Principles of animal forms and functions

Intro :

What is an animal? This is a tough question, with no consensus answer, as " animal" is not a taxon and is not defined with a specific synapomorphy. (well, some say, animals = metazoa, but there is no consensus) To start with the basics, maybe one should first define what is an organism, that is to say, what is a living being.
Well, a living being is an open thermodynamic system that withdraws organic matter or/and energy from its environment and processes it to produce precious energy for its growth and development.
It evolves through time and comes from another living being that gave birth to it.
A living being is able to modify its physiology and behavior after the treatment of a particular stimulus. Thus, to live and evolve, a living being needs to gather numerous information about its surroundings.
To do so, he will verify the three major living functions : Nutrition, Reproduction, and Relation.

That being said, we, the authors, have decided to define an animal as a eukaryotic, heterotrophs pluricellular organism without cell walls that are able to move voluntarily. So, yes Insects are animals, but Blobs (*Physarum polycephalum)*? Not sure of that.
Nowadays, scientists estimate that animals are about 22% of the total species on Earth.

An animal should never be studied without its environment and its constraints. The chemical and physical characteristics of the aerial environment are extremely different from the aquatic environment.

Those physical and chemical constraints explain why there is a diversity of forms and functions in animals.

Ok, let's get a bit more into definitions.

What we will call the form of an animal is its global shape but foremost how its inner parts are shaped and connected. Whatever that a spider has eight eyes and a pig only two, the important piece of information is that both have eyes close to their central nervous system. Whatever that a cow has a stomach in four parts and a butterfly a stomach specialized in dissolving the pollen (oh my god, so cute), the important piece of information is that both have a digestive system in the global shape of a tube, with at least an entry and most of the time an exit (Cnidarian, like jellyfish, have their anus and mouth in the same place... So the fecal matter is released by the mouth.)

What we will call the functions of an animal is the purpose of each part of it. Indeed, to build matter, a LOT of energy is needed, so there is no useless part of a living being.

The body of an animal is formed of multiple layers and each of them shows specific forms and functions that help the body to make its journey through life.

Please: have a look at the chapter of last year, on their presentation of each type of cells and tissues. https://fdvbio.wordpress.com/2019/02/15/what-makes-an-animal/ (It is very helpful

for the mastering ;)). You'll see that tissues are more than an addition of cells, organs more than an addition of tissues and systems more than an addition of organs. Each time, the community gives new functions. This phenomenon is called emerging properties.

We won't talk about it, yet you need to know it. Again, please read this part of their chapter.

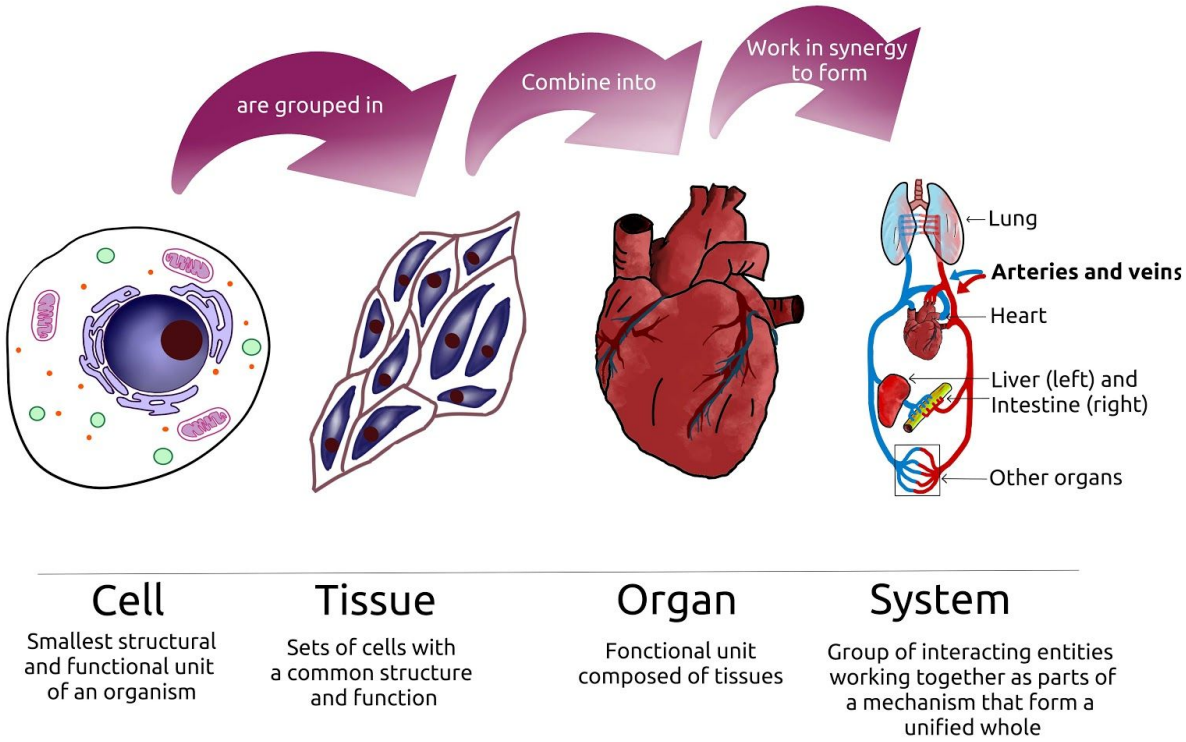

Figure 1: Physiology and the different levels of organization in an organism from the cell to the system
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We said earlier that the body of an organism answers three main functions, called Nutrition, Reproduction, and Relation.

The Reproduction functions are the most obvious of the three. If life has a meaning or a purpose, it would be to reproduce to ensure the prosperity of the species. (OK, CALM DOWN, PUT DOWN THIS GUN). They deal with the genesis of new individuals, the sexual behavior leading to procreation, possibly the care of youngs, gametogenesis and so on. The body parts dealing with this function are obviously inside the reproductive system but also in the endocrine system. Indeed, to attract a sexual partner (in the case of sexual reproduction), hormones may be released.

Of course, reproduction implies that the partners can identify themselves (or the parents recognize the children). That leads to the Relation function. It deals with the organism's

interactions with the external environment (living and dead… (we're talking about the sun and the wind, right?)), its perception and the answer to those stimuli (movement for example). The body parts implied are in the sensory system, the nervous system, the muscular and skeletal system, the endocrine system, immunitary system… Actually, for the body to work properly, it needs homogeneity in the work of the different systems and communication between cells, so all the body is concerned by the Relation functions. *Remember your course about communication between cells… far far away in your memory… the plasma membrane structure…*

If you need help remembering, below is a quick recap.

