# Environmental toxicology

## INTRODUCTION TO ENVIRONMENTAL TOXICOLOGY & TOXICOLOGICAL CONCEPTS

**LAB. 1**


علوم البيئة \المستوى الثالث

م.م ياسمين شاكر محمود

# Introduction to Environmental Toxicology

- It is **best defined as** the study of the fate and effects of toxic substances on an ecosystem and is based on scientific research employing both field and laboratory methods.
- as it is related to environmental toxicology **requires** an understanding of ecologic principles and theory as well as a grasp of how chemicals can affect individuals, populations, communities, and ecosystems.
- Environmental toxicology **builds on** the science of toxicology and the principles of toxicological testing, though its emphasis is more at the population, community, and ecosystem levels

# Introduction to Environmental Toxicology

- Toxins are poisonous substances **produced by**
- plants (Phytotoxins),
- animals (Zootoxins),
- bacteria (Bacteriotoxins);
- a substance is toxic **when it** acts to destroy or impair cellular function.

# Introduction to Environmental Toxicology

- The term **venom** refers to poisonous substances secreted by certain animals, such as bees, spiders, and snakes.
- When substances produce symptoms that are popularly referred to as intoxication (or poisoning) they are referred to as toxicants.
- There are **naturally occurring toxicants**, as well as toxicants that result from technological advances involving the manufacture and use of chemicals in industry and agriculture

# Introduction to Environmental Toxicology

- For many decades infinite dilution was a common solution to the problem of **waste disposal**. Vast oceans (hydrosphere), land (lithosphere), and air (atmosphere) were the "buckets" in which "drops" of potentially toxic wastes were diluted—indeed, waste disposal was viewed as just that—a "drop in the bucket."
- **Hazardous waste** is defined as waste that, because of its biological, chemical, or physical characteristics, or quantity or concentration, may pose a danger of morbidity (disease) and mortality (death) to organisms.

# Toxicological Concepts

- **Toxicity,** the state of being poisonous, is also a general term used to indicate adverse effects or symptoms produced by poisons or toxicants in organisms.
- Toxicity will vary according to both the **duration and location** of exposure to the toxicant, as well as the species-specific responses of the organism.

# Four distinct types of toxicity characterize the duration and location of the poisonous state

- **1- Acute toxicity**: involves a sudden onset of symptoms that last for a short period of time, usually less than 2hours. * The cellular damage that produces the symptoms associated with acute toxicity is usually reversible, resulting in recovery by the organism from the adverse effects brought on by the toxicant.
- **2- Chronic toxicity** results in symptoms that are of a long, continuous duration. The permanent nature of chronic toxicity is due to the irreversible cellular changes that have occurred in the organism. If cellular destruction and the related loss of function are severe, the organism may die

- **3- Local toxicity** occurs when the symptoms are restricted to the site of initial exposure to the toxicant.
- However, when the adverse effects occur at sites far removed from the initial site of exposure the term
- **4-Systemic toxicity** is used. The ability for toxicants to be absorbed at one site and distributed to a distant region, such as an organ, results from transportation within the organism via the blood or lymphatic circulatory systems
- Exposure to Carbon Tetrachloride **(CCl4)** , an organic solvent used in industry, provides an example of the different types of toxicity. At high concentration for a short period of time, exposure to CCl4 vapors may result in toxicity and could involve minor eye and throat irritations.
- But the toxicant is now absorbed through the skin or oral and ocular mucosa, it may **enter the bloodstream** and be transported via the blood to the **brain**

toxicity is also classified according to the timing between exposure to the toxicant and the first appearance of symptoms associated with toxicity.

- **1- Immediate toxicity** results when the symptoms occur rapidly within seconds or minutes following exposure to the toxicant.
- **2- Delayed toxicity** adds to the difficulty in establishing the cause-and-effect relationship.
- For example, diethylstilbestrol (DES) is a nonsteroidal drug prescribed for women during pregnancy to prevent miscarriage. It is now known that daughters born to mothers who took DES are at risk for developing vaginal and cervical cancers during adolescence.

