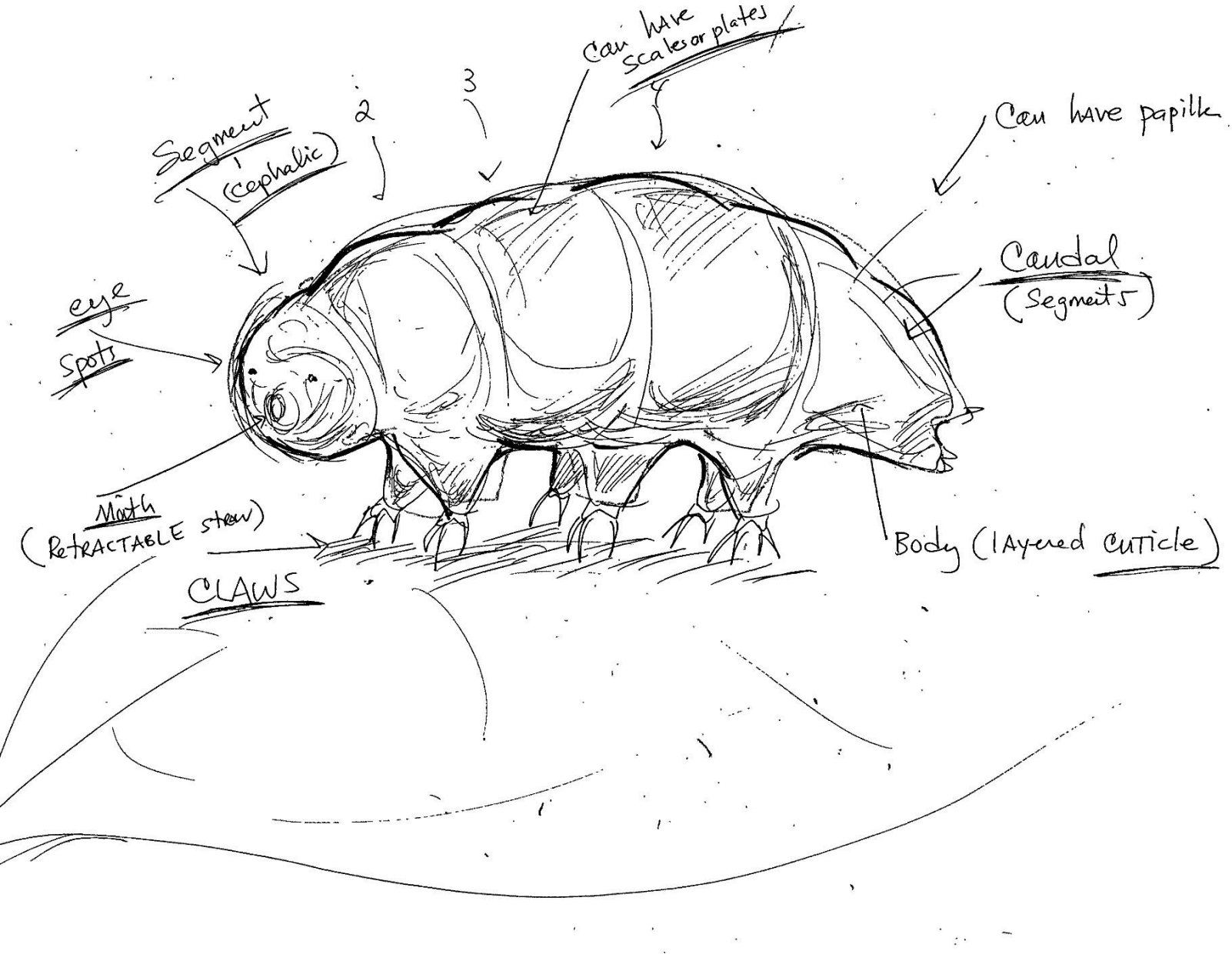
Tardigrades are bilateral animals, with a front end and a back end, a dorsal and a ventral side. They are also segmented with a cephalic end (head segment) and three trunk sections. Each one of these has a pair of **lobopod** legs. The little stumpy legs terminate in a variety of claw variation and the last segment (5th) is the tail end or caudal segment, with littler legs mostly so Tardigrades can at least hold on to their moss so they don't get swept away. There are male and female Tardigrades so they have sperm and eggs and they can carry out **parthenogenesis.** They also have external fertilization and can self-fertilize like a pea plant. They have a gut or full digestive system but no circulatory or respiratory system. **Why do you think they might lack a circulatory and respiratory system? Do they breathe through their skin?**
How thick is their cuticle? They look and act like larva going through molting stages (ecdyzoans). **How do you think Tardigrades get oxygen? How do they get their nutrients around and remove waste?** Tardigrades have no problem getting food, as they have complex mouth parts and well-developed muscles. And if there's no food to suck up, they can always enter a cryptobiotic state, which is kind of like an extreme diet. Tardigrade's have a brain and a ventral nerve chord with ganglia in their little lobopod feet and little eye spots to detect light. Not too much has been said about their other senses, like olfaction, gustation, and hearing. **What might you infer about their other senses? Are they reduced or enhanced?** Externally they can also have scales or plates and little sensory structures called Cirri.



phylum Tardigrada

Notes

What kinds of genes give Tardigradas segmentation?
They seem to have a 3 major sections,
Who would that make them related to- you?



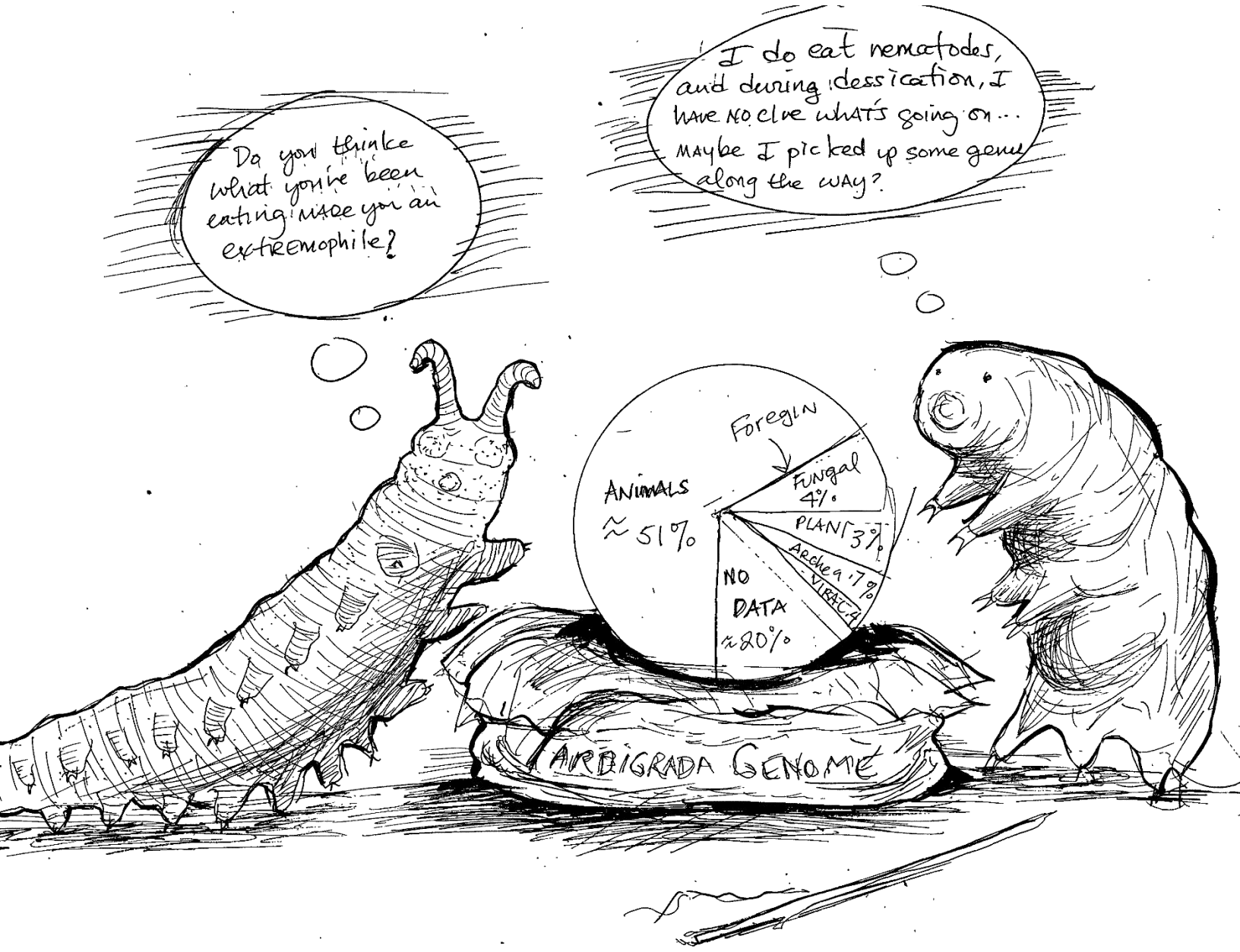
Outer anatomical detail including characters like **claws, scales, mouth parts**, and **papillae.**

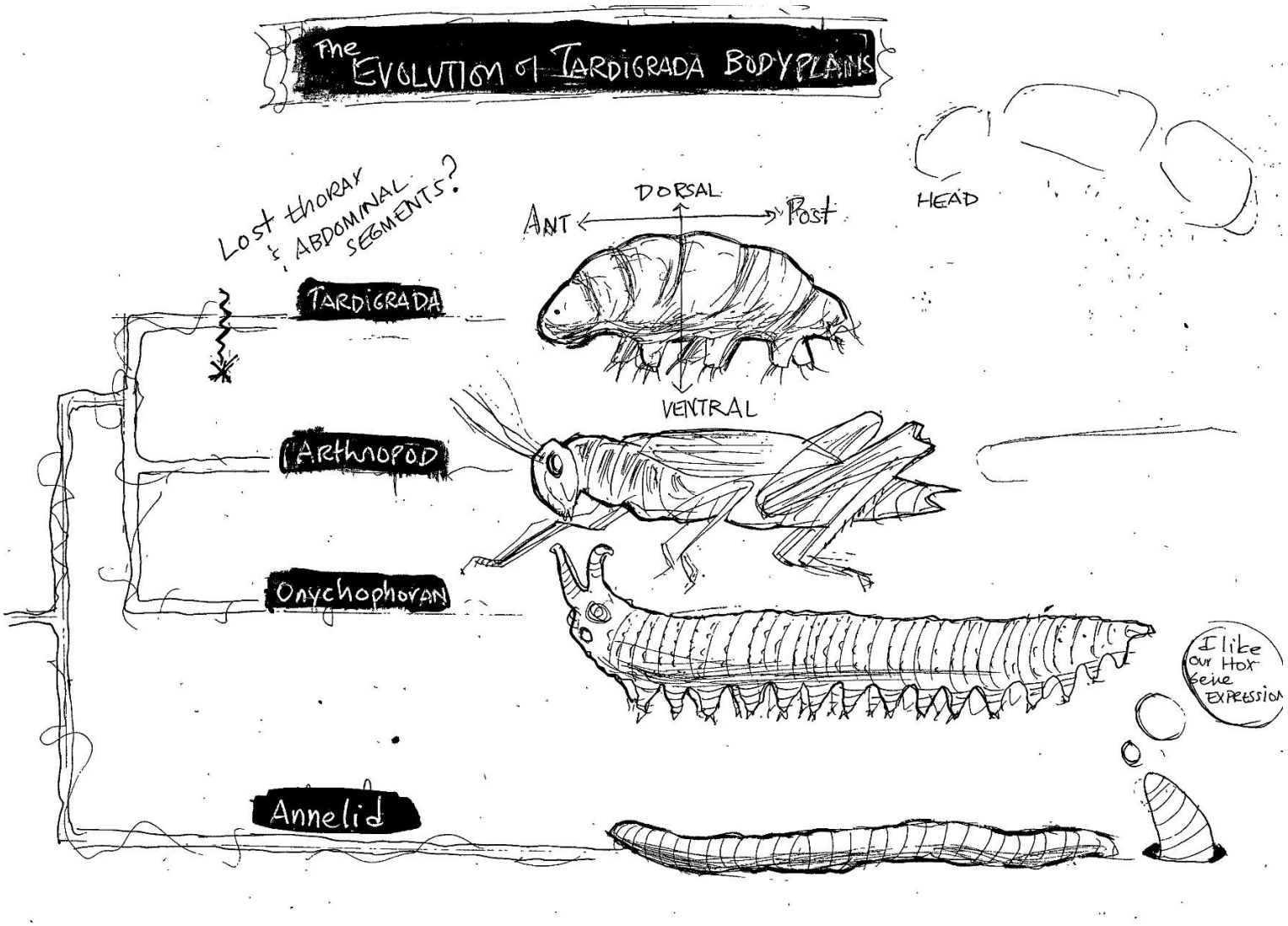
These are important ***morphological characters.***

Notes

To preserve DNA and its life, Tardigrades can enter into an almost "death state," where they expel the water from their bodies. This is called a TUN.

Why is eliminating water important to entering into desiccation- seeds do it all the time?


Do you think what you've been eating made you an extremophile?
I do eat nematodes, and during dessication, I have no clue what's going on... Maybe I picked up some genes along the way?
Foreign
ANIMALS ≈ 51%
FUNGAL 4%
PLANT 3%
Archea 1%
VIRAL ?
NO DATA ≈20%
TARDIGRADA GENOME



Body plans: Losses and Gains in Tardigrade

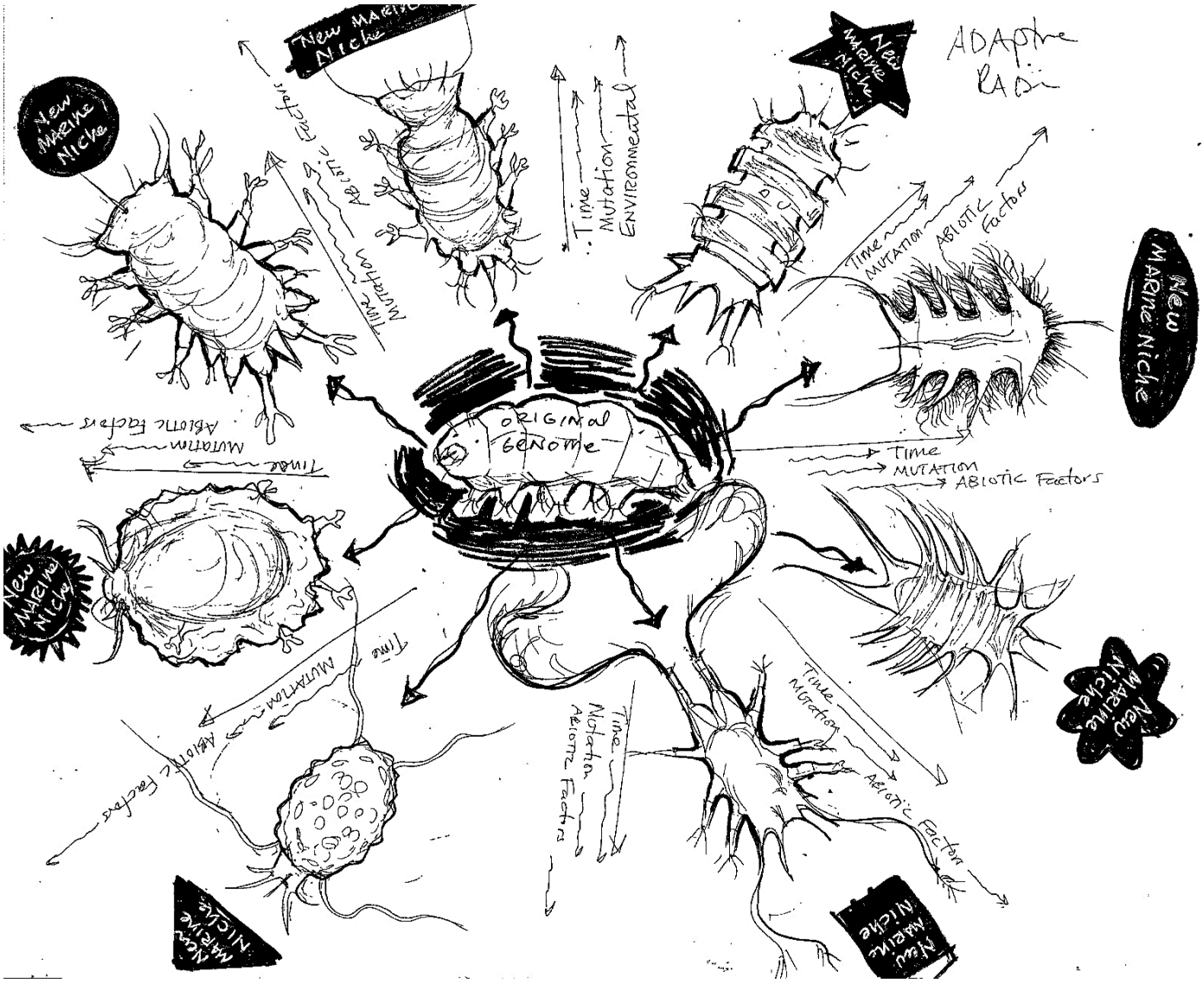
The debate about who Joe Tardigrade's relatives continues. Annelids and arthropods all have segments, which they picked up in the Cambrian period. This "explosion" of body types was built on the sudden appearance of segmentation and Nature's way to create a variety of body plans. Joe was one of many unique and innovative animal pioneers. In fact, Tardigrade's closes relative, the Velvet worm (ochonoyphora) has many, many more segments than Tardigrade, but it still might be related to annilids.

Some research suggests that Tardigrades lost their middle, that's right, they may have lost their abdomen and thorax- but why? And how? There are sets of regulatory genes that specify a tissue pattern in a repeated unit called a "segment."
Tardigrades have five HOX genes just like the velvet worms but velvet worms have so many more segments. How did that happen? Did something get duplicated? You can make a flip book later on that reveals changes in mouth parts

and the eye (at the end of this workbook) but you can make a flip book about any evolutionary change, including the loss or gain of segments. To lose segments you have to lose genes or they have to be sort of turned off from producing their proteins. You don't always need a lot of segments. Tardigrades ended up doing pretty well without extra segments.

Notes

Can you develop a hypothesis for why Tardigrades evolved the way they did?