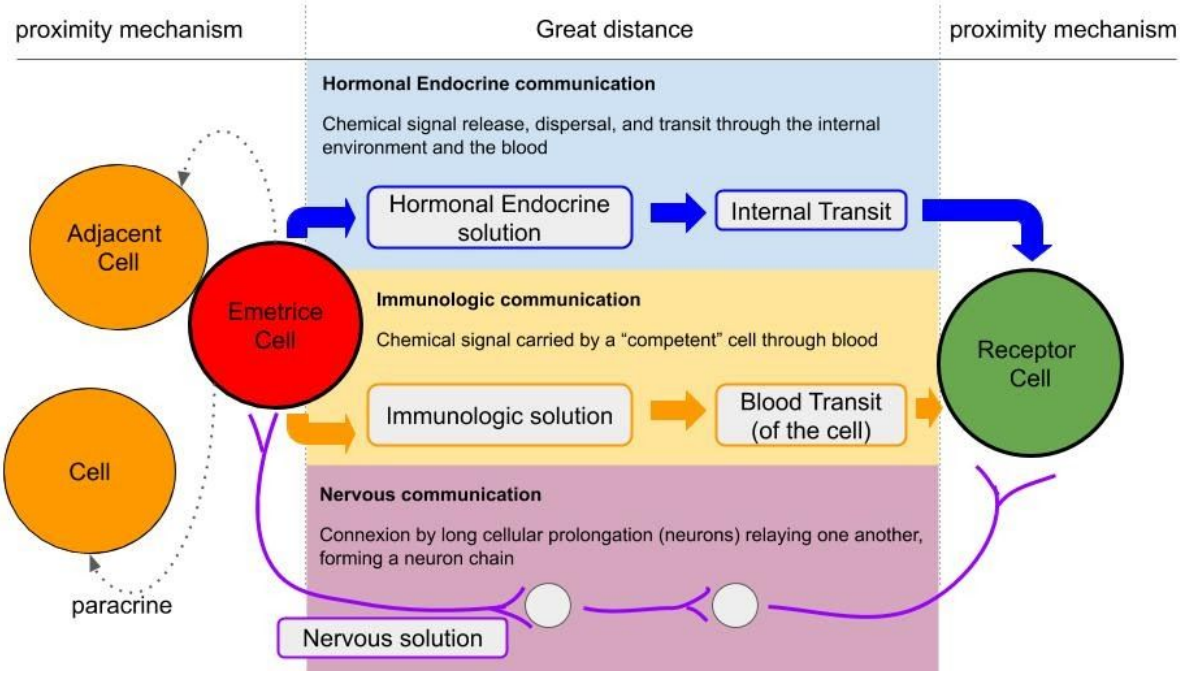

Figure 2: Communication system between cells within the body
The 3 communication systems are showcased above in blue, yellow and purple.
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But to do the jobs, everything needs energy. Energy is the key AND the brake. Energy is like the Graal. Each second of its life an organism is in need of energy. And Energy comes from food. The Nutrition functions manage the in and out of matter in the organism, its digestion, its storage, purification and circulation inside the body. All the vital functions are in the Nutrition function.

Let's make a little scheme to sum up:

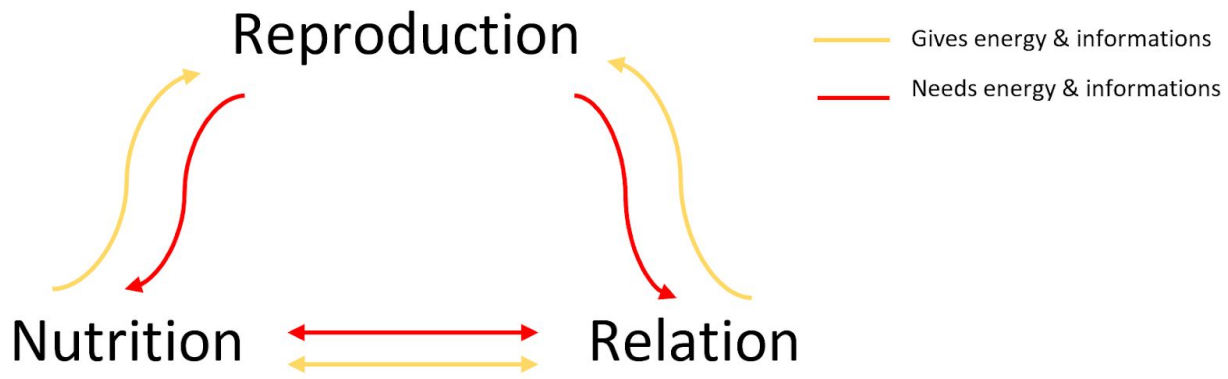

Figure 3: Repartition of energy needs
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Here, you're probably a bit confused. " Ok… where are they going, this introduction is too long". Don't worry, it's almost finished.

As you saw in the previous scheme, all the functions, that is to say all the systems inside an animal, are connected. They're more than connected, they can't operate alone.

Do you start to feel a bit dizzy as you see a HUGE AMOUNT of information coming to you? Perfect.

Our mission is to help you understand HOW everything works, HOW all the systems are connected. For that, you need:

1. To know what are the systems, body parts, functions and so on we're talking since the beginning of this course
2. To know what each system needs and produce, to understand which one will help which one.
3. Not to get lost by too much information.

So the plan for this course will be the following:

Cycle 1 : Food intake

1) About finding food
2) Treatment
3) Output

Cycle 2 : Reproduction

1) Interaction
2) Treatment
3) Output

It seems to be repetitive and it is. But don't worry, we won't say the same things in the two parts. The goal is to first explore what are structures to then observe what are the interactions.
We don't want to make a catalog and transform this *exciting* course into something boring, so in the first cycle we'll follow the story of " how my food is transformed into energy (and a bit into fecal matter and urine)" and in the second cycle we'll follow the story of " I want to reproduce, how to do it? "

A lot of what you're going to read will be related to other chapters. We'll provide links for you to complete your journey.

Ready? Let's go.

Cycle 1 : Food intake

Let me introduce you to the main character of this part: **food**.

Animals may be herbivorous, carnivorous or omnivorous, but in the end they all are heterotrophs, that is to say they use organic matter to produce organic energy (forget this photosynthetic slung (*Elysia chlorotica*) please, exceptions[1] may always be found).