# Lab.2
# Toxicological concepts

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# Toxicological concepts

**Toxicokinetics** is the study of 5 time-dependent processes related to toxicants as they interact with living organisms

**Absorption**: how toxicants enter the organism

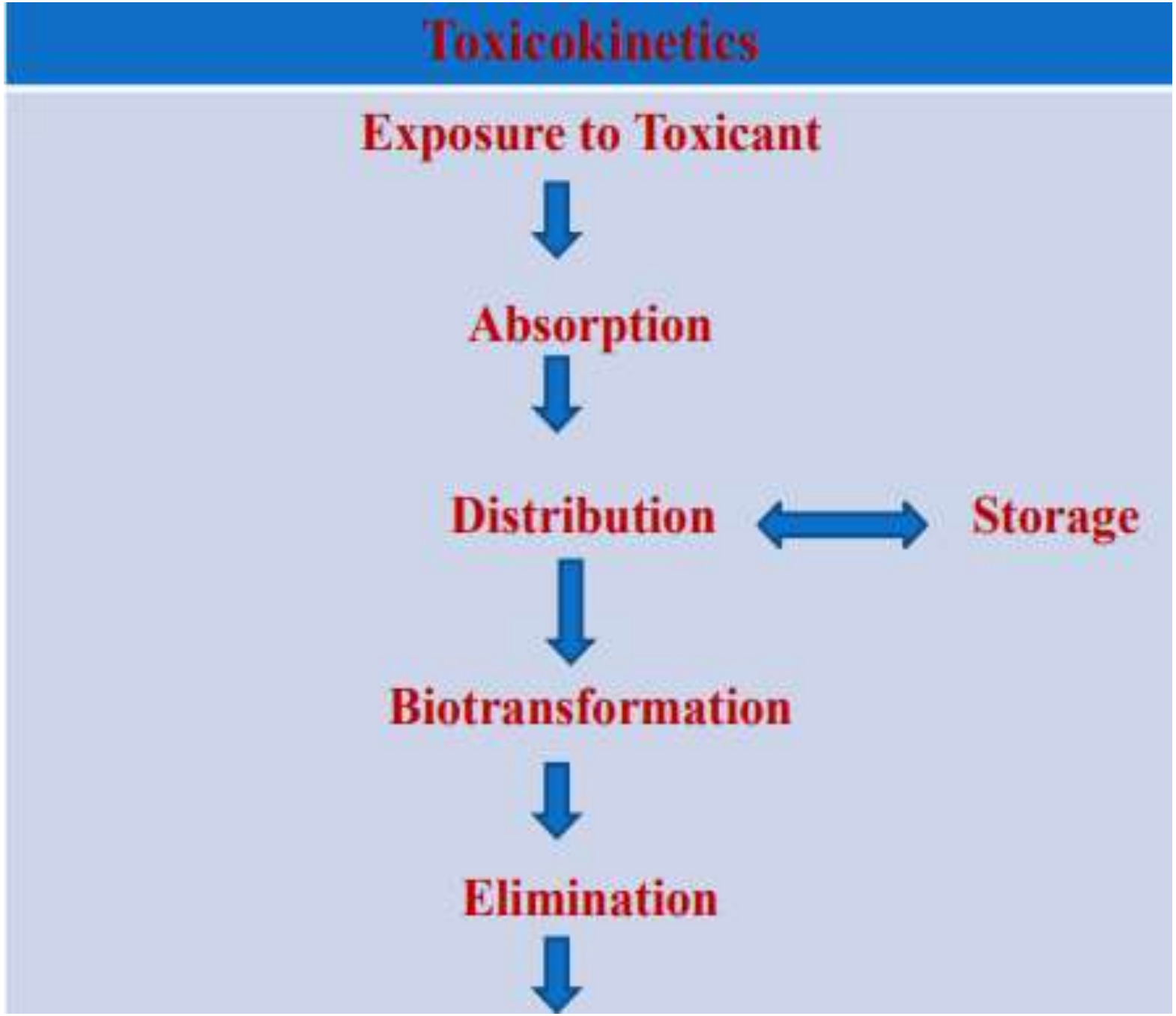
**Distribution**, how toxicants travel within the organism;