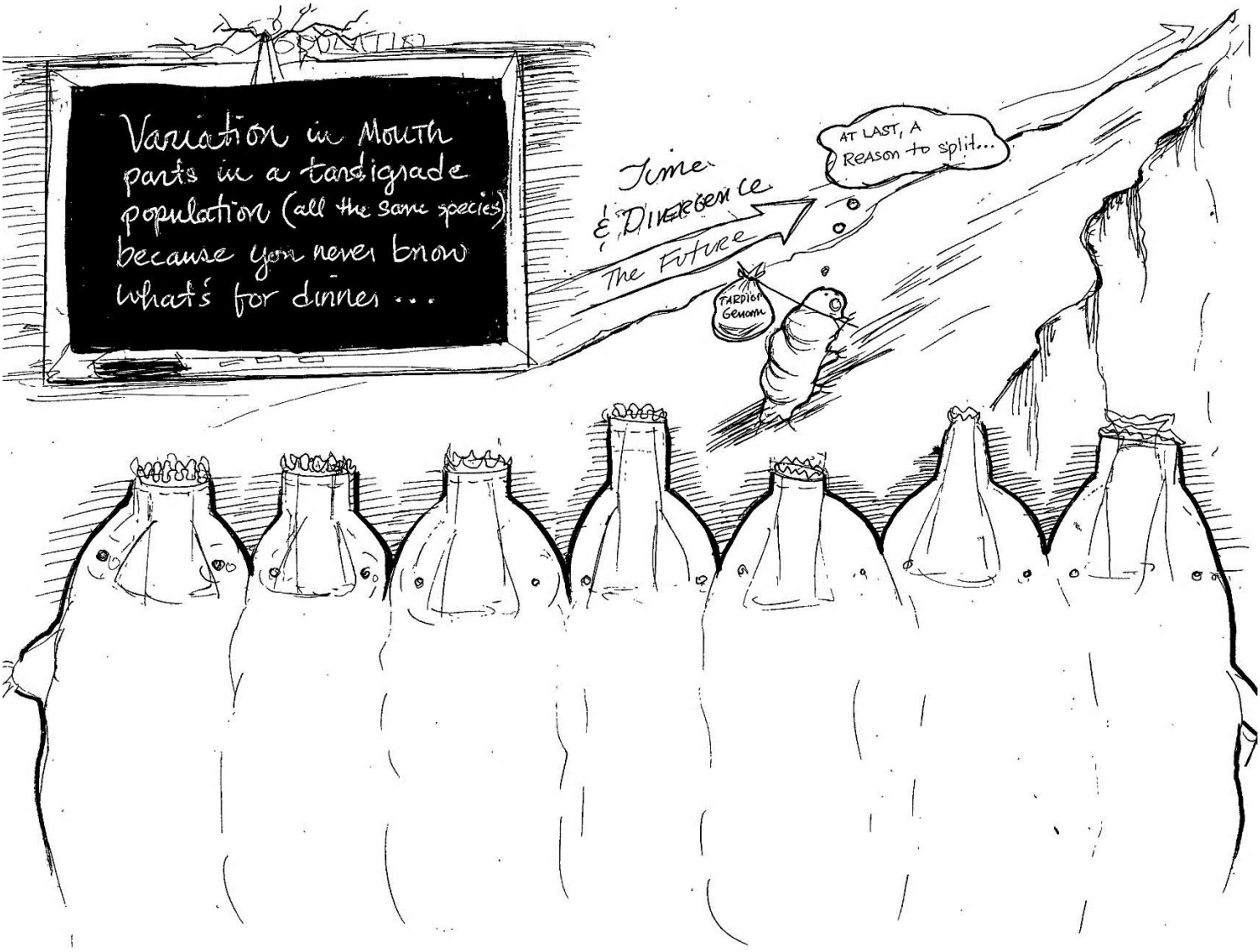


Speciation

Tardigrades have been described as having somewhere between 800 and 1,200 species. Their distribution throughout the planet may be due to their extremophile potential is locked in their genome or somebody else's genome. When new places provide new opportunities, the genome of the Tardigrades can expand and evolve. This is called "adaptive radiation." This process of expansion and change in populations over time is often illustrated as species radiating out to fill new niches. The class Heterotardigrada is a family that has diverse and unique looking Tardigrades. From their original founding population, they have come to modify their claws, body scale, sense organs, and appendages to adapt to marine life. They thrive throughout marine environments and have adapted spikes, body size, mouth parts and cuticle. **If you were given a Tardigrada to adapt to new environments, what kinds of structural and physiological changes would take place?** A few pages from here and you will get

a chance to imagine what anatomical, behavioral, and physiological changes would suit your hypothetical environment. Suppose Tardigrades ended up in your gut, what might happen to them and you? Superpowers? A stomach ache?

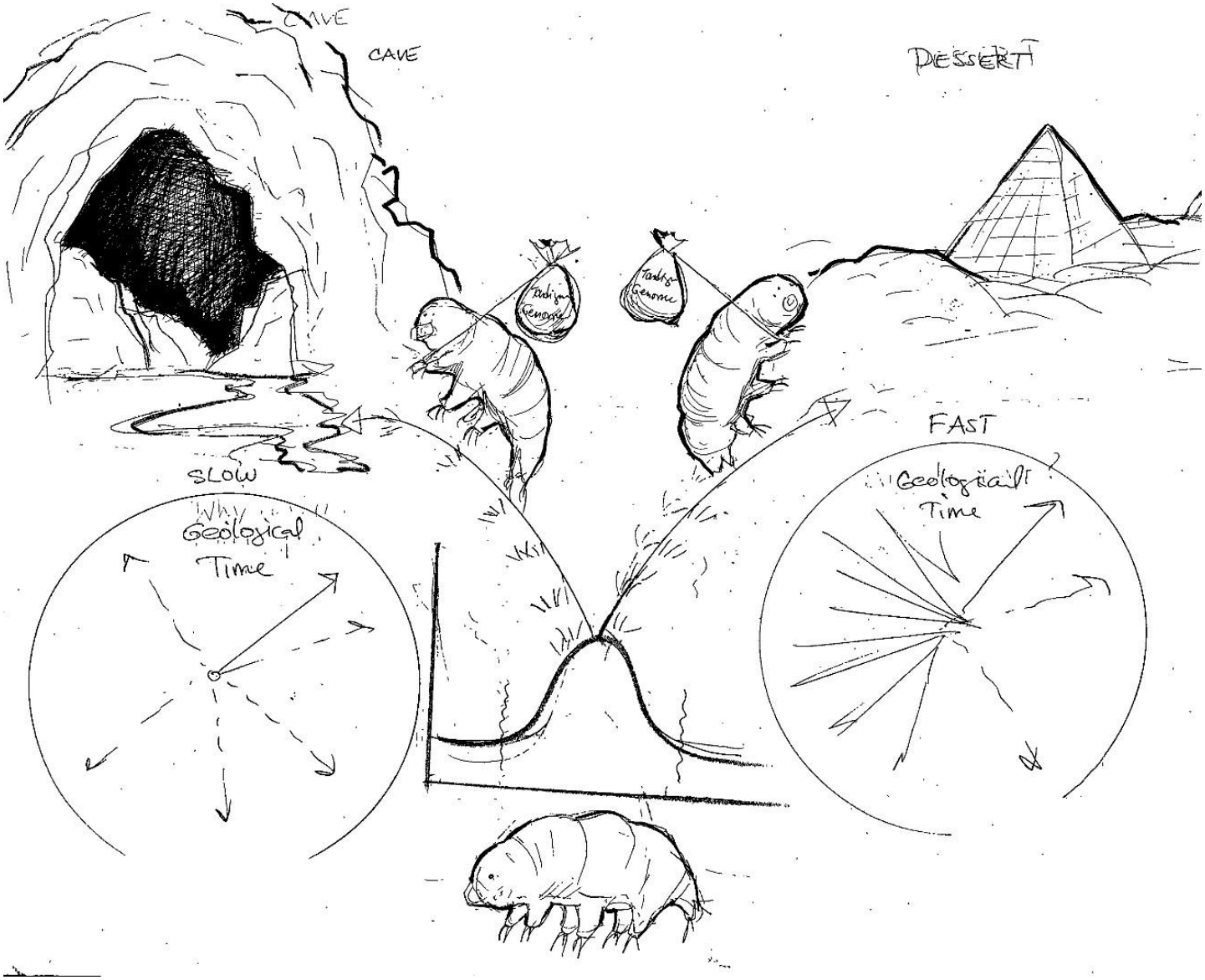
In evolution, they have split from the original population and diverged into new forms that best suited the new conditions or places, with help from random mutations.

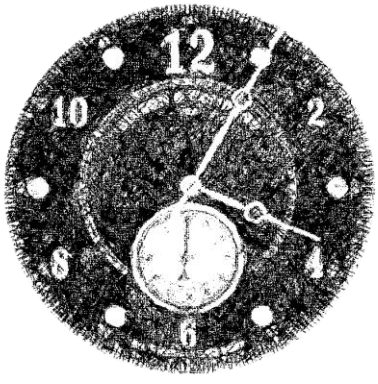


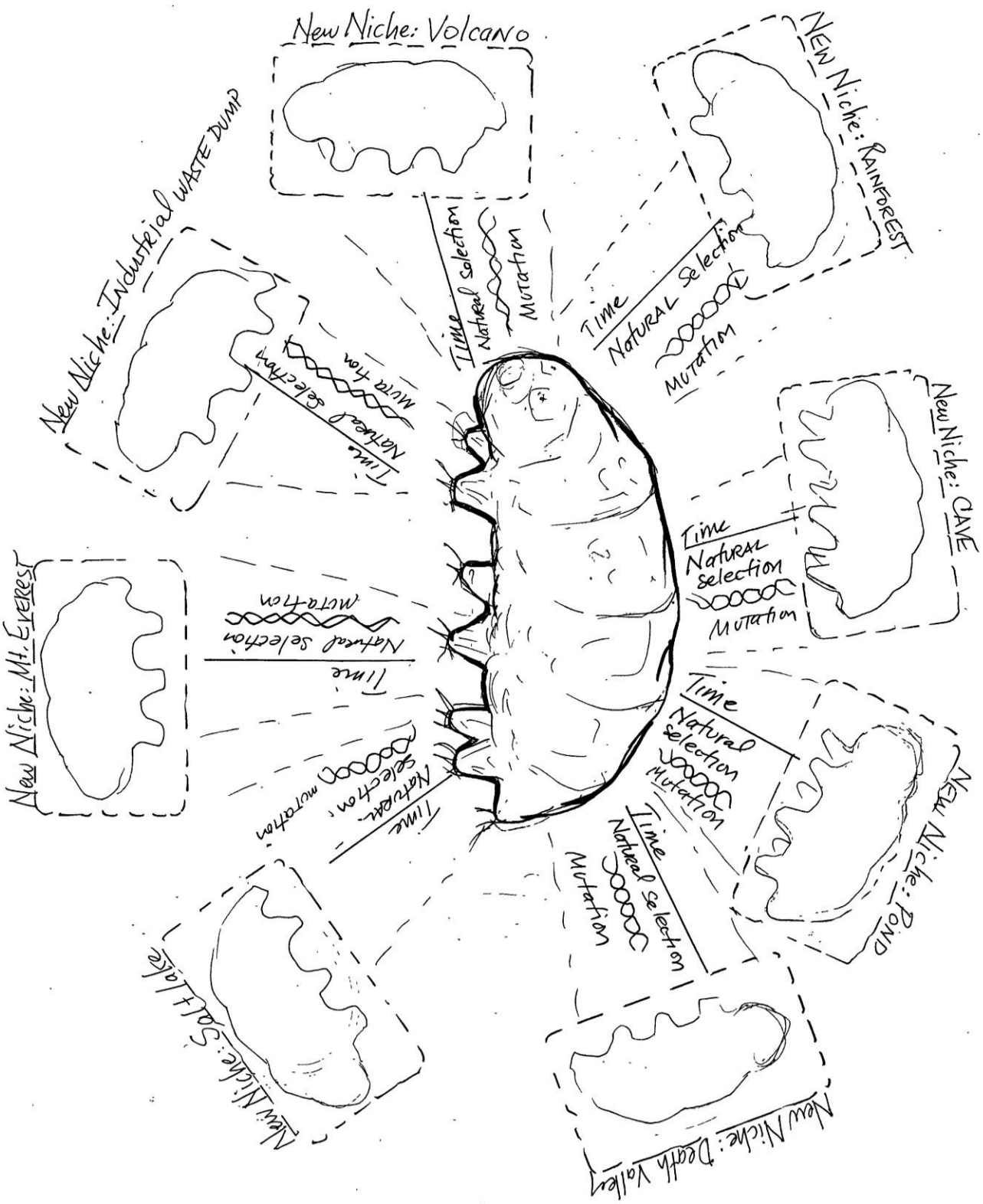
Variation in a population…

Different claws on different species- and among species there is variation

Why and how did so many Tardigrada species come into being?

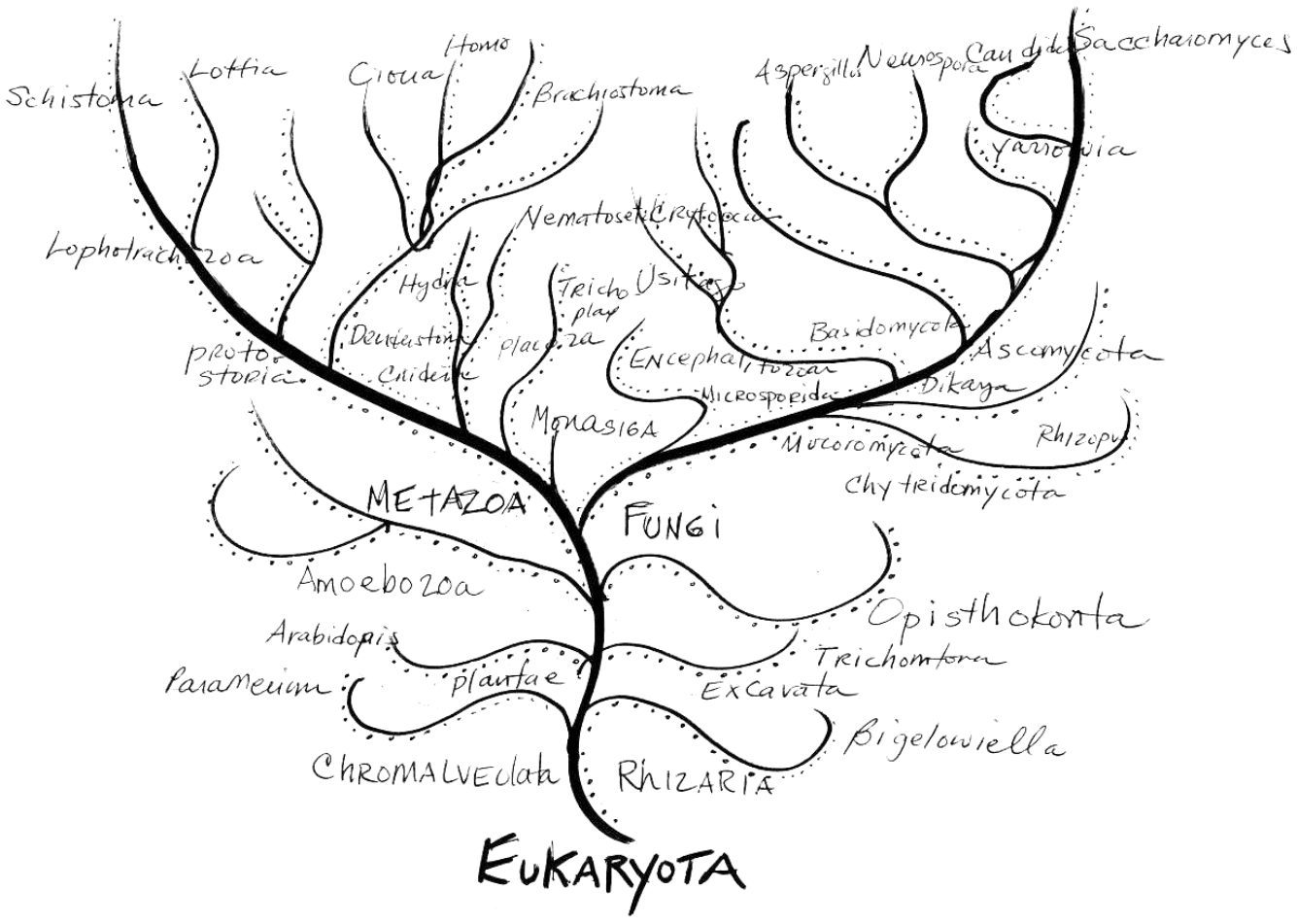






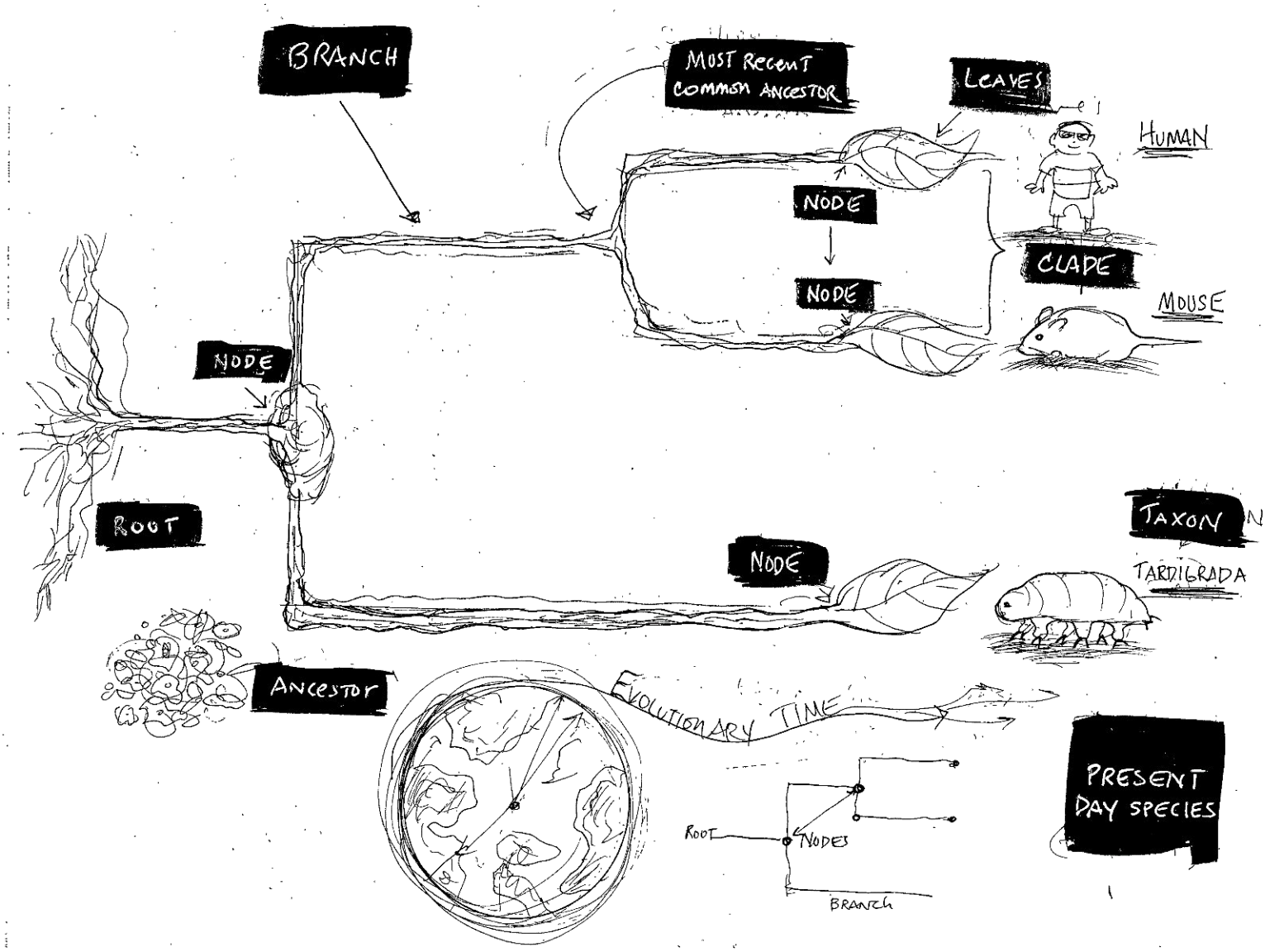
Here's your chance to **speciate** a Tardigrada

Notes



An Evolutionary Tree shows relationships

Phylogenetic "Trees" are visualizations that help organize relationships in time and they help place all the diverse species, which just keep diversifying…



The Tree of Life and Tardigrade Time

Trees are a way of organizing information about living things. Typically, lines are drawn showing an ancestor and descendants. Time is represented from the time of the ancestor to the recent species. Trees help show relationships between different organisms. For Tardigrades, questions still remain about its relationships. In some ways, water bears resemble annelid worms and in other ways they seems more related to arthropods. If th tree is just of a species, then it's called a "species tree." The trunk of the tree is called the "root."