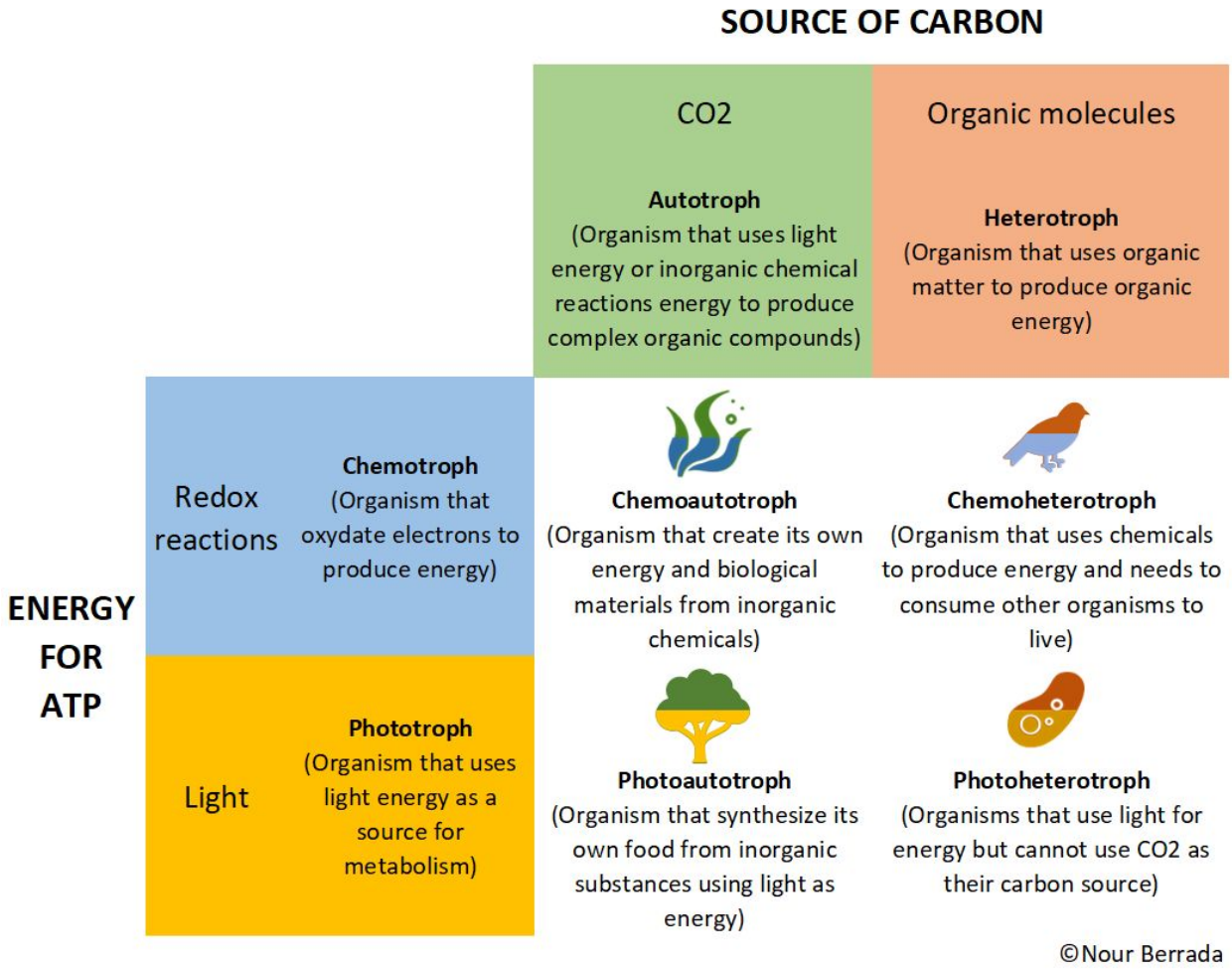

Figure 4: Table identifying multiples way organism have to produce complex organic compounds using energy from different sources

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They find in organic matter biomolecules (carbohydrates, proteins, lipids, and nucleic acids) and some ions (sodium, magnesium, potassium, calcium, phosphorus, sulfur, chlorine, fluorine, iron, and others). Once smashed into small bricks, they are stored or used to build cell structures, hormones and so on.

[1] Some exceptions indeed…

In addition, all animals need water. Indeed, water is the major component of plasma and blood, of interstitial fluid and intracellular fluid. Water congregates with hydrophilic molecules to form gels, like mucus and extracellular matrix.

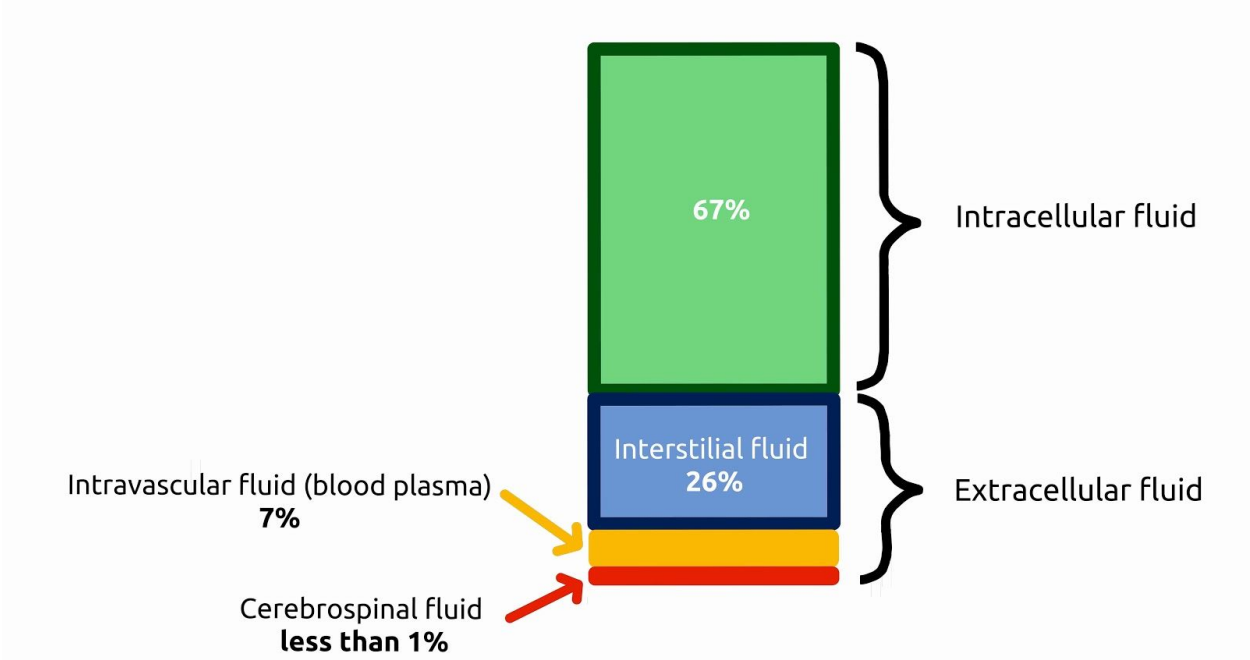

Figure 5: Repartiton of the total body water in mammals between the intracellular compartment and the extracellular compartment
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Water is involved in several chemical reactions in the body, like redox.

$$H_2O \Leftrightarrow 1/2\ O_2 + 2H^+ + 2e^-$$

I. I'm hungry! Where is my food ?

Let's say a pigeon[2] is looking for grains. The grains are outside its body, placed randomly in its environment. So our pigeon (let's call him[3] Jean-Pierre Pigeon, JPP for close friends ;)) has to first localize his meal.