**Storage**, how some tissues preferentially harbor a toxicant;

**Biotransformation**, how toxicants are altered (or detoxified) by chemical changes in the organism

**Elimination**, how toxicants are removed from the organism

# Toxicokinetics



# Toxicokinetics

- An understanding of the time-dependent behavior of a toxicant as related to its: Absorption, Distribution, Storage, Biotransformation, and Elimination is necessary to explain how toxicants are capable of producing : local or systemic toxicity, acute or chronic toxicity, and immediate or delayed toxicity.
- **Toxicodynamics examines** :the mechanisms by which toxicants produce unique cellular effects within the organism.
- If toxicants exert their influence at the level of the cell, the mechanisms will involve Cellular components.

# Toxicokinetics

- Whether reversible or irreversible cellular injury occurs will depend on the duration of exposure as well as the specific toxicokinetic properties of the toxicant

- Classification of Toxicants:  Many classification schemes for toxic agents have been proposed. No single classification system can be expected to adequately distinguish all known toxicants.

| Classification | Categories |
|---|---|
| Physical state | Gas, liquid, solid, dust |
| Use | Pesticide, solvent, food additive |
| Chemical structure | Aromatic amines, aliphatics, glycols |
| General action | Air pollutants, chronic poisons, industrial toxins |
| Effect | Carcinogens, mutagens, teratogens |
| Target organ | Neurotoxins, hepatotoxins, nephrotoxins |
| Mechanism of action | Stimulants, inhibitors, blockers |
| Poisoning potential | Slightly toxic, moderately toxic, supertoxic |
| Labeling requirement | Oxidizer, acid, explosive |
| General or use class | Plastics, organic chemicals, heavy metals |

# Determination of Toxicity

- **Toxicity testing involves four steps**.
- First, a test organism must be selected. Plants or animals can be used. Algae, bacteria, mice, rats, rabbits, or nonhuman primates are often selected as the test organisms.
- In vivo (in life) studies use the whole organism for toxicity testing. Humans, for moral and ethical reasons which are culturally defined, are normally not chosen as the test organisms

- **Second, the response (end effect)** to be observed and recorded must be selected. The response needs to be easily observable and quantifiable.
- Of the many possible responses, some that are commonly used include changes in the total number of cells in a bacterial colony, the presence or absence of biochemical products produced by cultured cells, changes in cell morphology, number of tumors produced, alterations in sleep patterns, and changes in growth and development of an organism

- Third, a selection of the duration of the test or exposure period is necessary: The duration may range from a few seconds to years, depending on the type of test being performed.
- Eye irritant tests may only take a few seconds, whereas reproductive studies may take years, particularly when multiple generations are examined

- Fourth, doses to be tested are selected. For in vivo studies the dose is expressed as the weight in milligrams (mg) of the substance being tested per kilogram (kg) of body weight of the experimental organism.
- For in vitro toxicity testing, the weight in milligrams (mg) of the substance being tested per milliliter (mL) of medium containing the cells expresses the dose, written as mg/mL.

# Determination of Toxicity

| Organism | Weight (g) | Dosage (mg/kg) | Dose (mg/animal) |
|---|---|---|---|
| Mouse | 25 | 100 | 2.5 |
| Rat | 250 | 100 | 25 |
| Guinea pig | 500 | 100 | 50 |
| Rabbit | 1,500 | 100 | 150 |
| Cat | 2,500 | 100 | 250 |
| Monkey | 5,000 | 100 | 500 |
| Dog | 10,000 | 100 | 1000 |
| Human | 75,000 | 100 | 7500 |