The linage of Joe Tardigrade as we have seen is pretty old going back some 600 million years in the Precambrian. In some books Tardigrade was simply classified as "unclassified," a maverick in the taxonomic world humans created. In the theater of the Cambrian explosion, body segmentation took center stage and the dress rehearsal for the future of Tardigrades may have already included HGT, equipping Tardigrades with their extremophile genes and allowing them to sustain themselves over the periodicity of dramatic natural changes or it could be that Tardigrades just evolved a cool way of scrambling their own DNA. It could also could be both and mechanisms unknown.

The naturalists that study organisms use their anatomy, life cycles, embryology, molecular data, and along with the fossil records, they attempt to reconstruct the past. For Tardigrades, some of the characters used to identify differences and infer relationships included their complex mouth or buccal structures, their claws, which vary in populations and among species, reproductive parts and other structures. This information can be used to understand their lifestyle, that is, what they feed on and where they live and of course their evolution. The cuticle is important for Tardigrade as well, as holes called aquaporins can let water in and out, this is important for an organism who lives in freshwater and marine environments. Let's face it, if your mouth works like a retractable straw, you're not going to be chomping on tortilla chips! You could suck some sap, and if the conditions change, you could even turn that mouth-straw into a parasitic harpoon and start sucking on some blood! Body plates, spines, spurs, as well as reproductive parts are also characters used to identify and observe variation and change. **What characteristics do Tardigrada share with Nematodes? Arthropods? With Annelids? Can you list them- and then draw them?**

Which of these looks like it could be a Tardigrade trait?

Crossed muscles **Circulatory system**

Round muscles **Straight nervous system**

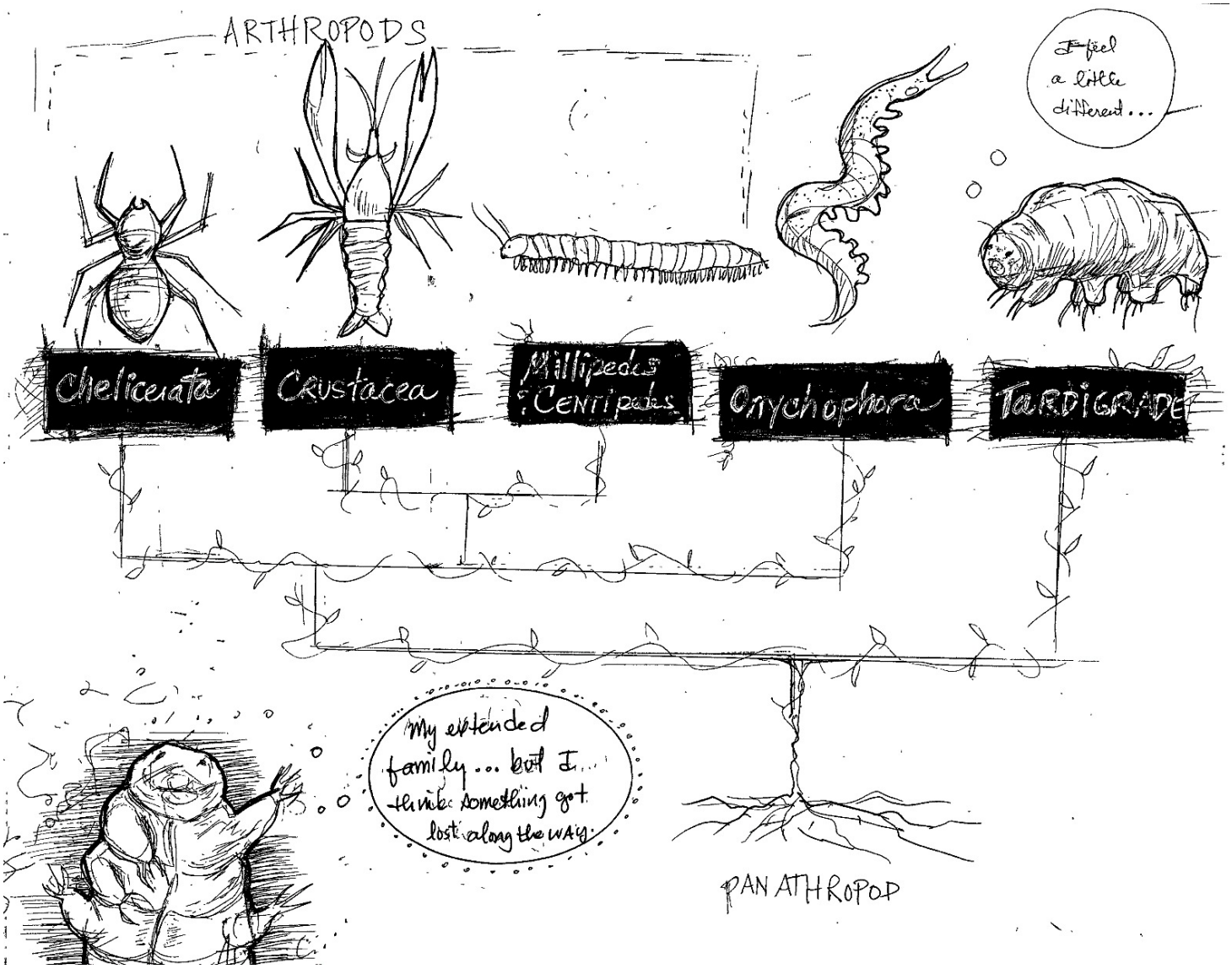
Chewing mouth parts **longitudinal muscles**

Ladder like nervous system

Sucking mouth parts

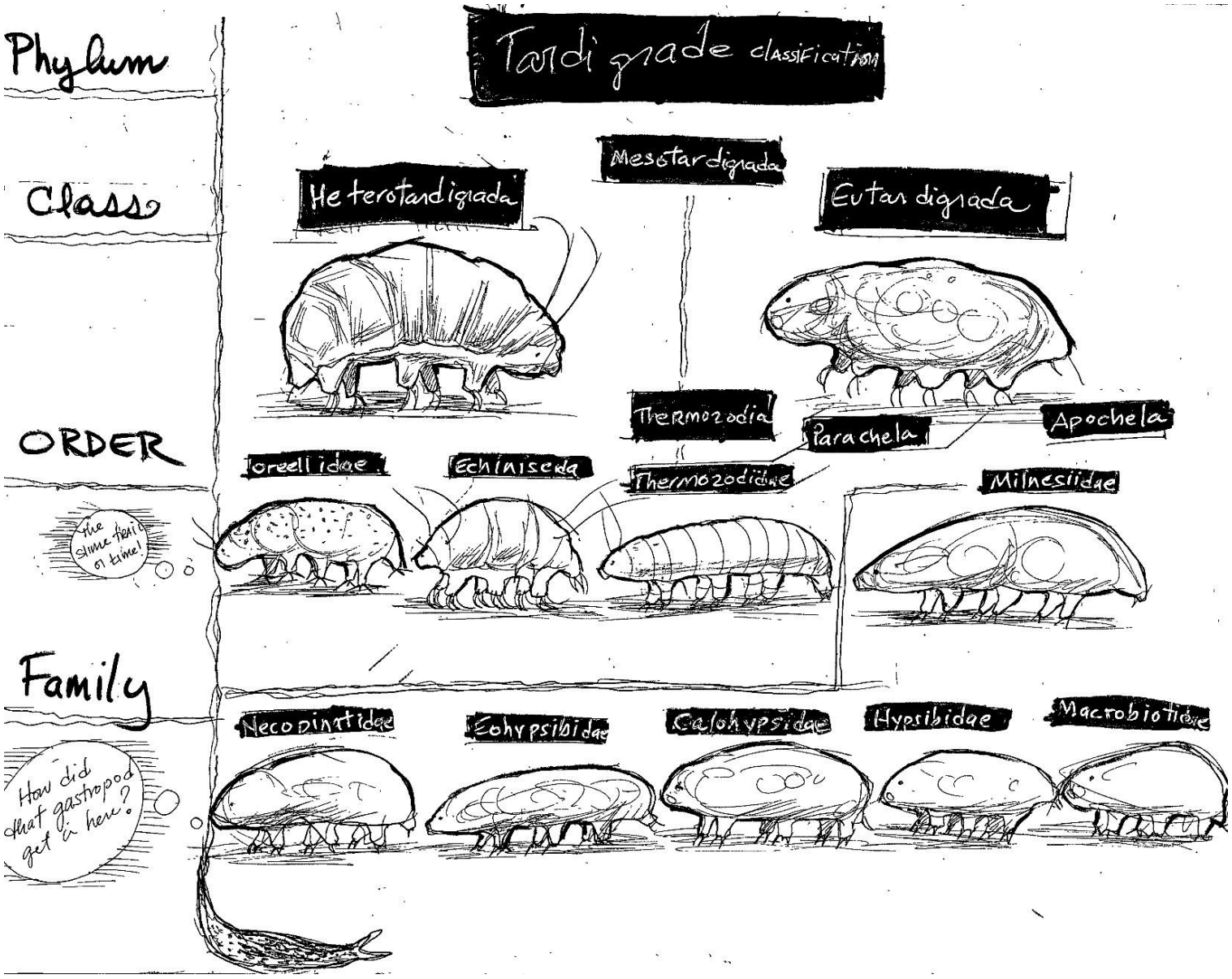
No legs

Legs



Respiratory system

Remember Tardigrades also are classified as Metazoans (animals) and as Ecdyzoans (molting) organisms so there are lots of different labels for them. Within the animal grouping, they are protostomes with mouth development first and anus development later. In human descriptions of a "place" for Tardigrade, we also put or lump them in with the arthropods (insects, crustaceans, ticks, mites) and other protostomes and then we call that ancestor a "pan arthropod."



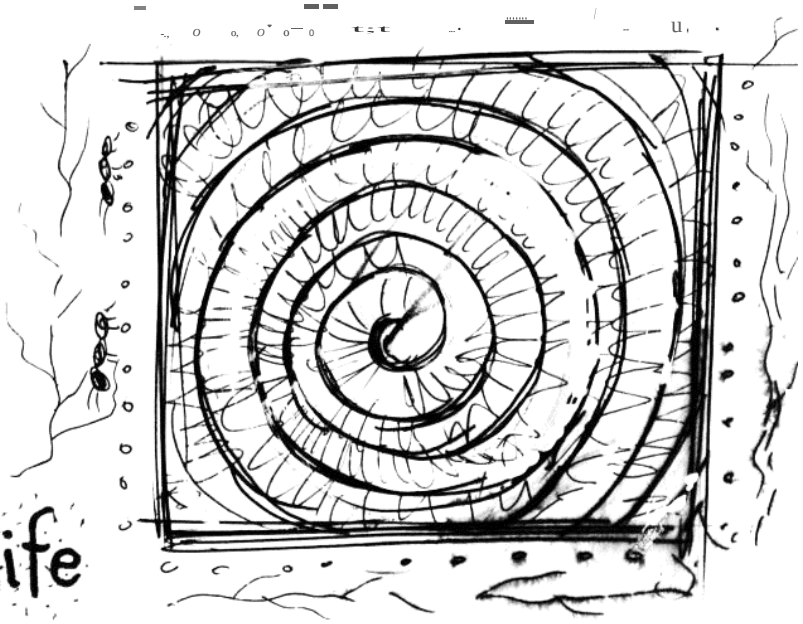
Phylum is another catagorization where we position or order Tardigrades. The next level "class." includes Heterotardigrada and Eutardigrada. There are several families, and then the most inclusive grouping; Genus and Species. The classification of Tardigrades is based on morphological and molecular studies using 18s rRNA. The close relatives of Tardigrades, the Arthropods, and the Onychophorans make up the Pan Arthropods we talked about earlier. The hierarchy helps us organize them, but the Tardigrades and others like them are rather caviler do not care what we think. Interestingly, while there are 2 classes there is a dubious 3rd group has remained elusive as it was found in a hot spring in Japan and the hots spring was destroyed by an earthquake!

TIME TREE OF LIFE

The Time Tree of Life and Joe T.

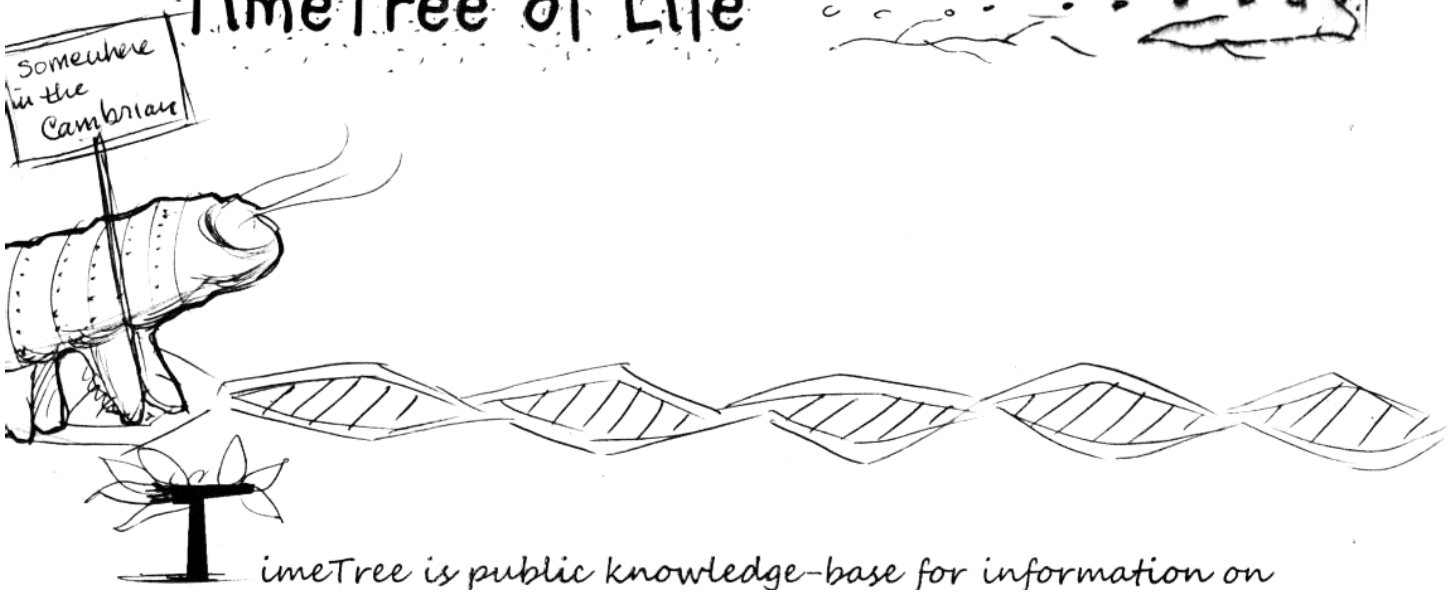
Our buddy Joe Tardigrade is such a fascinating fellow he invites us for continued exploration. In the TTOL you can explore the relationships in geological time that we've been discussing. While the TTOL database does not contain data from extinct relatives of Tardigrade, it does have its extant, closest relatives, and different classes of them. The TTOL is constructed from a wide range of research, allowing you to search all sorts of organisms. So if some lab somewhere was studying Tardigrades their studies might be in the TTOL. The TTOL can help you think about their relationships and develop a pattern of thinking about time and space on our planet. Change over time is a rule of Nature and reveled in relationships and the patterns of Earth's evolution. Some organism like the Tardigrade have life spans and properties that defy our concept of time, in fact the geological time of the planet is often outside our scope of conceptualizing time. It's easy to talk about billions of years, but we have no idea what billions of years feels like. It's challenging to try and imagine that much time. Try it out, what would it feel like to be around for say 1 billion years? Or 500 million like the Tardigrade? What other fascinating qualities can you discover?

In the next couple of pages, color and explore the TTOL with some simple exercises and form some of your own conclusions about Tardigrade:



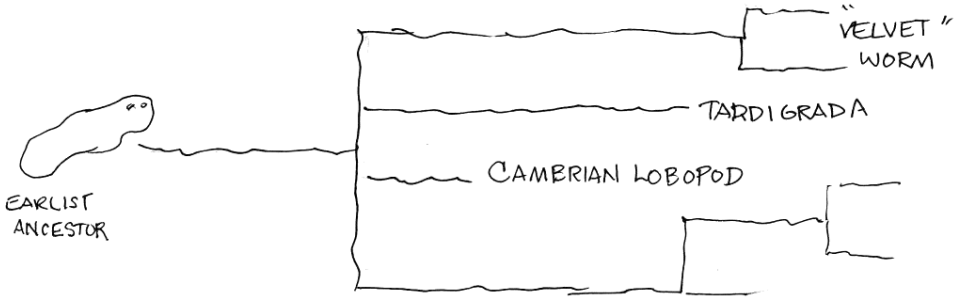
SEARCH . . .