[2] Myriam: I loooove pigeons, did you know? / Irina : Birds are the best !! o0
[3] Yes, "him", it is my final word.

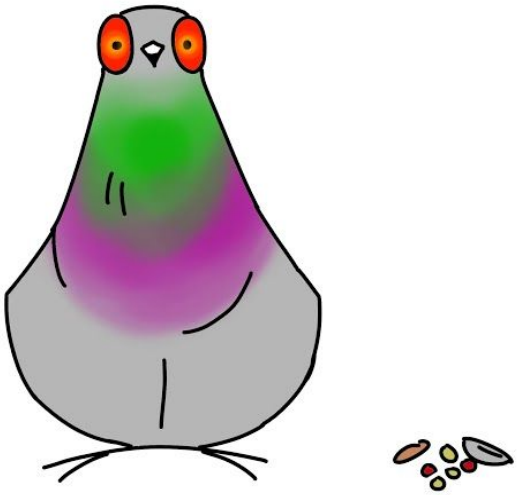

Figure 6: JPP first apparition

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Jean-Pierre the Pigeon (JPP), as all animals, has specialized body parts to do so. They are part of the sensory system. Let's see what tools animals have to help them in their "Finding Food" quest !

A. Five senses? Heh, it's a bit more

Fonction	Example
Visual perception	JPP has two eyes whereas a spider may have eight. Grasshopper have compound eyes (thousand of tiny photoreceptors put together)  Figure 7: MMhhhhh, I see grains Author: Irina Delamare Licence: free use

Audio perception	Tetrapods are able to detect pressure variations and analyze them (that's sound). Fishes are able to detect particles moving around them and "hear" through the movement of particles floating in the water.
Feeling perception	Vibrissae are tactile hair found in most mammals.
Taste perception	Human taste buds can recognize sweet, sour, salt, bitter, and umami, which is the taste of the amino acid glutamate
Smell perception	Squid seems to have an organ able to detect noxious chemicals in the water
Electroreception and electrolocation	"Electrical fishes" are able to detect electrical fields with structures called lateral lines
magnetoception	Drosophila have eyes equipped with cryptochrome: this lovely thing make them able to **see** magnetic fields.
Nociception (detection of tissue-damaging stimulus; may be assimilated with pain perception)	All vertebrates (including Teleosts) have nociceptors
Gravity perception	Some aquatic invertebrates, including molluscs,cnidarians,echinoderms, cephalopods, and crustaceans are equipped with statocyts, structures able to detect the gravity field and where is the up and down.
Écholocation	Bats find they preys, using a sonar

As you may have noticed, some senses are not directly useful to localized food. But remember, each animal is part of its environment : **JPP has to fight to survive.** While he's searching for food, he is in competition with other pigeons and with other granivorous, he is the prey of evil cats and dogs, he might be smashed by a car or glue in a trap, he might get lost and lose his eggs (that is to say the eggs of its partner).

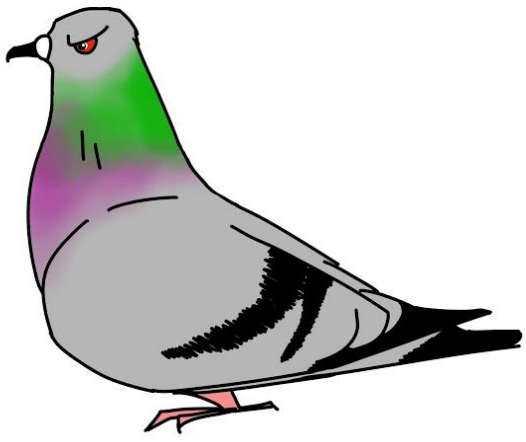

Figure 7: “I’m a tough guy, like it really rough guy, just can’t get enough guy, chest always so puffed guy … I’m that baaaad guy …” (JPP : “And I really like Billie Eilish song’s, hihi”)
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His skin (called the integumentary system) protects him from viruses, bacterias… and air, which is cool to breeve but dehydrates cells. The skin is composed of dead cells (so they won’t be dehydrated, right? I mean, it’s too late.)

JPP is a bird, he might search in the three dimensions of space. Most aquatic animals are able to do the same. However, terrestrial animals are bound to the ground and are even more subject of all the treats we mentioned above.

B. It’s time to finally eat!

The perception system has somehow detected *something.* The nervous system of JPP is immediately engaged in the analysis of that something acknowledging if the *something* is small enough to enter its mouth. You may see a pigeon in a rush to eat a small rock looking like a grain, you will never see a pigeon trying to eat a flower. (JPP : “ But I like flowers …”)
Nonetheless, the answer to the *something* stimuli is quick.

Figure 8: JPP and flower, such a love story ...
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When an animal has localized food (or something looking like food), the next step is to make the meal enter the digestive system. As it seems obvious, it is not. Each species has its own way to do so.

For example, Cnidarian (as jellyfish, coral or sea pens) have tentacles covered with cells called cnidocytes. Those cells contain organelles able to chemically detect the contact with a prey, then launch harpoon-like structures and poison. The prey, according to its size, may be totally paralyzed. One captured, the prey is moved toward the mouth by the retraction of the tentacle.

It is interesting to notice the role of teeth in the feed intake. There are different types of teeth. The canines are used for tearing apart meat but also help to defend oneself for some animals. The incisors are used to cutting smaller bites of a meal. The molars are used for grinding food. In all these cases, teeth mechanically reduce the size of the intake, in order to facilitate digestion. But there are other (darker) types of teeth, as the three teeth of leeches

used to hold on their host, or the hundred tiny teeth of the snail, used for keeping in place leaves while the snail smash them with its tongue.

II. Into the wild or *How food is assimilated in the body*

The digestive system will DESTROY food. Smashed into elementary particles (fatty acids, carbohydrates, nucleotides, amino-acids), the nutrients will be absorbed by the body through the cells of the alimentary canal then assimilated, that is to say reused or transformed.

The wastes are dessicated before being released, via the anus or the mouth (our friends the Cnidarians).

A) Presentation

The digestive system is composed of two parts: the alimentary canal and some accessory organs, like teeth, tongue, salivary glands, liver, pancreas and so on.

The alimentary canal is basically a tube. Keep in mind that the cells are the walls of the organs, that means that the content of the GI tract is actually *outside the body*.