# *Environmental toxicology*

## علوم البيئة\المستوى الثالث

## Lab. 3

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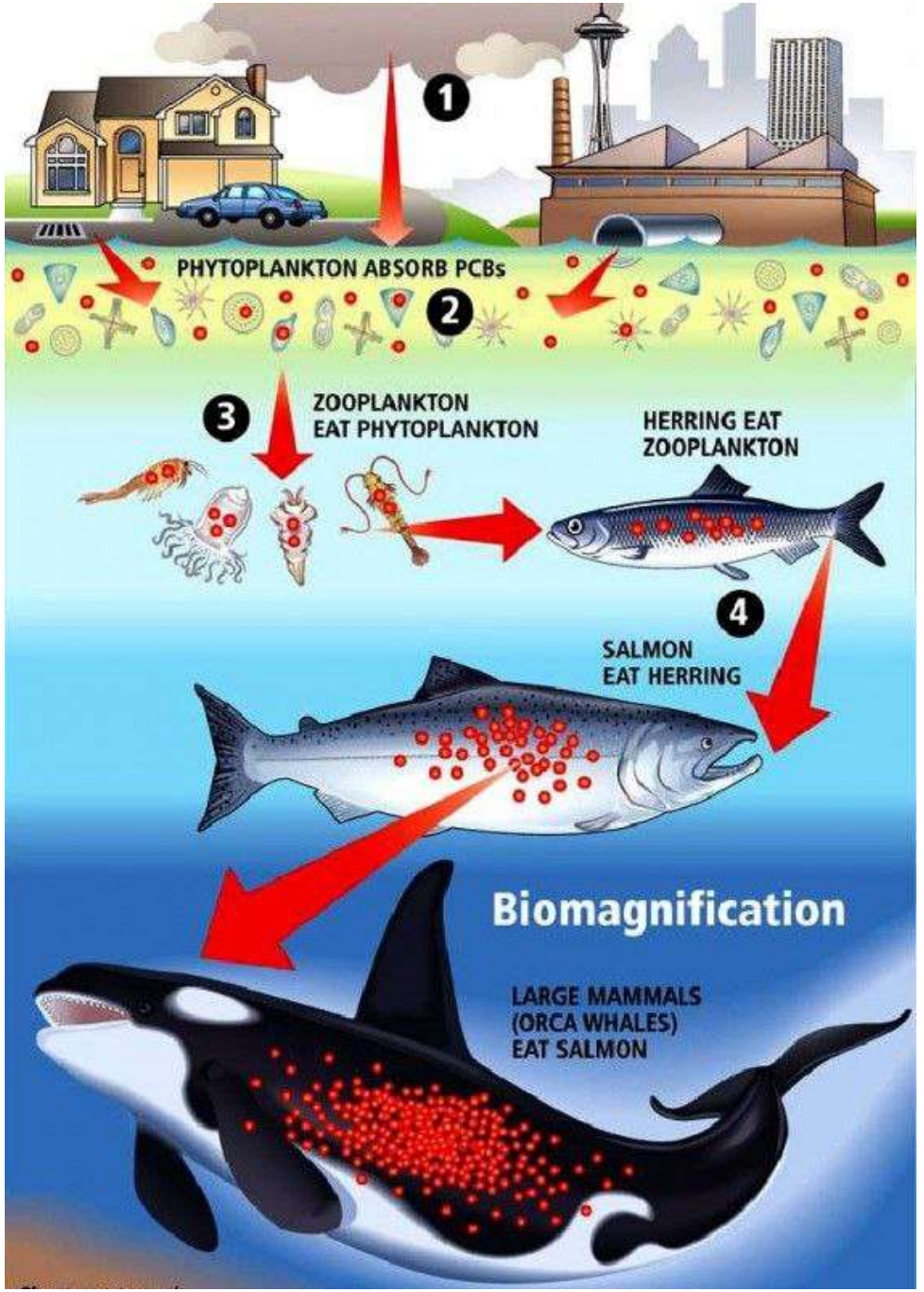
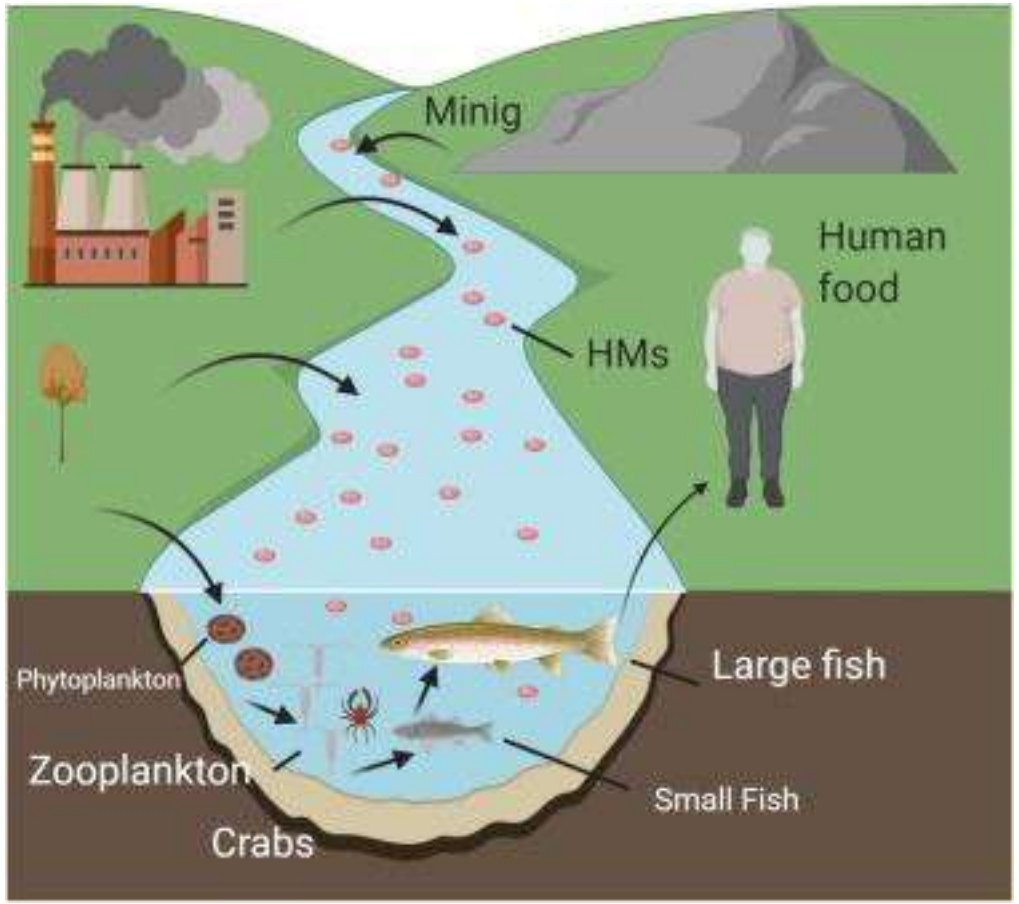
# Harmful effects of toxins