TimeTree of Life

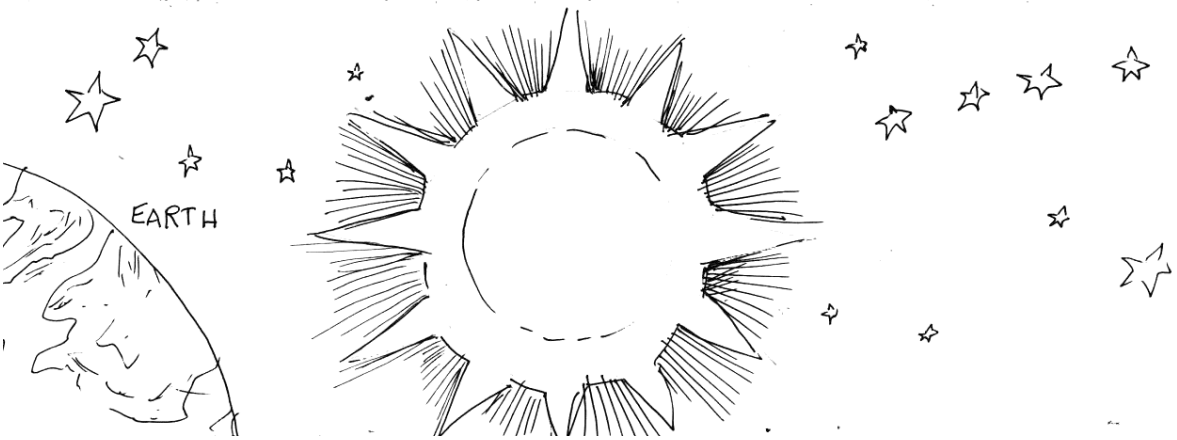


TimeTree is public knowledge-base for information on

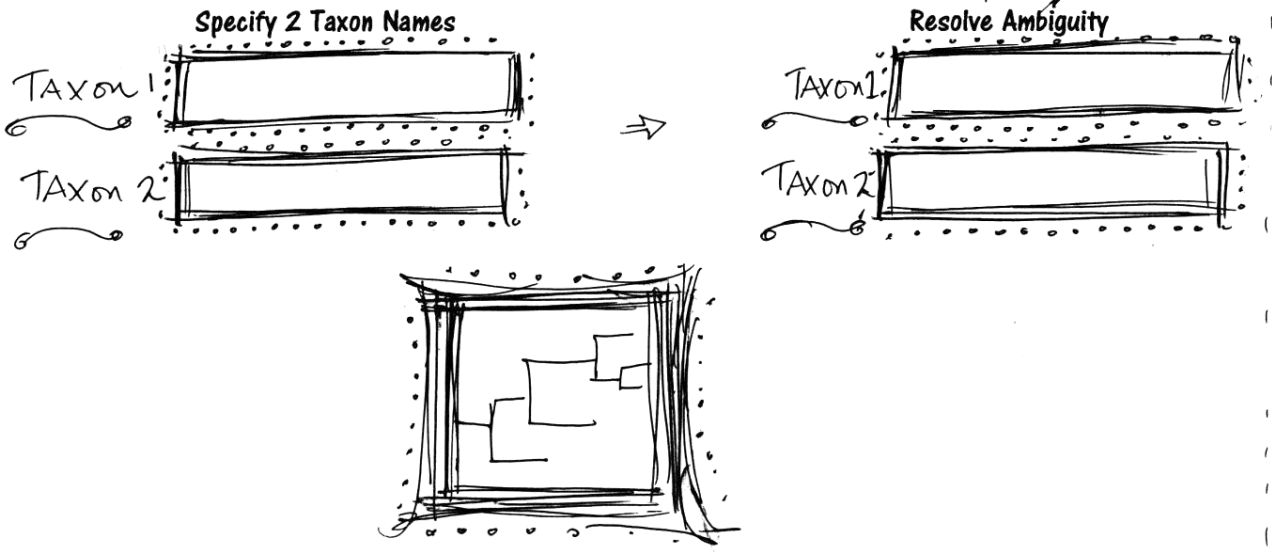
1. **NODE TIME:** to find the divergence time of 2 species or higher taxa
2. **TIMELINE:** to drill back in time and find evolutionary branches from the perspective of a single species
3. **TIMETREE:** to build a timetree of a group of species or custom list



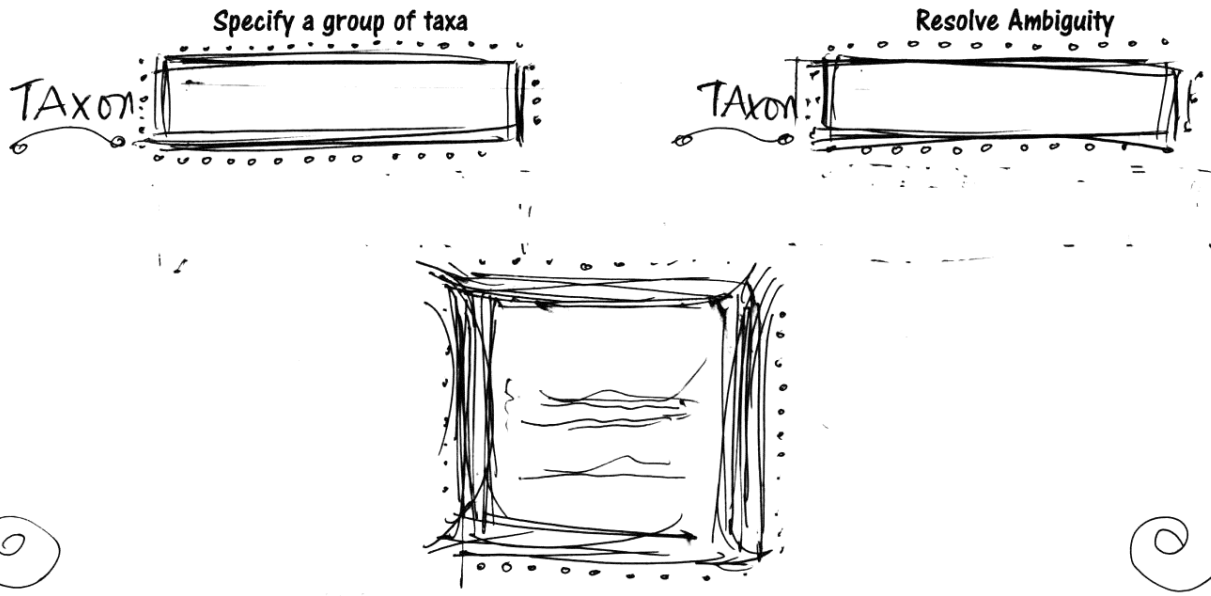
TimePanels: showing events in geological time and astronomical history are provided for comparison with timelines and timetrees. Results can be exported in a different formats for additional analysis and publication.



Get divergence time for a pair of taxa



Get an evolutionary timeline for a taxon



Build a timetree . . .

Specify a group of taxa

GROUP

Resolve Ambiguity

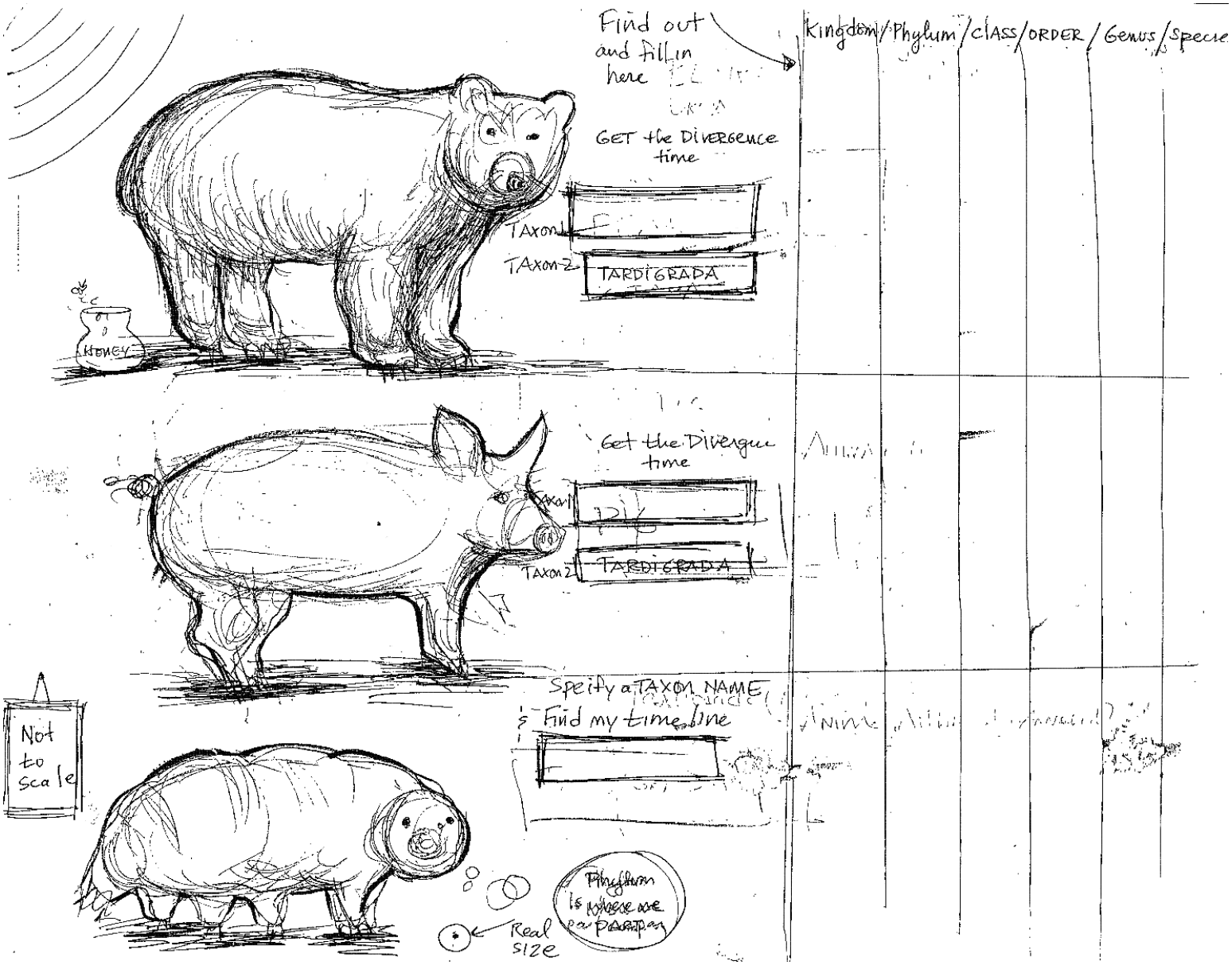
GROUP

OR . . .

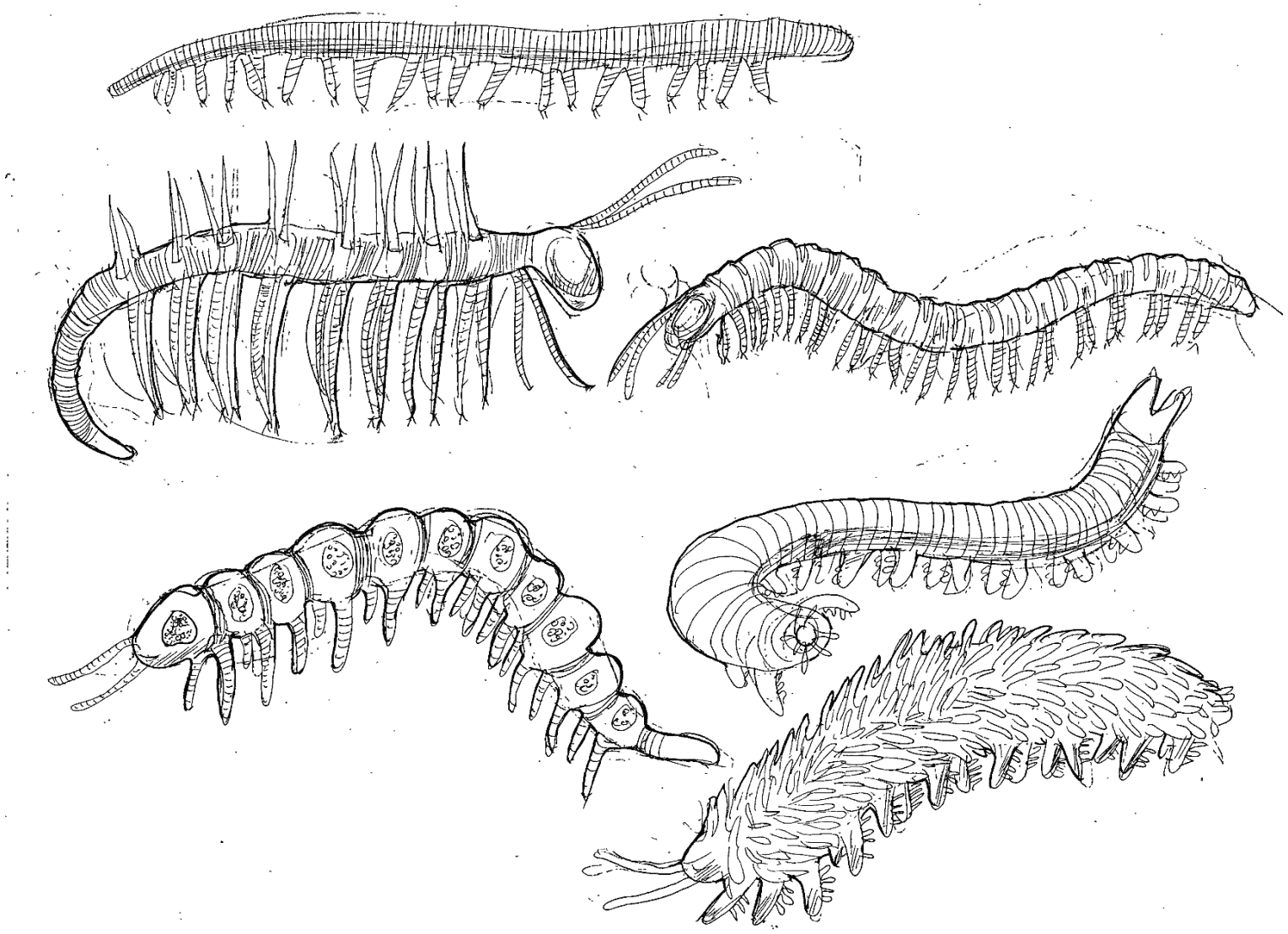
Or Load a list of species

UPLOAD Browse

Notes



Compare, just for fun, bears, pigs, and Tardigrades



What is Speciation??

The future of Tardigrades

Tardigrade, in the classical system of taxonomy, the "old" order would start with Kingdom and would be animals just like us They also have their own Phylum, Phylum Tardigrade, but what if they were to diverge due to climate change? What if new molecular events pointed to a different taxonomic affiliation? What if a catastrophic event took place? Would we still be still calling them Phylum Tardigrade? Would we still be here to call them Tardigrade? What if new mechanisms of tolerance of extremes in environments emerge? Can Tardigrade tolerate our plastic pollution? Many species cannot. What if we find a unique metabolism with sugars and DNA repair mechanisms that don't exist in other animal phyla? What if Tardigrades break down plastic long after we've gone extinct? What if we find that disordered proteins actually confer a benefit to desiccation and to survival? What if Tadigrade biology changes the way we think about biology? We may marvel and Tardigrades and seek to learn the secrets of their distinctive genomes and perhaps imagine immortality, but what if we just come to learn one thing, what if we learn that simple, little living things are more complex than we could ever imagine? Maybe we would care more about the planet and the life that's part of it? Maybe that's the real lesson.

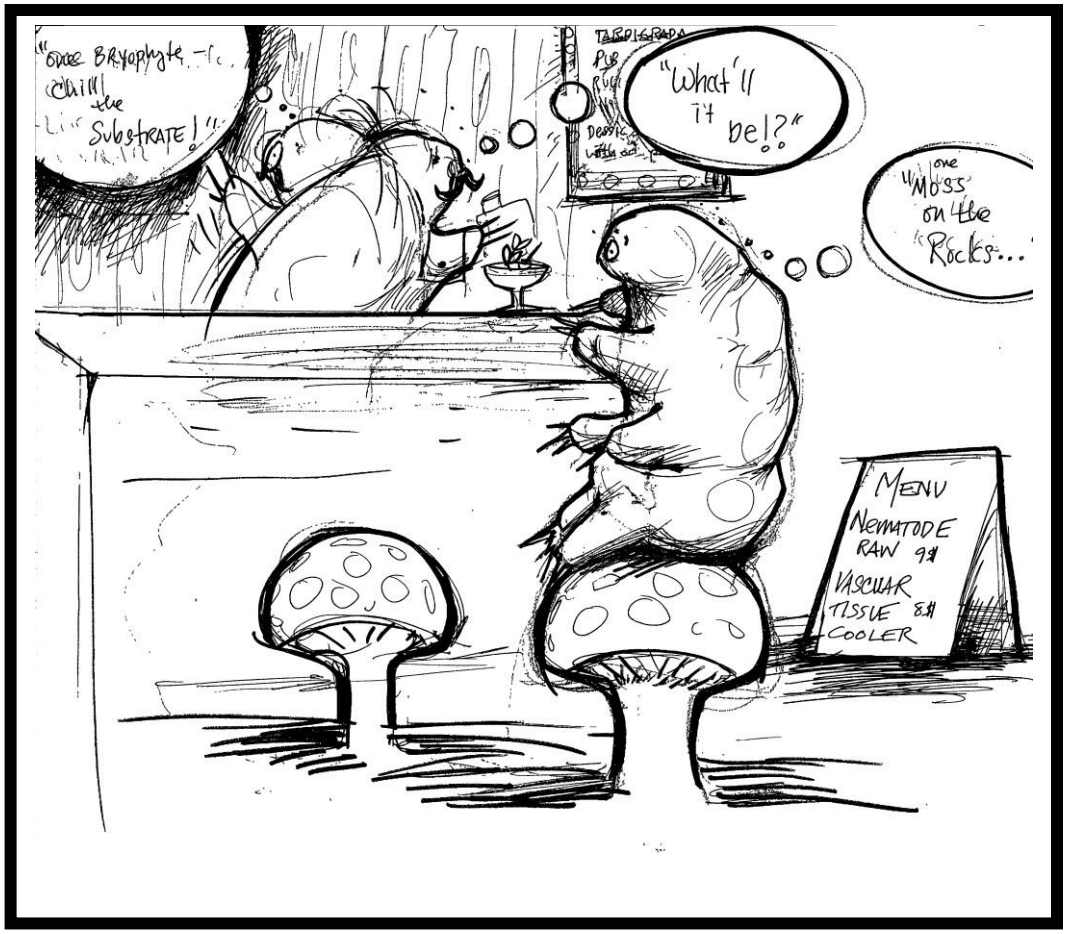
The idea of a species is a fuzzy concept in biology, as organisms in a population change, adapt, and modify, ebb and flowing with whatever changes they encounter. A species is like an out of focus, elusive, fuzzy, in motion shadow. Tardigrades are no different. For Tardigrades, species would mean they could not breed with another species and form viable, living, offspring and those offspring would be able to reproduce. With parthenogenesis and hemaphrodism and possibly other variable modes of reproduction, a species may be difficult to define- but that's what we love about Tardigrades, their complete ambivalence to being pigeonholed and classified- they like to remain undefined!

Sugars like Trehelose may hold clues to Tardigrade evolution, proteins sequencing, and new species are always evolving but if you're genome is potpourri of genes that are scrambled and changing, you are presented with a challenge in the classification department.

We can say that in classification, there are living (extant) and nonliving (extinct) organisms and at some point, most living things become extinct, certainly Tardigrades will certainly be here long after we are gone.