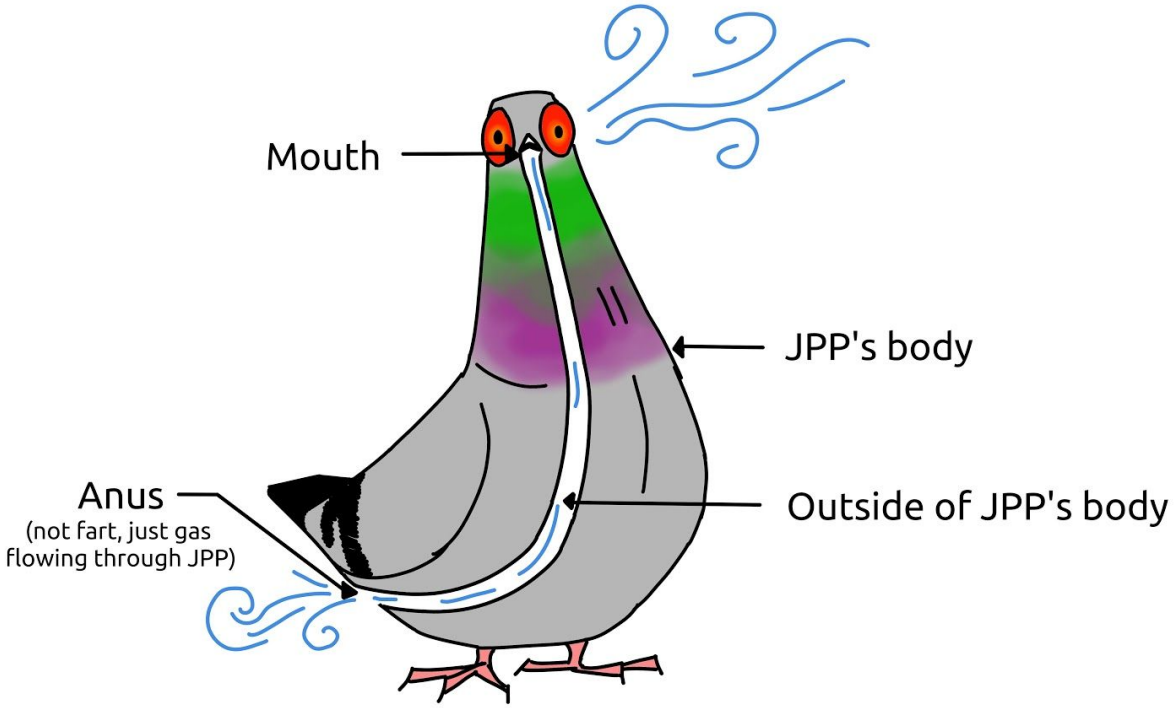

Figure 9: JPP's insides are actually outside !!
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However, even if the content of the digestive system is outside the body, we do not want air flowing through it, which could damage the organism. Air dehydrates cells. As a result, animals like JPP must have a structure (beak, even lips) that close temporarily the alimentary canal.

Digestion (process that transforms biomacromolecules into assimilable nutrients = the process of smashing things) is a mechanical process as well as a chemical process.

As the digestion process requires a lot of organs to work, a certain amount of energy and oxygen is needed.

In humans, the regulation of the system is under the control of the central nervous system (in this case, the autonomous nervous system (ANS)) but also under the control of its own nervous system. The ANS will then give priority to the digestive system for access to blood flow.

The ANS has two ways of operating: The sympathetic nervous system, designed to react in a situation of danger, and the parasympathetic nervous system, designed to relax the body. The digestive system is controlled by this one. To know more about the fonctionnement of your nervous system (and you should), go check the chapter The Nervous System

The two systems can't work simultaneously, that's why your digestion is disturbed when you're under stress. So if you should take away from this course one thing, it would be: be gentle with your little brain, when you're eating, you're eating, you're not preparing to fly away as fast as possible. It will spare you stomach cramps. Don't do it for you, do it for your brain ;)

Or take example on cows: evolution would have selected rumination as an answer to predation. Wild ancestors of cows shovelled into their rumen a huge amount of grass before taking cover. There the food went again in the mouth and was allowed to be quietly chewed.

B) Mechanical digestion

The mechanical digestion reduces the size of the macroelements. It helps to make the molecules more accessible by the enzymes and the acids playing a role in the chemical process.

As we said before, molars are used to grind food. Other structures are used to do so. For example, in some bird's gizzard (and also in snails stomach) , one can find some small rocks. With the contraction of muscles, the rocks mash the content of the gizzard.

The contraction of muscles also helps the content of the digestive system to move forward.

C) Chemical process

The chemical process begins as soon as food enters the organism. Water or saliva wet and soften the elements that are then more easily mashed by the mechanical digestion. In the saliva, one can find some enzymes that begin the lysis of the elements.

Spiders even have saliva so badass that it liquefy prey… Yup, spiders can't eat solid flesh, only liquid…

Saliva may be used for other things than digestion. Obvious example: cats (the nightmare of JPP) lick their fur to clean it. Another non obvious example: female mosquitoes use saliva to localize blood vessels. Apparently, mosquitoes saliva creates a little hematoma below the skin, that allows the buds to easily detect where the blood is.

On average, a human produces 1,5L of saliva per day. Miam.

Digestive enzymes are also found in the pouch (stomach, gizzard, intestine, rumen …) where the digestion occurs, in animals but also in the tract of carnivorous plants. There are different types of digestive enzymes, according to the type and specificities of the biomolecule they are digesting. For an illustration, an herbivorous, as it eats plants, has to digest more complex molecules than a carnivorous. Think about the cellulose of vegetal extracellular matrix or the lignin of wood: there is a lot of glucoses bonded with strong bonds.

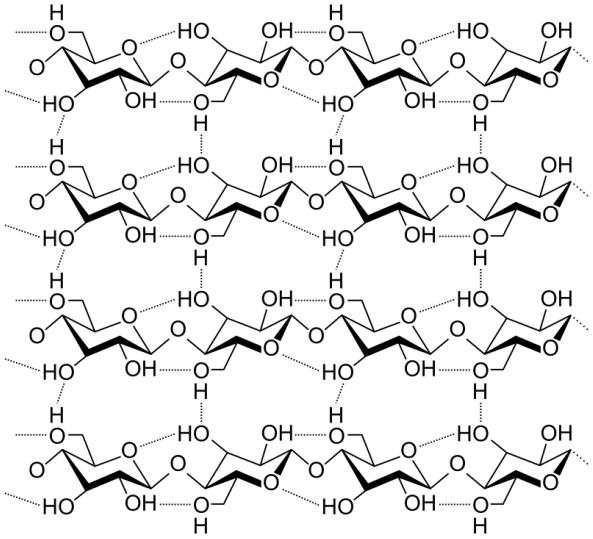

Figure 10: Portion of cellulose fiber.