Notes

Drawing Tardigrada & Evolution: For Self Teachers & Self Learners



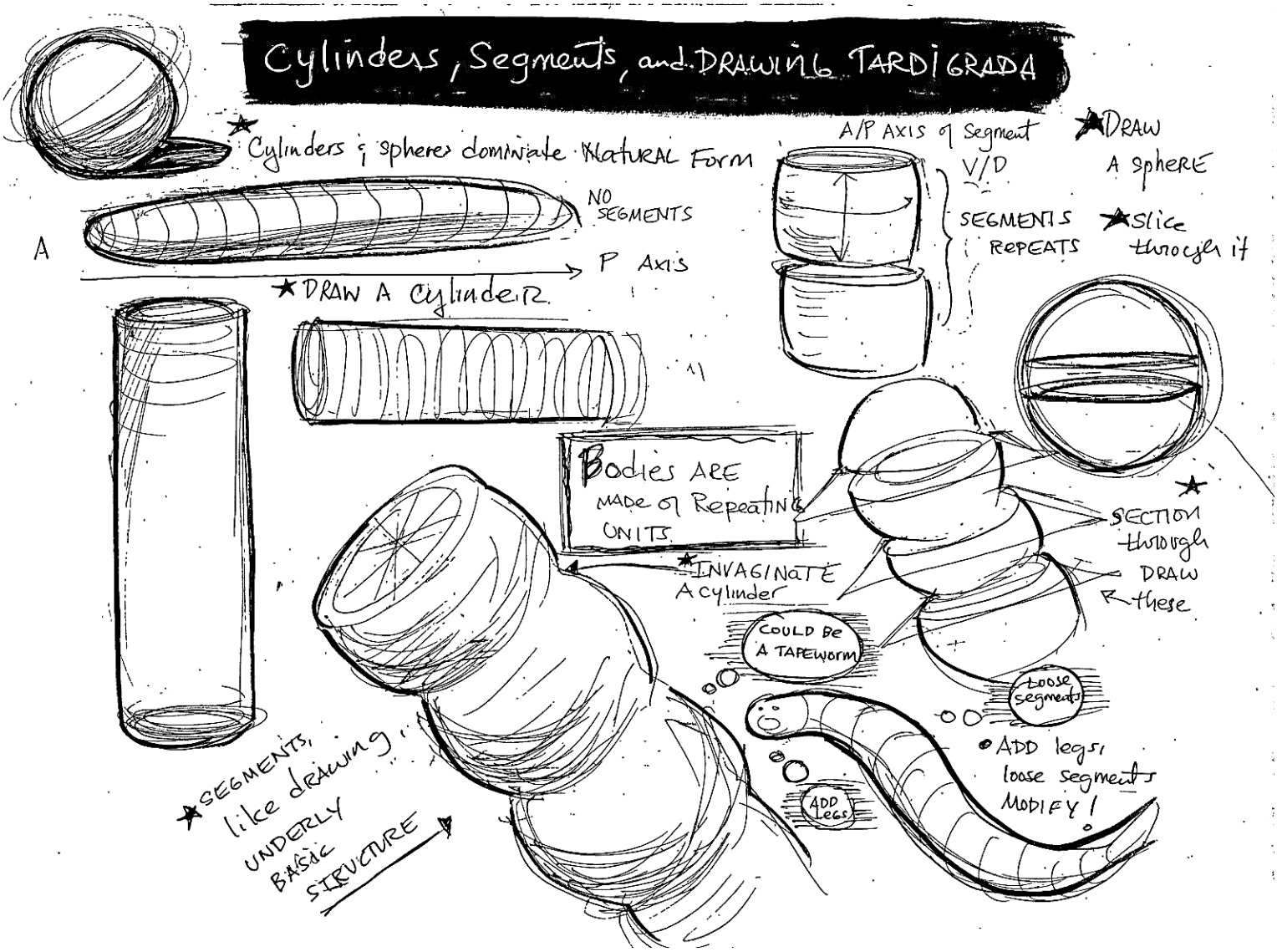
Drawing Tardigrade

Learning about living things would not be complete without observing and drawing them. Studying living things is deeply rooted in our ability to observe patiently. Biologists used to draw a lot, they used drawing to study forms, variations, and appearances. Drawing can be viewed as an extension of your memory and haptic systems (touch). It doesn't matter if you think you can't draw, *because you can!*

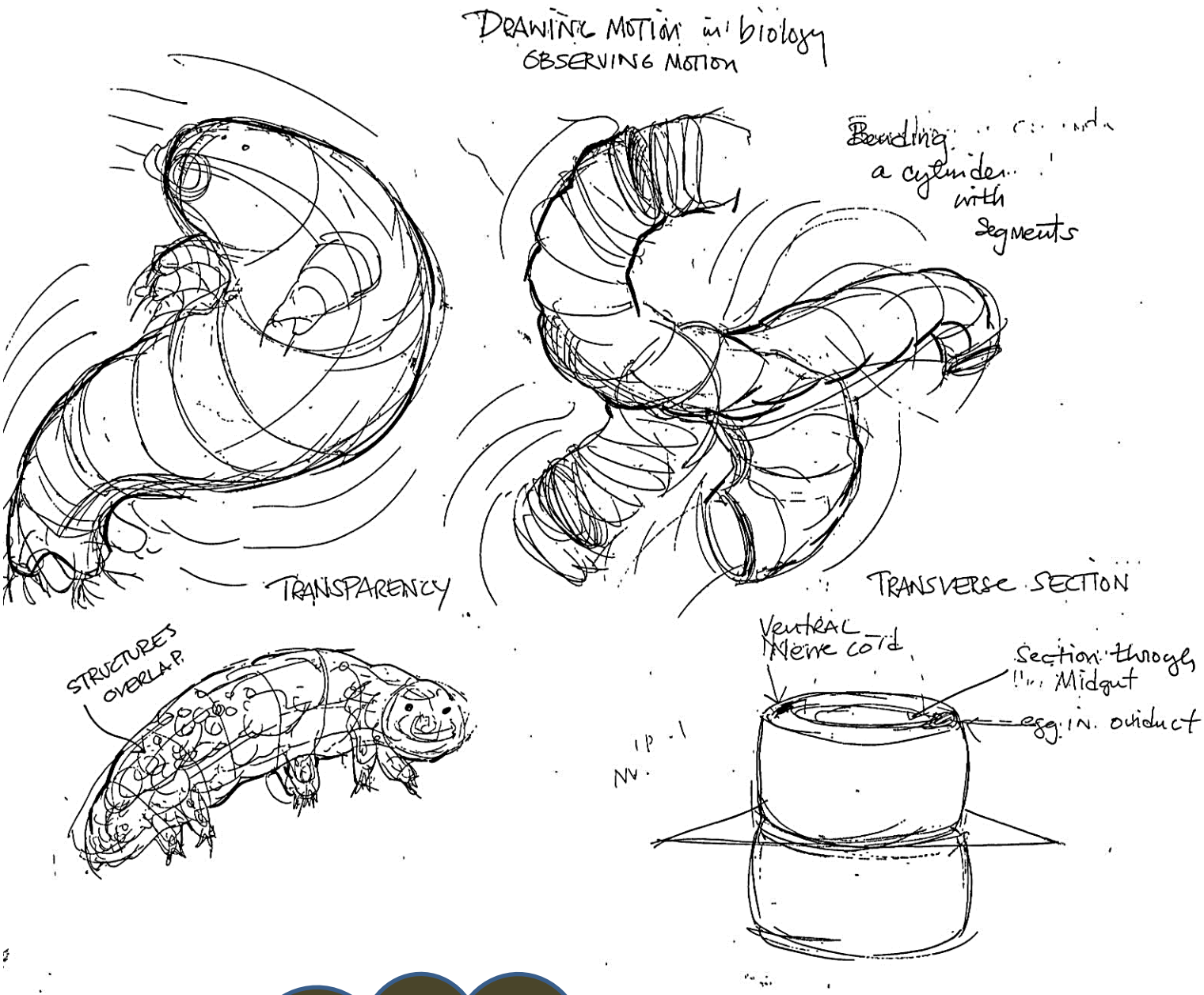
Interestingly drawing allows you to reduce the complexity of something to simpler components upon which it is built and then reassemble them. It helps in organizing your thoughts. For example, the basic segments that form the animal body also can represent the basic units you draw. Drawing can recapitulate biological concepts to in your memory by allowing you to virtually dissect ideas on paper and build from simple to complex. So, let's start with some simple pages and then build to more complex. In no time at all you will be drawing Tardigrades.

If you've gotten some pond scum, moss, or classroom/lab has been housing a population of Tardigrada, then you can easily observe them under the microscope (you can put them back in their home too). The excitement mounts when you try to find a Tardigrade and then draw it. Some key things to remember are if you practice drawing frequently, it will become easier to draw and observe. Trying to draw something alive and moving is more challenging then drawing from a picture or something that is dead- in the case of Joe Tardigrada*, not quite dead.*

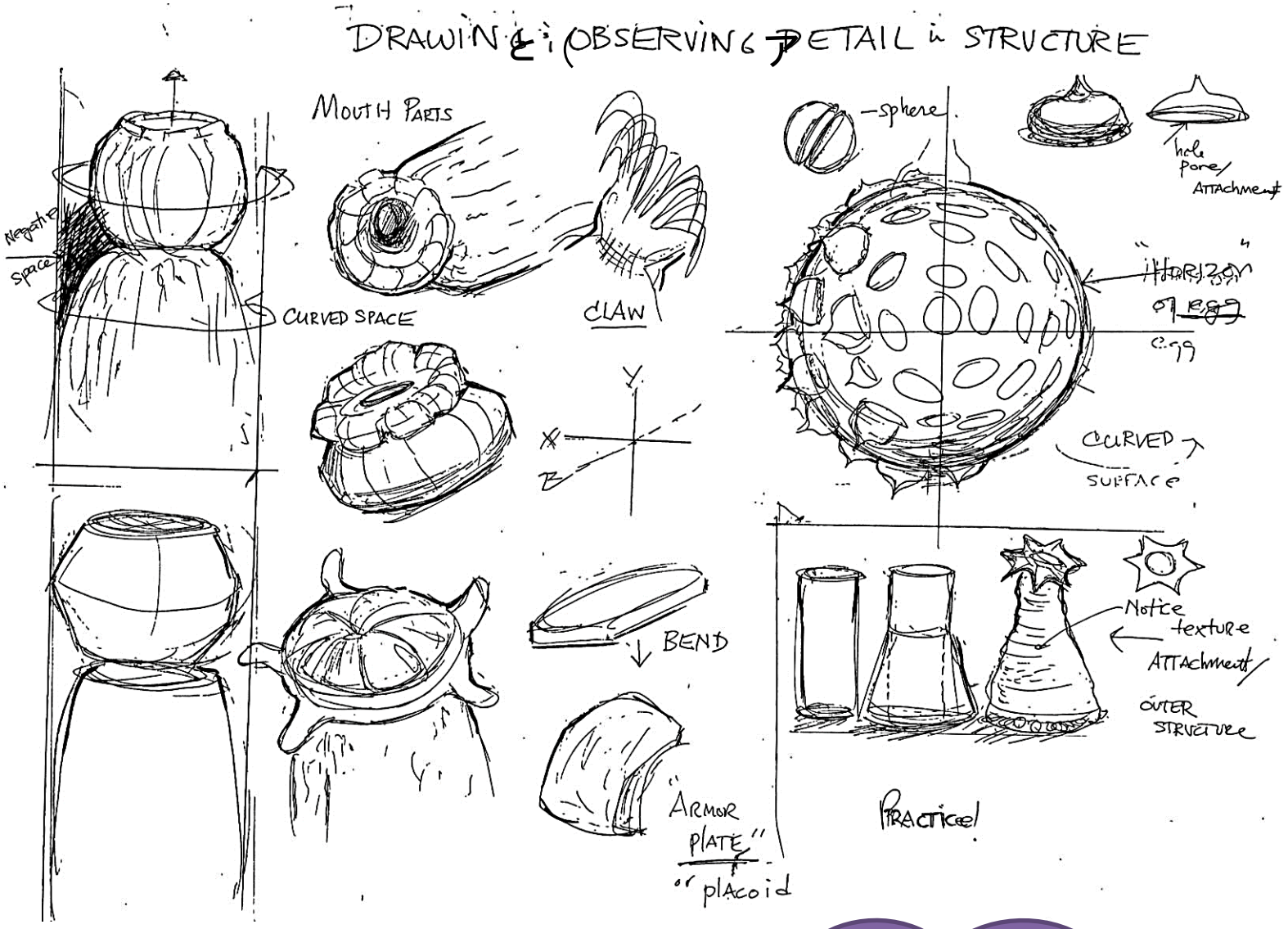
Here are some basic drawing practices to enhance your relationship with Tardigrades:



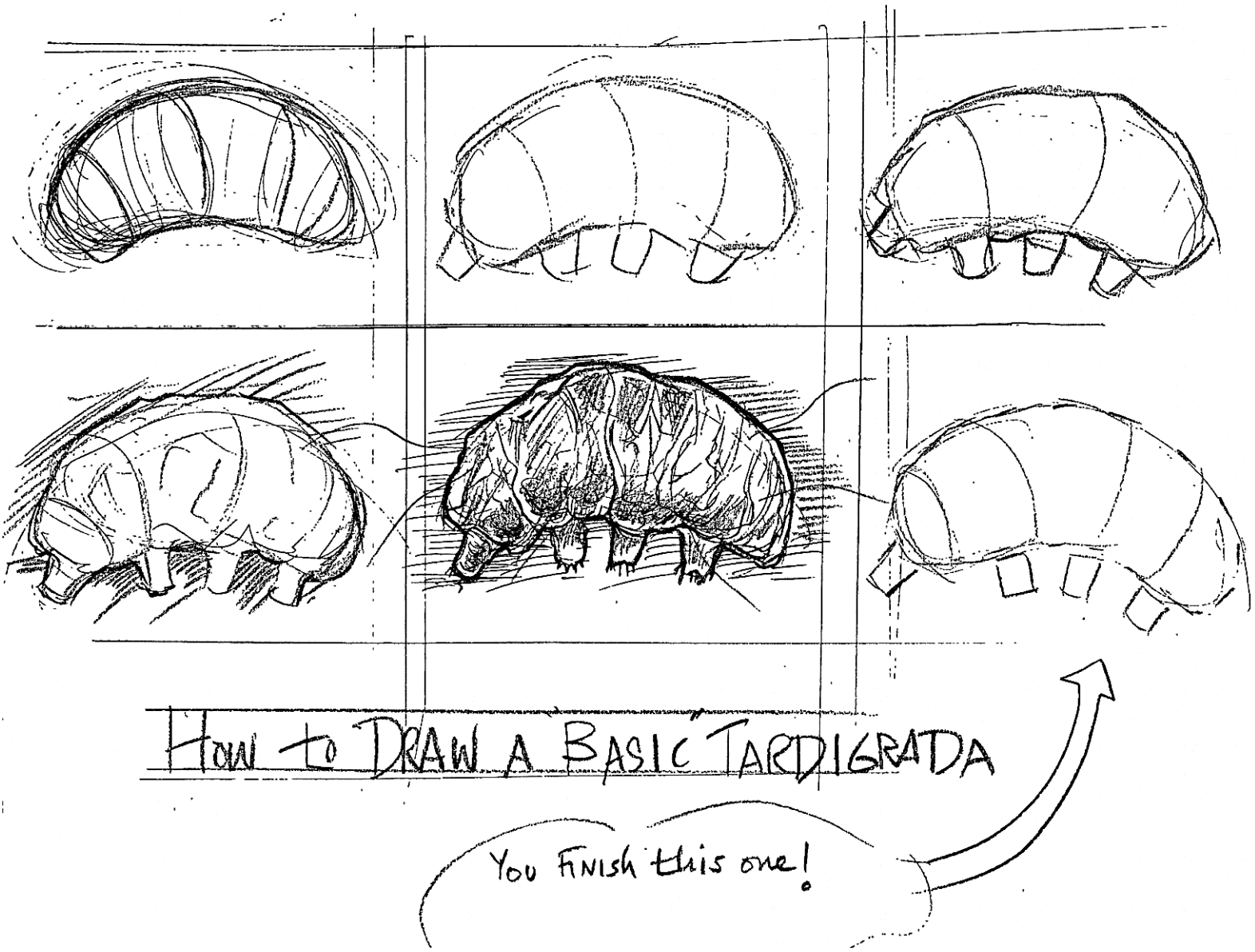
Natural forms are typically built on the pattern of cylinders and spheres. You can learn to draw Tardigrades by drawing trees or vessels or even a tall glass of lemonade!



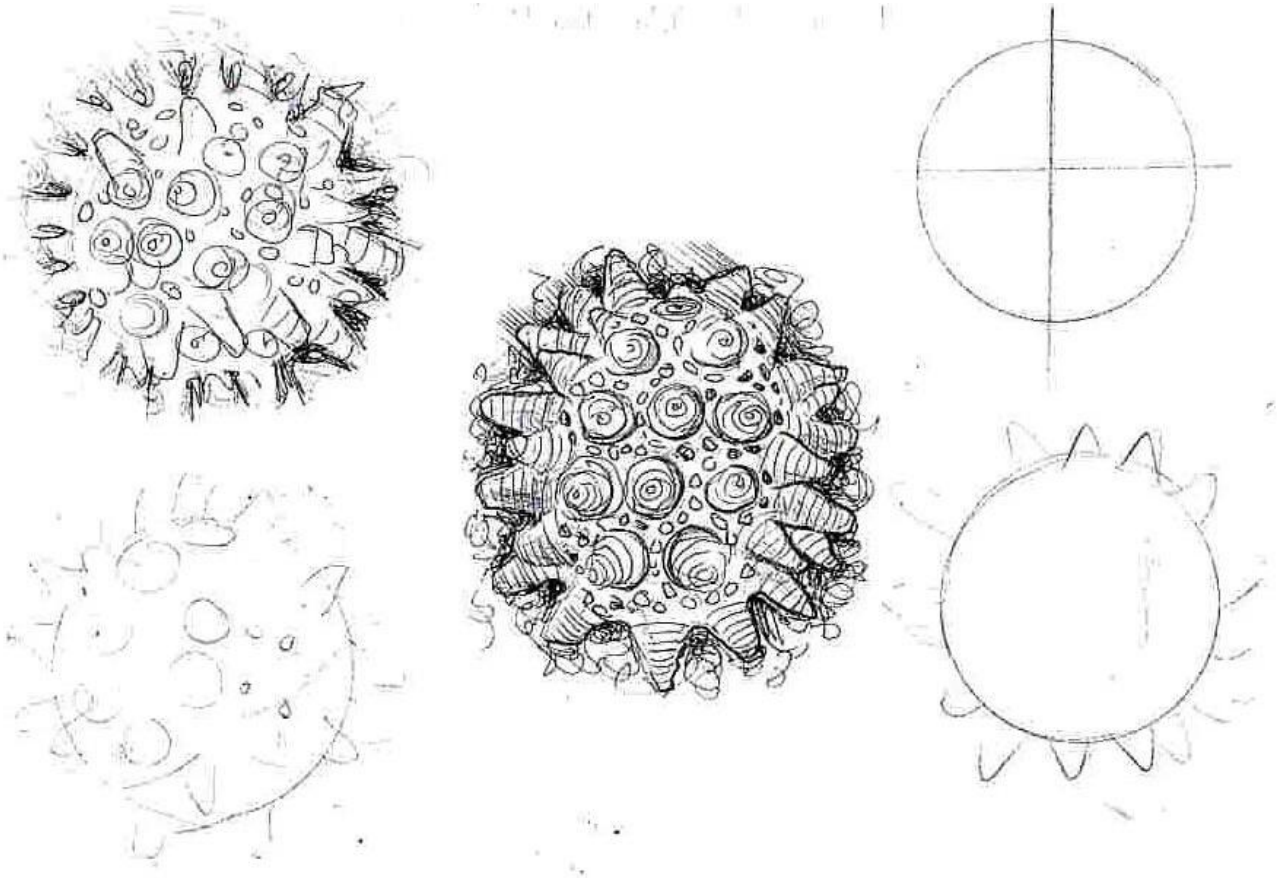
Look at a moving Tardigrade and try to remember the pattern of motion. Then quickly sketch it out. Look back and do the same. If you draw the cylinders well, it will become easier.