One can find:

- Lipases (split lipids)
- Proteases and peptidases (split proteins into peptides and peptides into amino acids)
- Amylases (split carbohydrates into oses)
- Nucleases (split nucleic acids into nucleotides)

One can also find hydrochloric acid in the alimentary canal. The stomach indeed produces HCL that helps to denature proteins. They are therefore easier to be cut by the enzymes. The pH of the alimentary canal is thus very low, around 1,5 in the human stomach.

Actually this pH is a wonderful environment for all the microfauna that live inside us! (perfect transition). Yes, your stomach is a small ecosystem. You're currently hosting bacterias, ciliates, archaea and fungi. There's a battle inside you. You can know more about the dynamics of your little cutie ecosystem in the chapter Population Ecology.

Interestingly, your microflora is responsible for the presence and the smell of your *flatulences and eructations <3*

They eat in your plate and you absorb their wastes. What a symbiosis.

D) Absorption

As we're speaking of absorption, the alimentary canal is designed for it. In particular, the small intestine (all the Tetrapods and Teleosts -96% of fish- have one) is designed for efficient nutrient absorption.

To understand why, you need to know that absorption is a physical phenomenon limited by the width of a surface and optimized by its length. The small intestine is composed of deep folds and fingerlike protrusions as well as very thin layers of cells, that means that absorption is optimized as much as possible. The small intestine of an African bull elephant has a length of 19m! (it is approximately 9 Adonis + 1 headless Adonis).

The walls of the intestine are lined with blood vessels. The nutrients pass through intestine epithelial cells, then extracellular matrix and the interstitial liquid, then to the blood, in order to be transported toward organs.

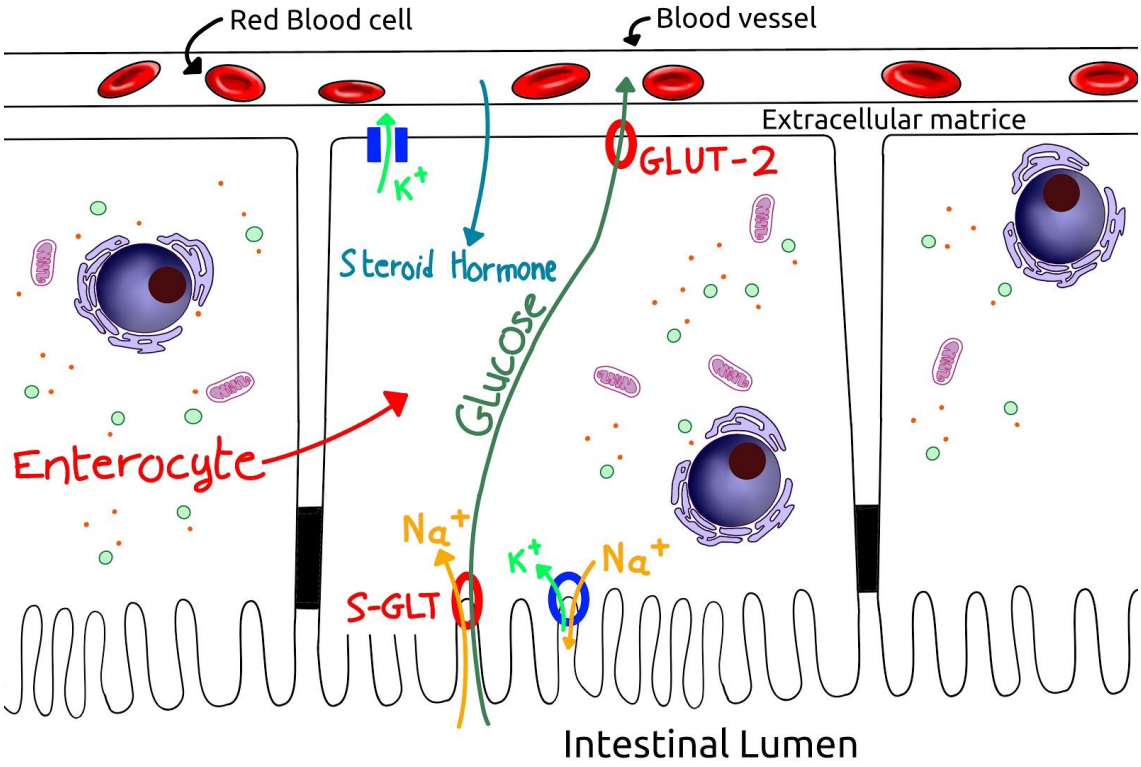

Figure 11: Transport of nutrients through intestine epithelial cells (called enterocytes): The transport of glucose
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The blood vessels are part of the circulatory system. This system is in charge of the transport of nutrients and oxygen, to provide everything needed to organs. The oxygen is provided by the

respiratory system, where exchange structures are specialized in the absorption of gas (by the way, carbon dioxide, which is a waste of the metabolism, is released out the same way). You'll learn a lot more in the chapter Gaz exchanges and circulation.

Just because it's cool: a human can swim in whale's arteries.

E) Complexity

Presented as we did, the digestive system seems calm and easy to understand. BUT.

As you guess, we make terrible simplifications.

Let's take an example: swallowing. It is a complicated process that requires coordinated activity of the tongue, palate, pharynx, and esophagus, over twenty-two muscle groups in all, controlled by separate regions of the brain.

At the same time, only when your parasympathetic nervous system is activated, your endocrine system joins the battle. Your cranial nerves V and IX stimulate the salivary glands to release saliva in the mouth. The stomach will receive the signal to release gastric juices. The pancreas will be stimulated by the cranial nerve X to release insulin and bicarbonate into the small intestine in order to neutralize the acid coming from the upper parts of the gastrointestinal tract.

And still, as you guess again, this is a terriiiiiible simplification.

Your body regulates each instant your biological constants, in an environment never at rest.

The mechanism in charge of these regulations is called homeostasis. It's a negative feedback loop, that is to say that when a variable is no more the standard value, the body induce balance.

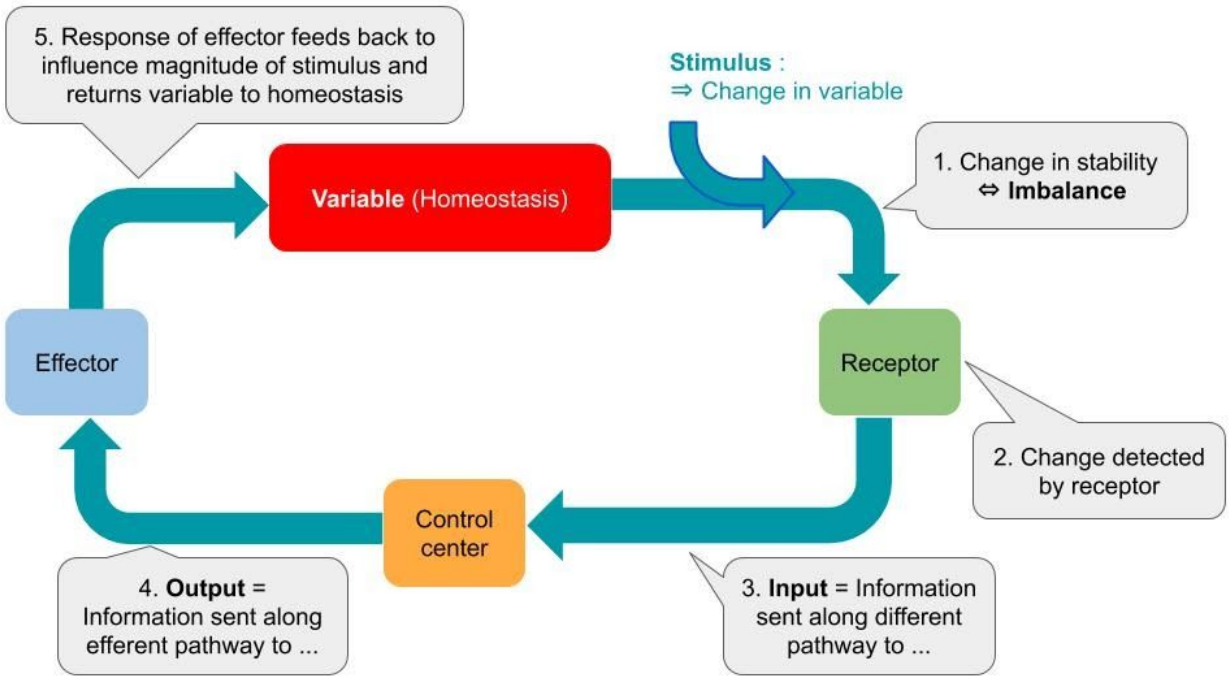

Figure 12: Homeostasis functionment: the evolution towards a stable equilibrium between interdependent elements
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For you to have an idea of the complexity of what is going on, the english wikipedia page of homeostasis record 17 cycles of regulation using homeostasis:

- Thermoregulation: *Animals able to control their inner heat are called homéotherms (in the contrary of heterotherms). Some will produce their own heat (like Mammals), they're called Endotherms. Some will find heat outside, with the sunlight for example. They are called Ectotherms.*
- Glycemia
- Iron levels
- Copper regulation
- Levels of blood gases
- Blood oxygen content
- Arterial blood pressure
- Calcium levels
- Sodium concentration
- Potassium concentration
- Fluid balance
- Blood pH
- Cerebrospinal fluid
- Neurotransmission
- Neuroendocrine system
- Gene regulation
- Energy balance

E) The end of the digestion or *It's time to go to the toilets.*

"Fecal matter can be used to judge the size of an elephant, since it retains its shape after falling to the ground"

That being said, let's talk about defecation.
Some components cannot be digested. For example, carnivores cannot digest lignin. Yet, once inside, it should go out. Wastes are dessicated, that is to say, the maximum amount of water is absorbed. In the human body, it's principally in the large intestine that water is absorbed, since the digestion is almost over and the water is more accessible.

So well, no magic in here, you just have to …. Get a bit of intimacy.

You can find a lot of interesting things in fecal matter. For example, some grains survive the digestion and finish their journey again in the soil. The acid would have strip the protection layer of the grain and allow it to germ. This beautiful phenomenon is called **endozoochory**.

Also, if you're a rabbit: welcome into the fantastic world of coprophagy (in order to digest multiple times those famous LIGNIN, agaiiin)

And now, our special guest: Urine!
The urine is basically some water full of wastes, found in blood. The kidneys, master in cleaning, have structures, called nephrons, that absorb all the nutrients and gaz of "coming blood", give again to the blood what is important (according to homeostasis) and eliminate the waste in urine.

III. Did we miss something?

JPP is full, he ate like he never did, he's full of energy!

Wait… Where does this energy come from?
We saw that the digestive system *uses* energy to split components into nutrients that are absorbed then on their way to other organs to be reused as elementary particles.

The answer is: *metabolism.*
Each action requires a certain amount of calories, which is the other name of kiloJoules. The break of covalent bonds release calories, in the form of potential energy: ATP.
The rate between the energy needed (for chemical reactions - Anabolism-) and the energy available (because of degradations - Catabolism -), is called the metabolic rate.

Cycle 2 : Reproduction

The time has gone to meet Lady JPP.

I. Interaction

JPP was sexually mature at 6 months old. Since then, he has learned what life is.

There are 3 main things that JPP needs to do in order to procreate.
First of all, he has to locate a partner. To do so, he uses the same senses that we describe before to locate food, in Cycle 1, part I- A). So we will not dwell further on the question, just read the chapter again…
Second of all, after locating his possible mate, how can he convince her to give him her flower ? That is where courtnership enters ! To know more about JPP sex life check the video below (It will just take 4 min of your time and it will change your vision of pigeons forevERRRR, so JUST DO IT !!!!!)

Pigeons sex life :https://www.youtube.com/watch?v=CVghGRZu6KE

Third of all, now that he found a partner that wants to mate with him, he needs to, I mean, do the … the thing … YOU KNOW !! So now, how do they do IT ? How do they allow their gammete to meet ?
To know more about this more technique part, I invite you to watch this wonderful documentary, I call it the Kamasutra of animal sex, recensing many ways animals do sex.

Call of the Wild: Sex in the Animal Kingdom (documentary 50mn)
https://www.youtube.com/watch?v=DIbclpS32qI
#AnimalPorn (If it's your thing we won't judge don't worry. Either way, it's a very handy documentary, so get your hands on it !)

II. Treatment

Reproduction (or procreation or breeding) is a biological process by which a “mother” organism produces a new individual using his genetic code. This principle is fundamental to all living organisms, by which the very definition of life is “the condition that distinguishes animals and plants from inorganic matter, including the capacity for growth, **reproduction**, functional activity, and continual change preceding death.” (by Google dictionary)[4]

[4] Irina : Everybody knows I loooove Google xD

There are two forms of reproduction that we will look at in this chapter : asexual and sexual reproduction.
Asxual reproduction is the most ancient form of reproduction.
But why did sexual reproduction appear in the first place? To answer this, let's imagine organisms as vessels, responsible for protection and transmission of the genes. (This is the theory of Richard Dawkins, "The Selfish Gene")
Looking at organisms as vessels whose sole purpose is to ensure the survival of the genes, we can indeed opt for 2 opposite ways to succeed. One of them would be to change as little as possible your initial genetic code (to conserve the genes, which is the exact purpose of the vessel). But what would happen in the case of a big catastrophe ? If the genes coding for the vessel are not able to permit the vessel to transmit his genetic information, the gene disappears, thus the vessel two. Here we just discribed asexual reproduction. To allow asexual reproduction to flourish, it need either a high tolerance to environmental changes, either a high reproduction rate (so many accidental mutation could occur and create **diversity**).
The second option would be to ensure diversity by mixing genes with another (closely related) organism. This is sexual reproduction. And that where The Selfish Gene takes all its beauty. This gene-centred view of evolution explains altruism. Indeed, the more two organisms are genetically related, the more sense (at the level of the genes) it makes for them to behave selflessly with each other.