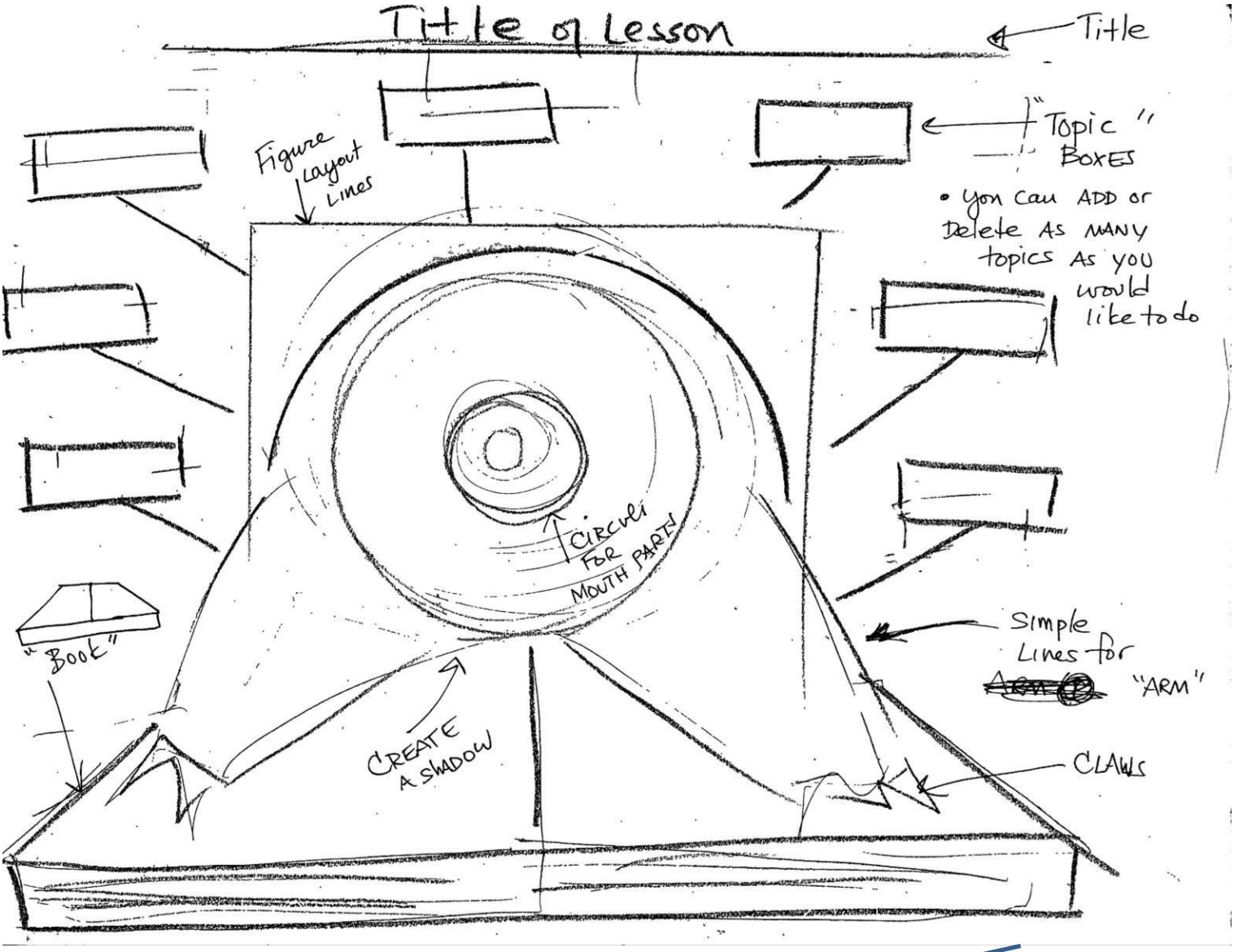
When you really look closely at Nature it is way more interesting than you could imagine. So much detail, such subtle textures, such creative patterns and colors. Just look at a female Tardigrade egg, it's like a jewel! And then look at that mouth, pretty complex and yet you can draw them because they are constructed on a foundation of spheres & cylinders


How to DRAW A BASIC TARDIGRADA
You FINISH this one!

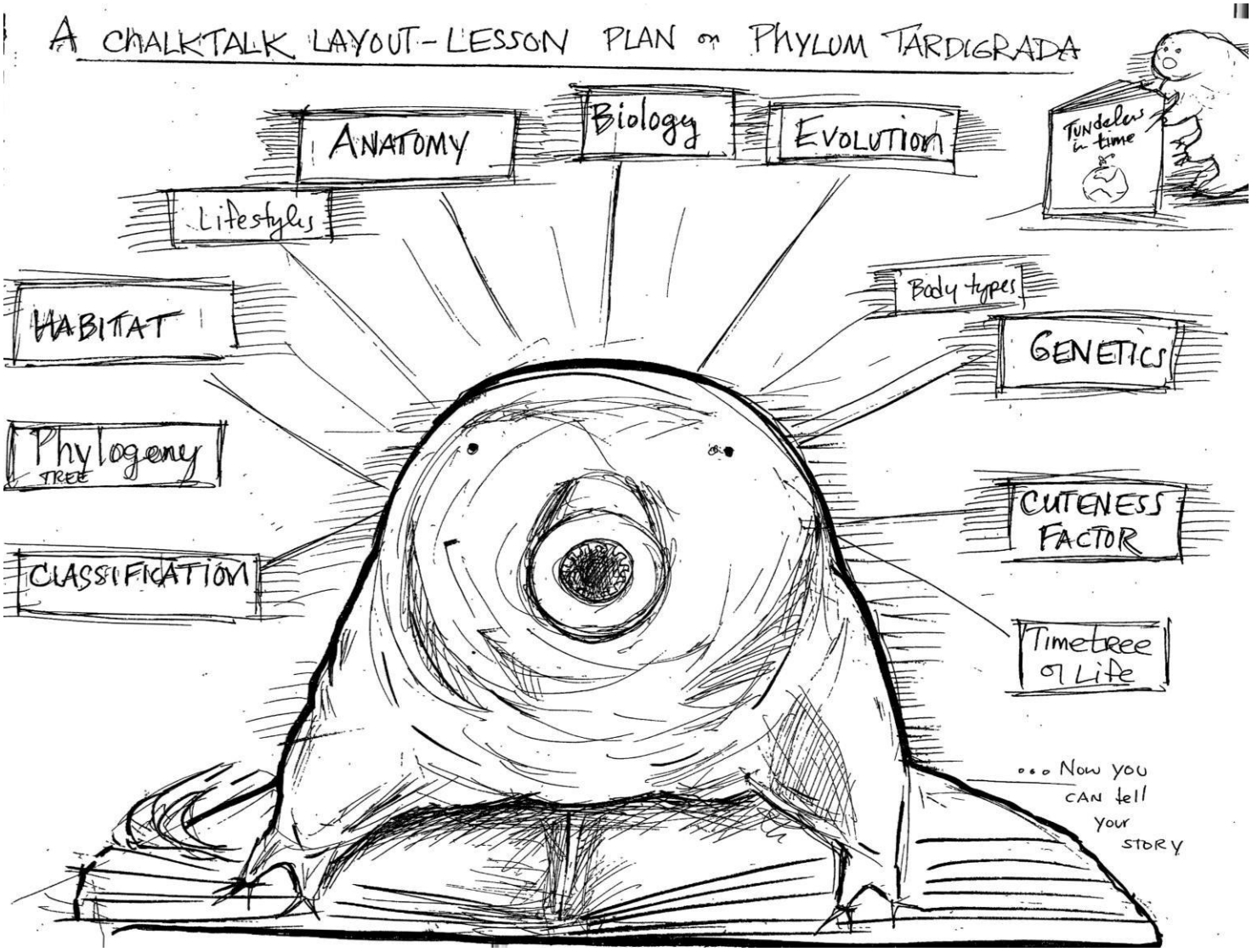
Draw a Tardigrade egg



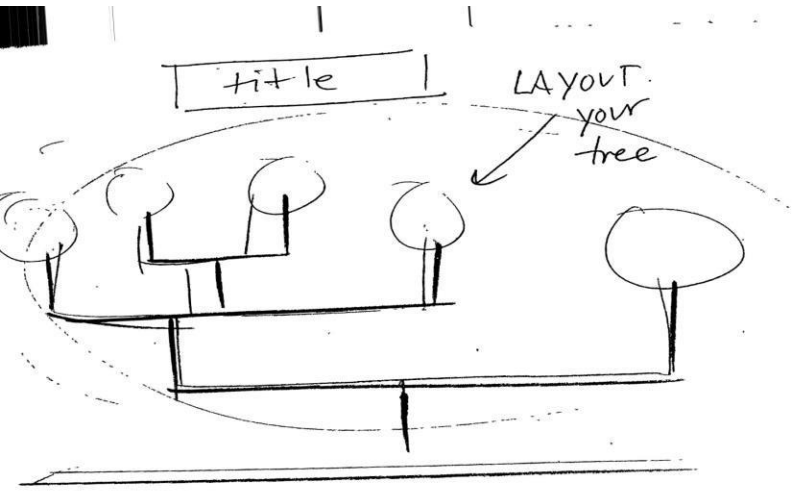
Layout your lesson plan with an eye-catching drawing!

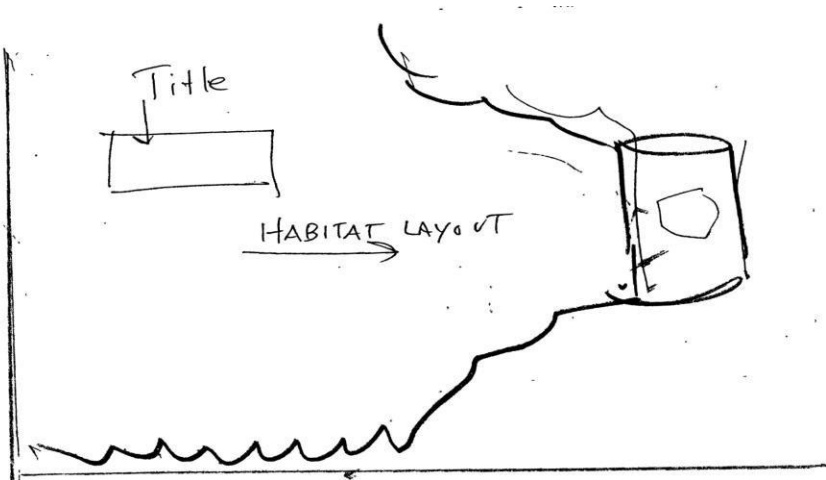


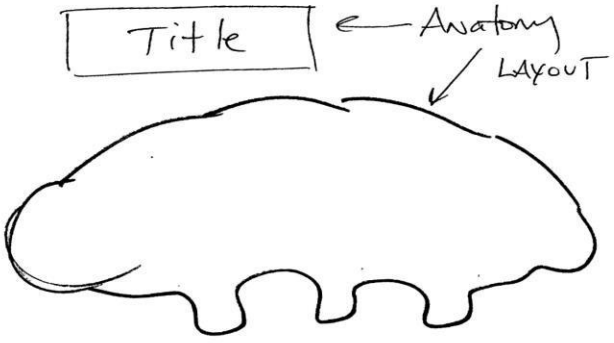
If you're a teacher/professor, demonstrate drawing for your students. Here is a layout to make your presentation easier. Practice drawing yourself and present it to your class.

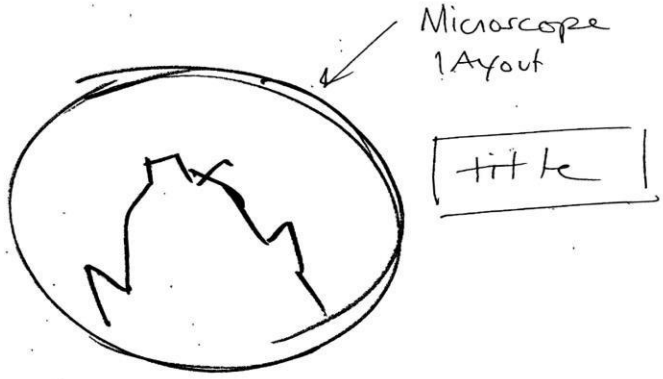


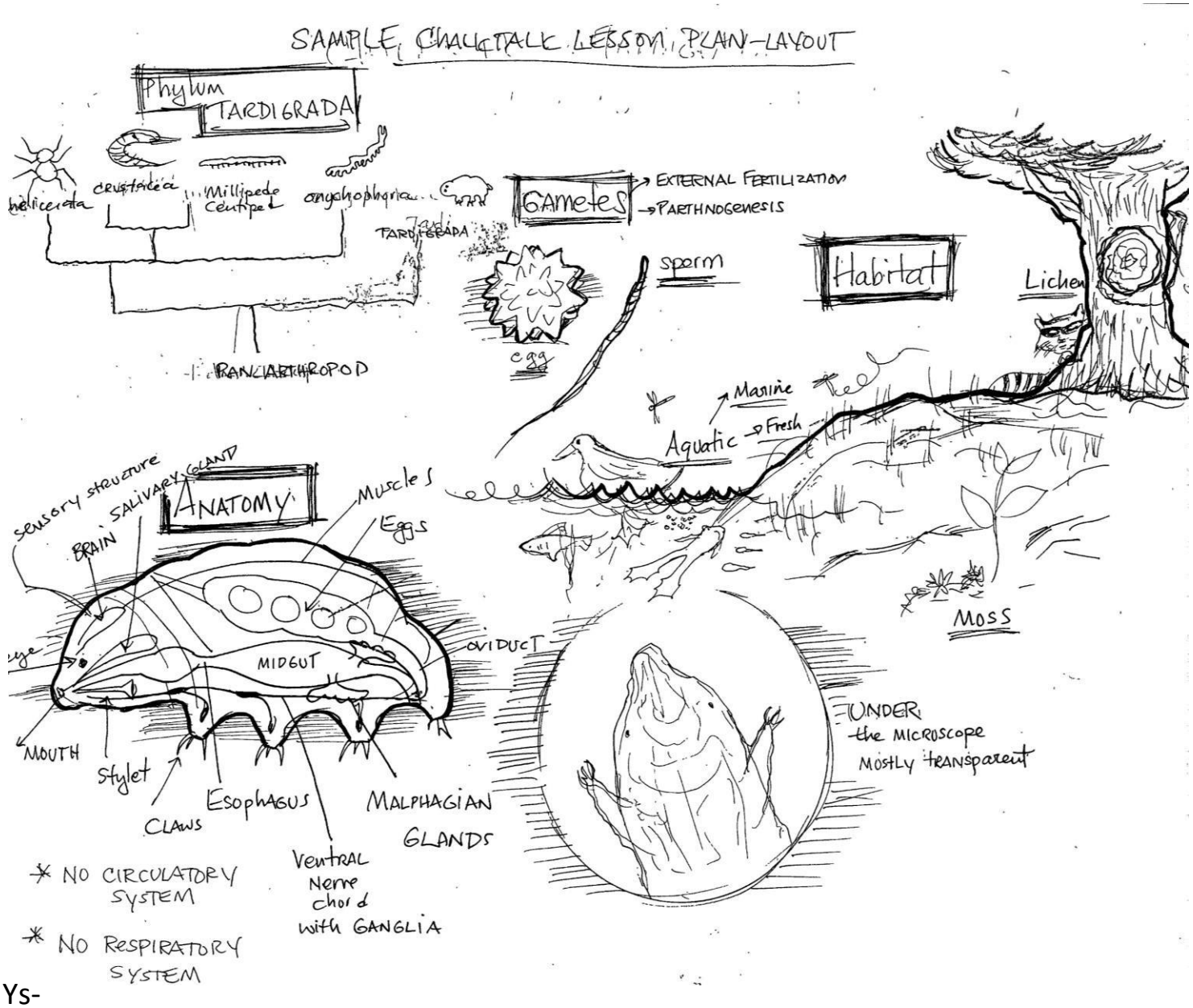
Here's your final image- from this image you can have discussions on any topic, giving the lecture an interactive, big picture context.