And NOW ladies and gentlemen, let's dive into the marvelous world of asexuality ****cough cough**** euhh I mean Asexual Reproduction !! ****Tadadadadaddaaaaa****

1 - Asexual Reproduction

Asexual reproductin is the ability to reproduce without the involvement of another organism by creating a genetically similar or identical copy of itself. (Ohh WoW :O !! A true feminist society …) Despite what you might have been thinking, asexual reproduction is not limited to single-celled organisms. Indeed, cloning for instance is a form of asexual reproduction.

We can identify many kinds of asexual reproduction in the animal kingdom, such as binary fission, fragmentation, budding, parthenogenesis …

Binary fission is the simplest of them all, it is exactly what you think, aka when an organism literally split in half.
Corals and Echinoderms (starfish, sea urchins, sea cucumbers …) reproduce through fragmentation, in which an organism is split into multiple daughter fragments that develop into fully grown individuals that are identical to their parents.

Hydras are invertebrates that are able to reproduce by budding (outgrowth due to cell division at one particular site). Thus they will splitt themselves into two or more copies of themselves. However, even if hydra and jellyfish are able to reproduce asexually, they may also reproduce sexually.

Many invertebrates (such as water fleas, aphids, some bees and parasitic wasps), and some vertebrates (like reptiles, fish, rarely birds and sharks) are able to reproduce asxualy by parthenogenesis. It is the development and growth of embryo without fertilization by a male. In these cases, the female will literally clone herself.

Mmmh, That was interesting, don't you think? Either Way, now let's talk about sex babiiiiiii **__NOPE, still not right … OK let's do it again__** Either Way, now let's talk about Sexual Reproduction !!

2 - Sexual Reproduction

For sexual reproduction to occur, you will need interaction of gametes belonging to 2 individuals of the same species. Gametes are specialized haploid cells containing half the number of chromosomes of normal cells. They are created by meiosis. They fuses with one another during fertilization, where typically a male procreate with a female to create a fertilized zygote.
Let's now consider a pair of gametes that are able to fuse. They can be of the exact same type, same size, same shape (it is called isogamy), or they can be morphologically distinct.
Some individuals can produce different kinds of gametes from one another. In the case of anisogamy, we distinguish in the species 2 kinds of individuals, those that produce large gametes called ovum or egg cell ⇒ The Females, and those that produce complementary and smaller gametes called sperm ⇒ The Males. In this case, the male brings only half of the genetic code, the female brings the rest to allow the cell to function well. The combination of those two gametes from both parents is called allogamy.
But there is another way … A darker way ...
A few types of organisms decided not to go with the flock, and because binarity is boring, they decided to have MORE THAN TWO SEXES !!!!! Indeed, many fungi and the ciliate Paramecium aurelia are examples of this. But yeah I know they are not animals, either way it's still cool to know.
Don't worry, for those of you who can't stand people other than yourself, there is also a way for you to reproduce ! It is called self-fertilization, also known as autogamy. It occurs in hermaphroditic organisms (an individual that can produce gametes of both sex) like snails and earthworm. The two gametes that fuse during fertilization are from the same organism.

The fertilized zygote will grow into a new organism who will share traits from both his parents.
Organisms that reproduce through sexual reproduction have different sets of genes for every trait (called alleles). This offspring will inherit one allele for each trait from each parent.
So, it will have a combination of the parents' genetic code.

III. Output

Now that we have seen that JPP is capable of having sexual interactions, we should definitely study what's going to happen for that brand new zygote.

There are two options depending on the type of animals we are considering : viviparous, oviparous and ovoviviparous.
Viviparity which means "live birth" is the development of the embryo inside the body of the parent giving birth to live offspring. On the other hand, oviparous, meaning "egg birth" gives birth to eggs that must develop before hatching externally from the mother. Finally, there are ovoviviparous animals, or ones that produce eggs but retain them inside the female body until hatching occurs, so that "live" offspring are born.

If we first consider the inner functioning of viviparous, fecondation marks the beginning of the prenatal period also called prenatal development which is determined with three stages : the pre-embryonic stage, which is a period of cell division and initial differentiation (cell maturation), the embryonic period, or period of organogenesis, and the fetal period, which is characterized by the maturation of tissues and organs and rapid growth of the body.
After a few days (4 days for humans) the zygote is divided in multiple cells and have become a blastocyst which will release digestive enzymes to bind to the uterus's wall and then become what we all know as an embryo.
This is where a really important enzyme will being produce by the cells to stimulates the corpus luteum (the remaining of the ovarian follicle) in the ovary for the secretion of estrogens and progesterone : the Human Chorionic Gonadotropin (HCG). This will support pregnancy and prevent menstruation.
Fun fact : This is the hormone which is detected in pregnancy tests !

The placenta is here a real interesting and main actor in the development of the embryo. It acts as the main endocrine gland during pregnancy (endocrine system) and produces estrogens and progesterone, two enzymes that will permit the uterus and breasts to enlarge and to maintain pregnancy.
It also and mostly permits all exchanges with the cardiovascular system, including oxygen and nutrients.

Considering the oviparous and ovoviviparous now, the inner functioning is a bit different… And it's considering our dear JPP !
Ovoviviparous animals are similar to viviparous species except that there is no placental connection between the foetus and the mother. And that's what makes all the difference !
To resolve the problem of nutrients exchange, the embryo is supplied by the "yolk", a nutrient-bearing portion of the egg whose primary function is to supply food for the development of the embryo. This part of the egg contains vitamins, minerals, proteins and lipids.
The particular fact about these two functions is that parents have to take care of the eggs against exterior parameters (temperature, hygrometry, weather) and possible predators ! This includes smoldering, building nets and protecting the eggs which appeals to all other systems that we studied before !

Okay fine, they had sexual relations, the fecondation happended and the pregnancy went well. Finally, the mother delivers the baby (or the egg hatch); but still, there's still a thing we didn't talk

about and include many fundamentals systems : how does the mother recognize her new-born baby ??

We are here talking about mother-child identification and that “simple” but essential principle rests on chemical signals. In fact, odor cues from newborns are absolutely salient to their mothers. Mothers are able to distinguish the odor of their own newborn baby from that of other newborns thanks to “pheromones”, chemicals capable of acting like hormones which are secreted and trigger social response in members of the same species.