title
LAYOUT your tree


Title
HABITAT LAYOUT

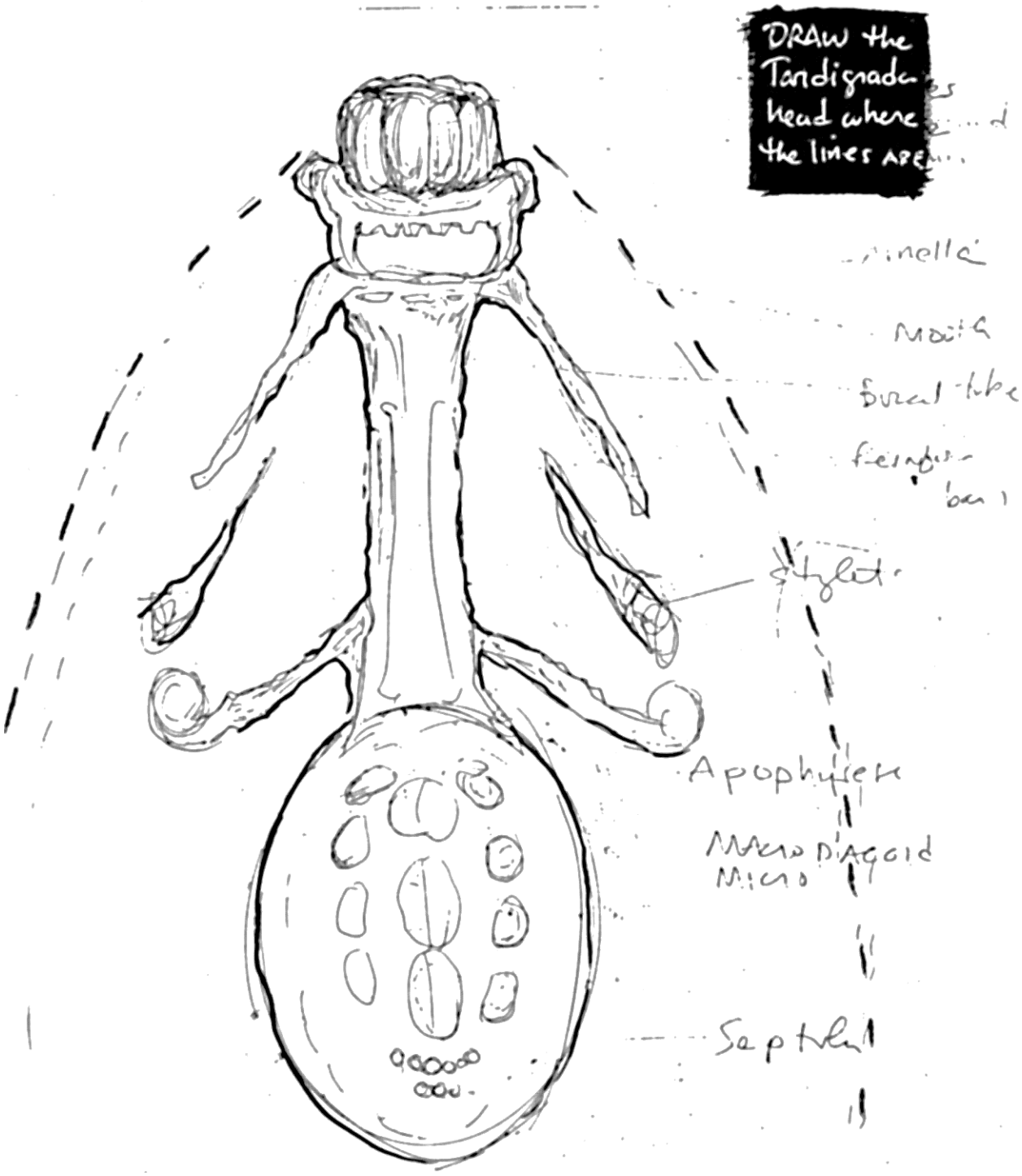

Title
Anatomy LAYOUT

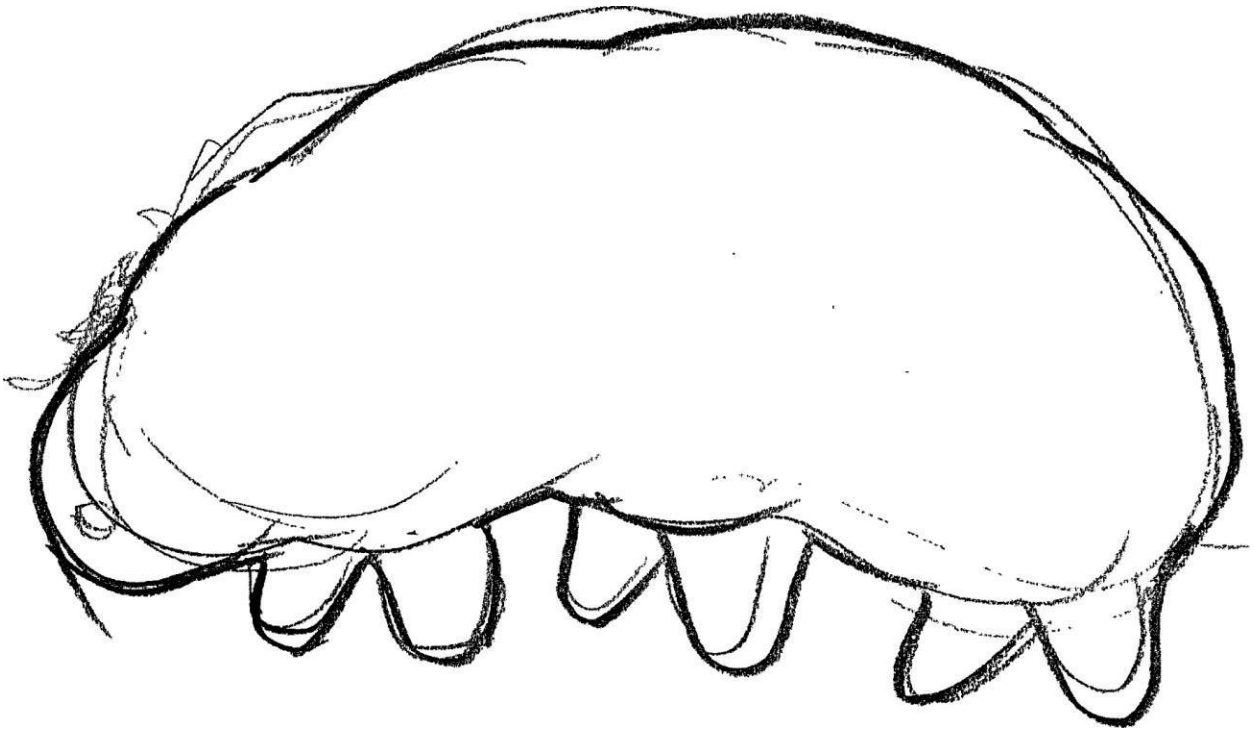

Microscope LAYout
title


SAMPLE CHALKTALK LESSON PLAN-LAYOUT
Phylum
TARDIGRADA
helicerata
crustacea
Millipede
Centipede
onychophora
TARDIGRADA
Gametes
EXTERNAL FERTILIZATION
PARTHNOGENESIS
sperm
egg
Habitat
Lichen
Moss
Marine
Aquatic
Fresh
PANARTHROPOD
ANATOMY
sensory structure
SALIVARY GLAND
BRAIN
Muscles
Eggs
MIDGUT
OVIDUCT
MOUTH
Stylet
Esophagus
CLAWS
MALPHAGIAN GLANDS
Ventral Nerve chord with GANGLIA
* NO CIRCULATORY SYSTEM
* NO RESPIRATORY SYSTEM
UNDER the MICROSCOPE
MOSTLY TRANSPARENT

Ys-

Here's a template to help you draw a mouth part…





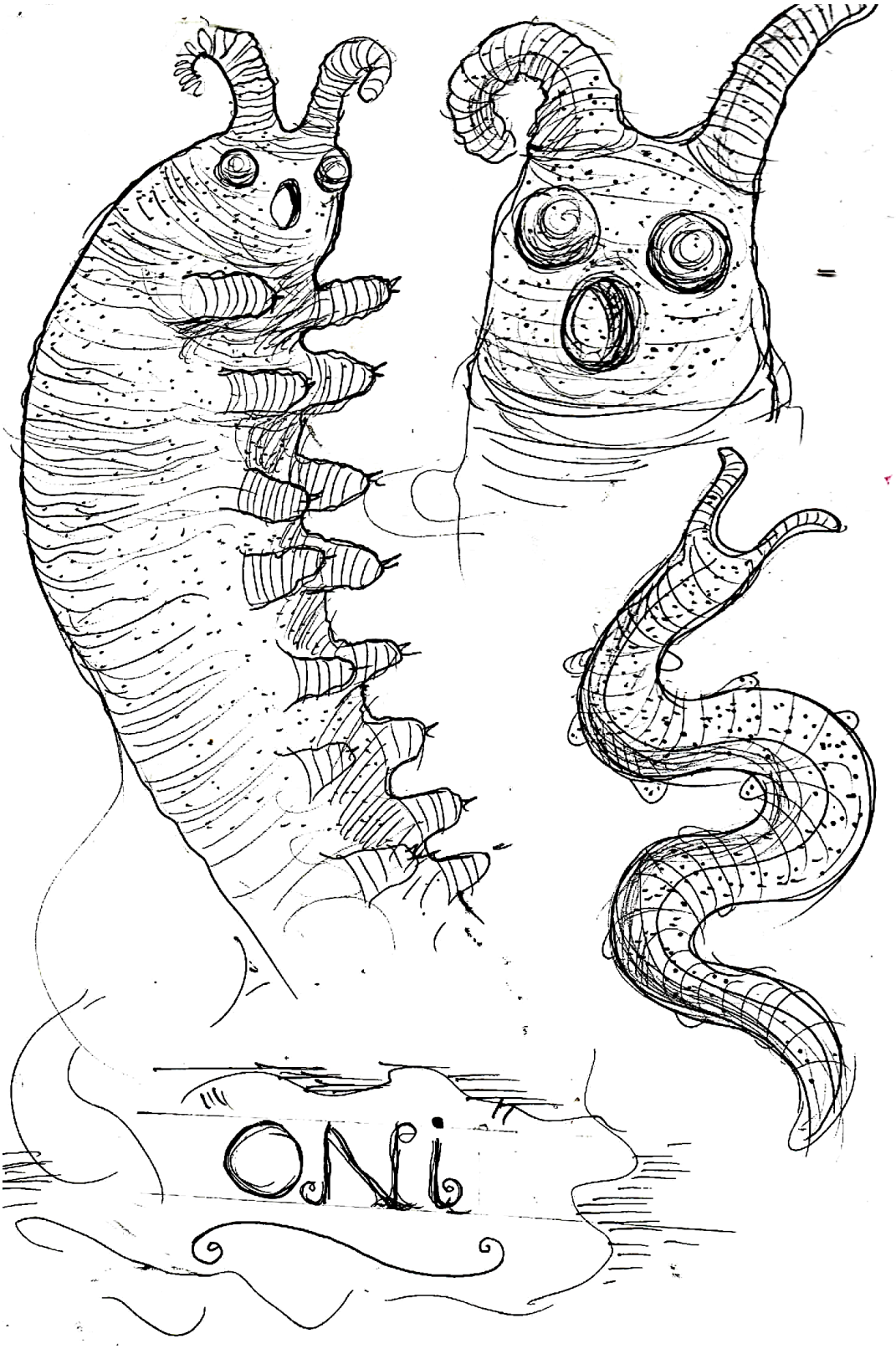
Using claws, mouth parts, body plates, and sensory structures: Morph a

TARDIGRADA

Draw a TUN too! *A What?*

Drawing some of Joe Tardigrada's Relatives

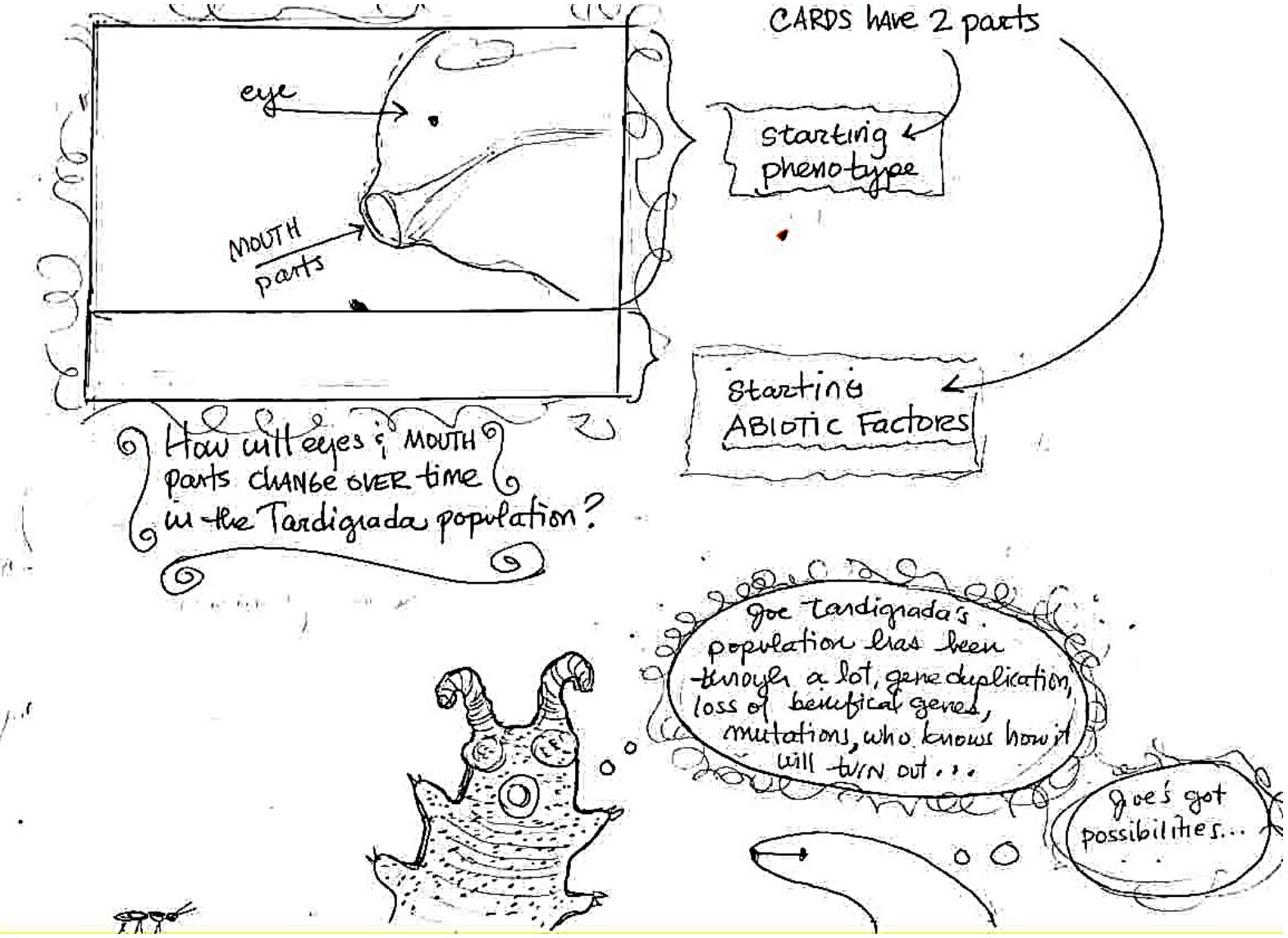

Nematodes
How to
draw Nemi
Nemi

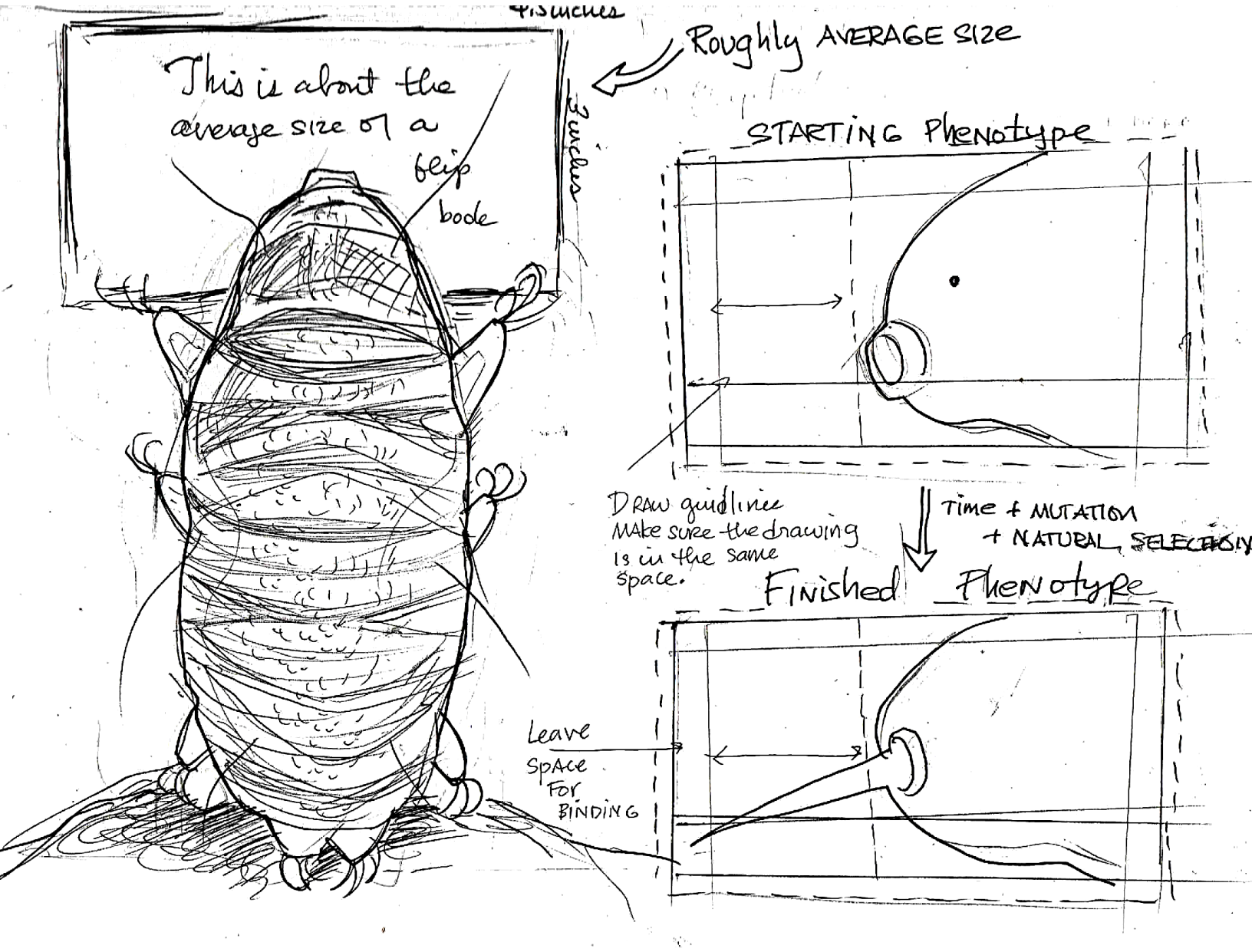

ONi


Onychophorans
eye
close-up
How to draw "ONi"

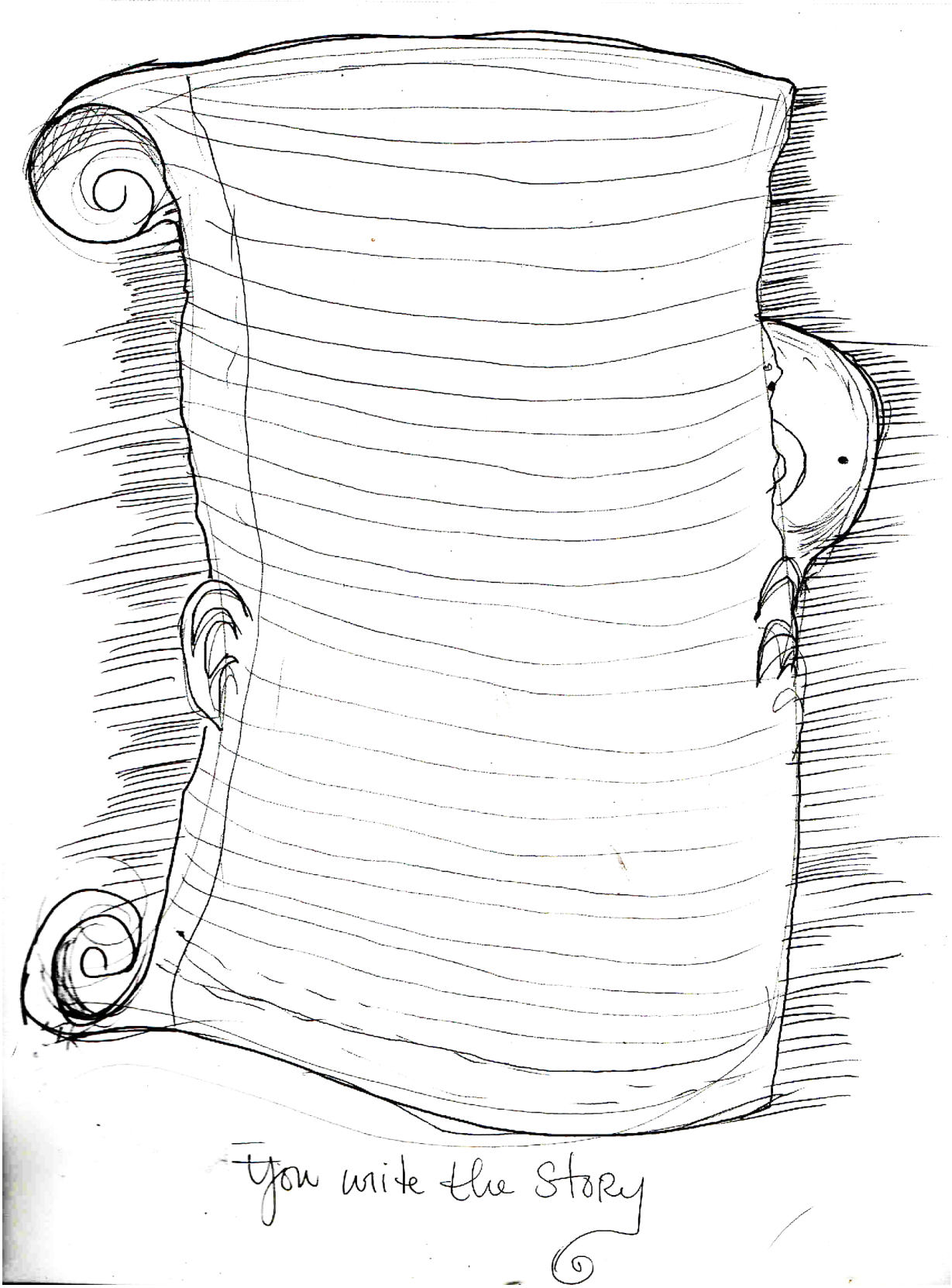
In this activity, you will make a flip book that begins with a very simple moss sucking Tardigrade and then finishes with it evolving into an ectoparasite. Then you will fill in the adaptive radiation "story" of this water bear population.

Making a Flip Book for Evolution


eye
MOUTH parts
CARDS have 2 parts
starting phenotype
starting ABIOTIC Factors
How will eyes & MOUTH parts CHANGE OVER time in the Tardigrada population?
Joe Tardigrada's population has been through a lot, gene duplication, loss of beneficial genes, mutations, who knows how it will turn out...
Joe's got possibilities...


This is about the average size of a
Roughly AVERAGE SIZE
STARTING Phenotype
DRAW guidlines MAKE SURE the drawing is in the same space.
TIME + MUTATION + NATURAL SELECTION
Finished Phenotype
Leave SPACE FOR BINDING

Make your evolution flip book of an evolving moss sucker into a parasite. Write the scenario in here, describing the ecological, geological, and maybe even HGT events that selected for your Tardigrada's new parasitic lifestyle.



Tardigrade on a Changing Planet: a little thought experiment

Imagine you discover a Tardigrade population living in a pond near you, sap is plentiful, and the weather is temperate. You have been studying your population for a few years and they haven't changed too much. One day you decide to go around the world and see it, before it changes too much. So, you take your muddy boots and travel to the caves of Mexico and then to the Pyramids of Egypt and then to the rainforests of Brazil and finally to the North Pole. Along the way you unknowingly have taken Joe Tardigrade and a small population of his kind with you. Each place you visit you end up losing more and more of the mud and moss on your boots. Predict what will happen to Joe in each one these conditions. What possibilities for change are there? What kind of nutrients will his population eat? Will his population stay intact or will it split? Will it breed with the local Tardigrades? How much time do you think it would take to split and diverge into new species? Think of all the character traits the Tardigrades from your pond have and draw a future evolution for this population.

You can have lots of fun with any species, including yourself- write poetry, draw, and model your Tardigrade in clay, fabric, or mud! Whenever you study any living thing create a portfolio of interesting ways to explore. Search the TTOL and find out who's related to who, when they diverged, and speculate about the future.

For Teachers and Self Learners

Drawing Tardigrada lesson on the board may seem complicated, but it's really not. To start your discussion, lecture, and activities on Tardigrades, introduce your students to a lecture that they can draw along with. "Drawing- Lectures," set the stage for your evolutionary theater. They are the setting and place to couch your discussion on Phylum Tardigrada. A Drawing Lecture is fun, informative, and endlessly creative. It is also a chance to unplug students from overuse and over reliance on technology, encouraging them to use technology when it's appropriate rather than addictively. Drawing Lectures are also contemplative, allowing greater focus, observation, and engagement. You do not have to been an artist to do them but walking into a classroom and creating "art" on the board allows students to create biological art with you.

To introduce your Tardigrada topic, there are two sample chalk talk board templates, complete with finished images. We recommend that you come in 15-20 minutes early

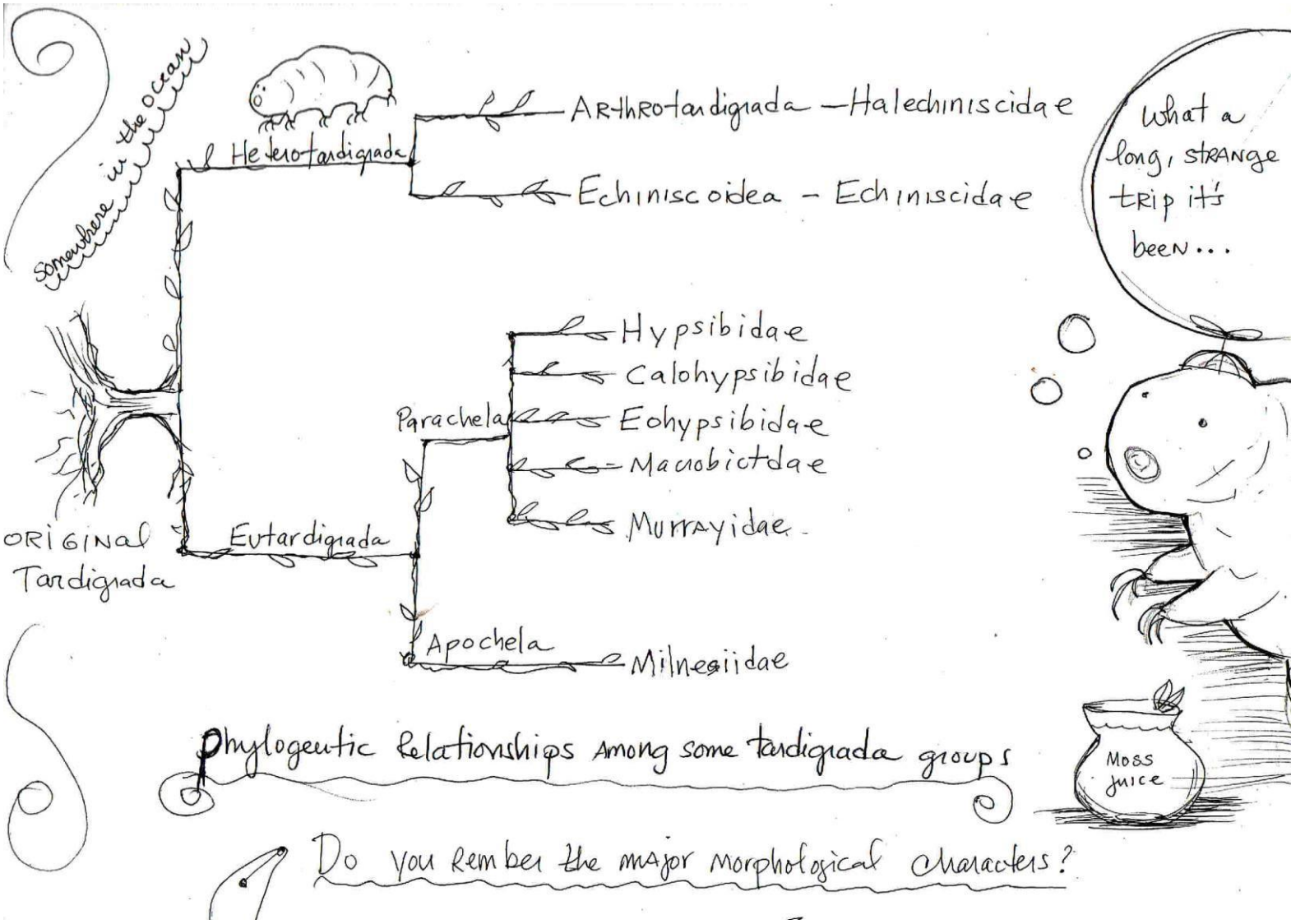
and create the first broad ideas board about Tardigrada. Discuss as many topics as you like by placing their titles in the boxes.

In the next board, do the layout with your students and fill it in as you tell the story of Tardigrade. You can modify these for whatever your discussion might include. Students may do the workbook first or following the Chalk talk. Have your students come prepared for class with pencils and paper.

The sequence of drawing and using the TTOL is based on your time constraints, however this is the suggested sequence:

1. Chalk talk Drawing Lecture with Visual PowerPoint
2. Trunderlers in Time Workbook in lab and as take home
3. TTOL database lab with or without wet lab with outdoor hike through woods
4. Exam and Portfolio Assessment

The End


Somewhere in the ocean
Heterotardigrada
ARthrotardigrada — Halechiniscidae
Echiniscoidea - Echiniscidae
ORIGINAL Tardigrada
Eutardigrada
Parachela
Hypsibidae
Calohypsibidae
Eohypsibidae
Macrobiotdae
Murrayidae
Apochela
Milnesiidae
What a long, strange trip it's been...
Moss juice
Phylogeutic Relationships among some tardigrada groups
Do you remben the major morphological characters?

Vocabulary for you to do!

Tardigrada Vocabulary (in no particular order)

Instead of writing definitions- draw drawing them!

Lobopod

Spallanzani

Heterotardigrada

Eutardigrada

Cephalic

Caudal

TTOL

Micrometozoan

Hydrophilious

Cryptobiotic

Anhydrobiotic

Osmobiotic

Cryobiotic

Taxon

Root

Branch

Node

Speciation

Adaptive Radiation

TUN

HOX genes

Cambrian

Panarthropod

Parthenogenesis

Phylum

Buccal

Spine

Placoid/plate

Cirri

Papillae

Ecydozoans

Metazoan

Extinct

Extant

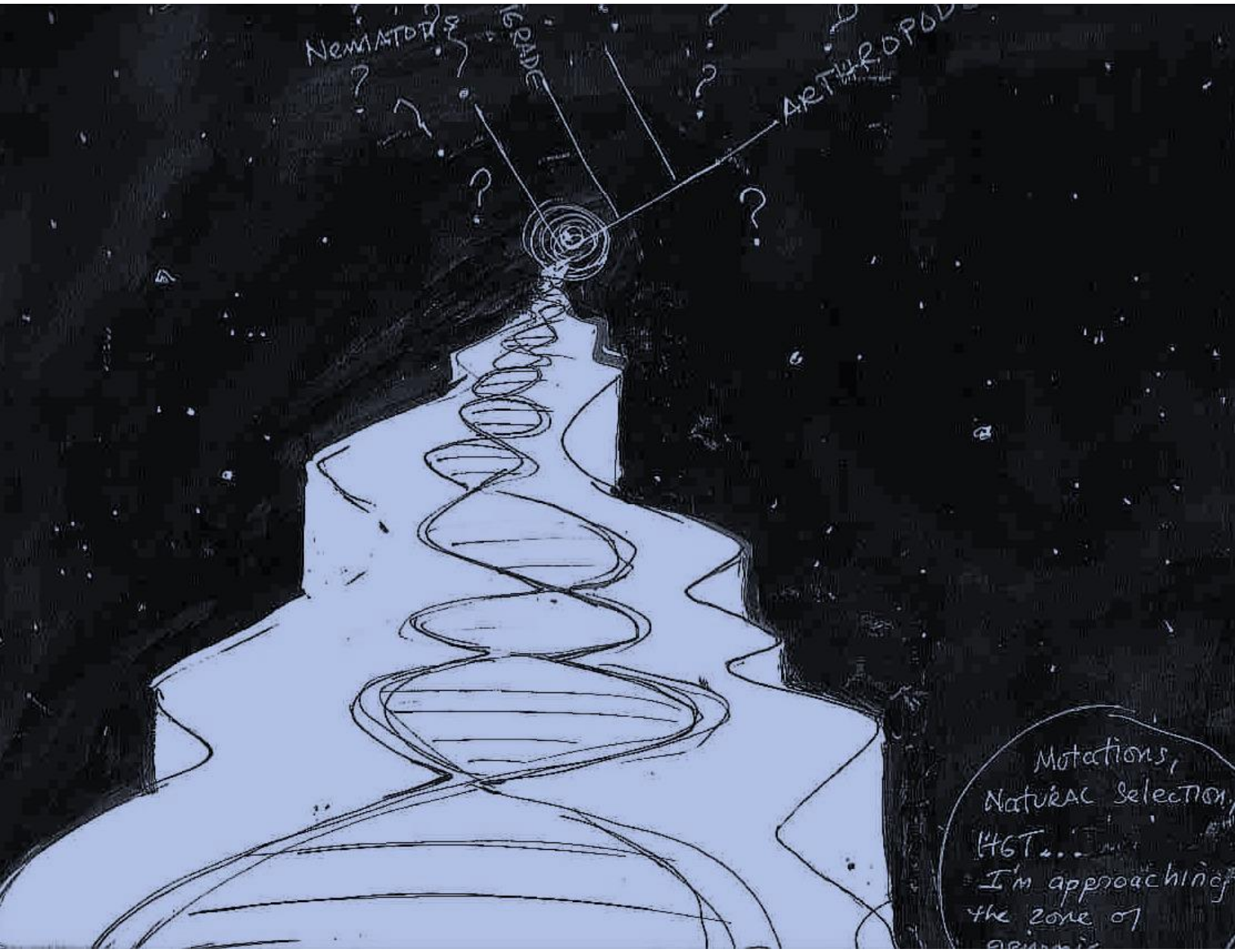
Cyclomorphosis

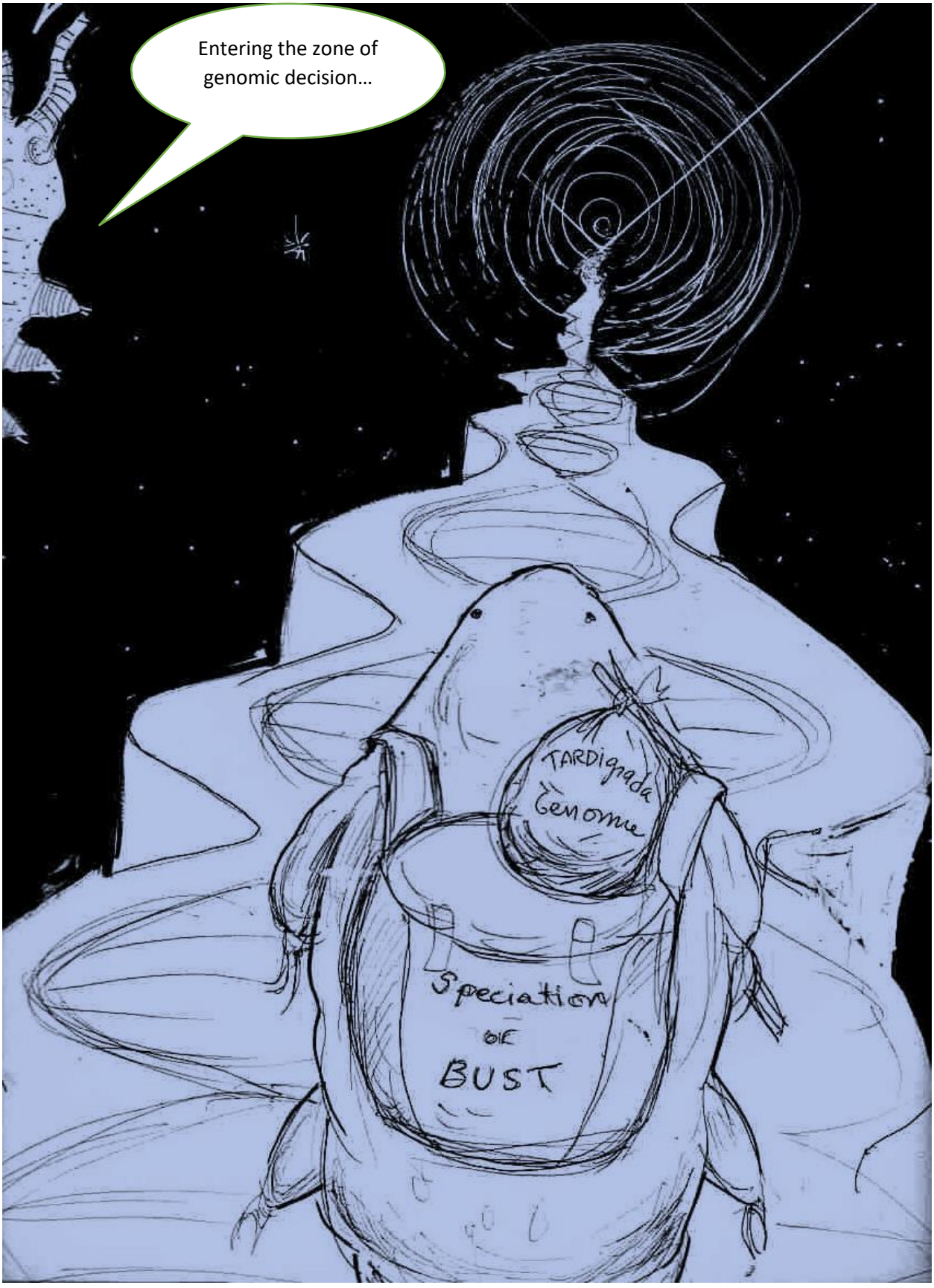
Horizontal Gene Transfer

Taxonomic character

Notes

Notes


NEMATODE
ARTHROPOD
Mutations, Natural Selection, HGT...
I'm approaching the zone of


Entering the zone of genomic decision…
TARDigrada Genome
Speciation OR BUST