- Harmful effects of chemical and biological agents can include toxins from pollutants, insecticides, and pesticides . All of which can impact an organism and its community through shifts in species diversity and abundance
- Resulting change in population dynamics impact the ecosystem by altering its productivity and stability
- There are many sources of environmental toxicity that can lead to the presence of toxins in our food, water and air
- These sources include organic and inorganic pollutants , pesticides and biological agents , all of which can have harmful effects on living organisms

# Pollutants polychlorinated biphenyls (PCBs)

- Are organic pollutants that are still present in our environment today despite being banned in many countries
- Due to the persistent nature of PCBs in aquatic ecosystems, many aquatic species contain high levels of this chemical
- Foe example, fish farmed salmon have been shown to have significantly higher PCB levels


1
PHYTOPLANKTON ABSORB PCBs
2
3
ZOOPLANKTON
EAT PHYTOPLANKTON
HERRING EAT
ZOOPLANKTON
4
SALMON
EAT HERRING
Biomagnification
LARGE MAMMALS
(ORCA WHALES)
EAT SALMON




# Heavy metal

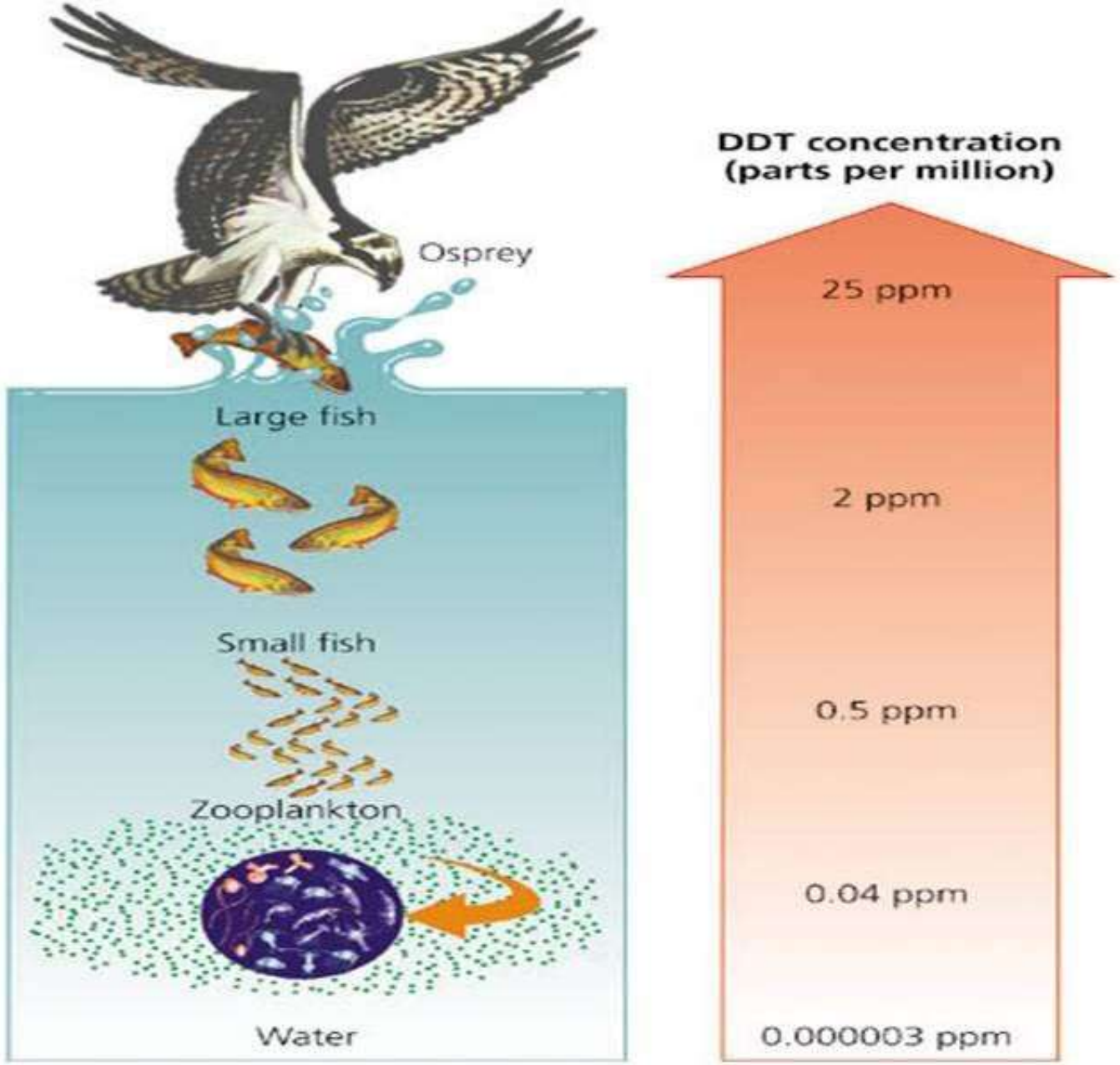
- Heavy metals found in food sources , such as fish can also have harmful effects
- These metals can include mercury, lead, aluminum and cadmium
- It has been shown that fish are exposed to higher cadmium levels and grow at a slower rate than fish exposed to lower levels or none.

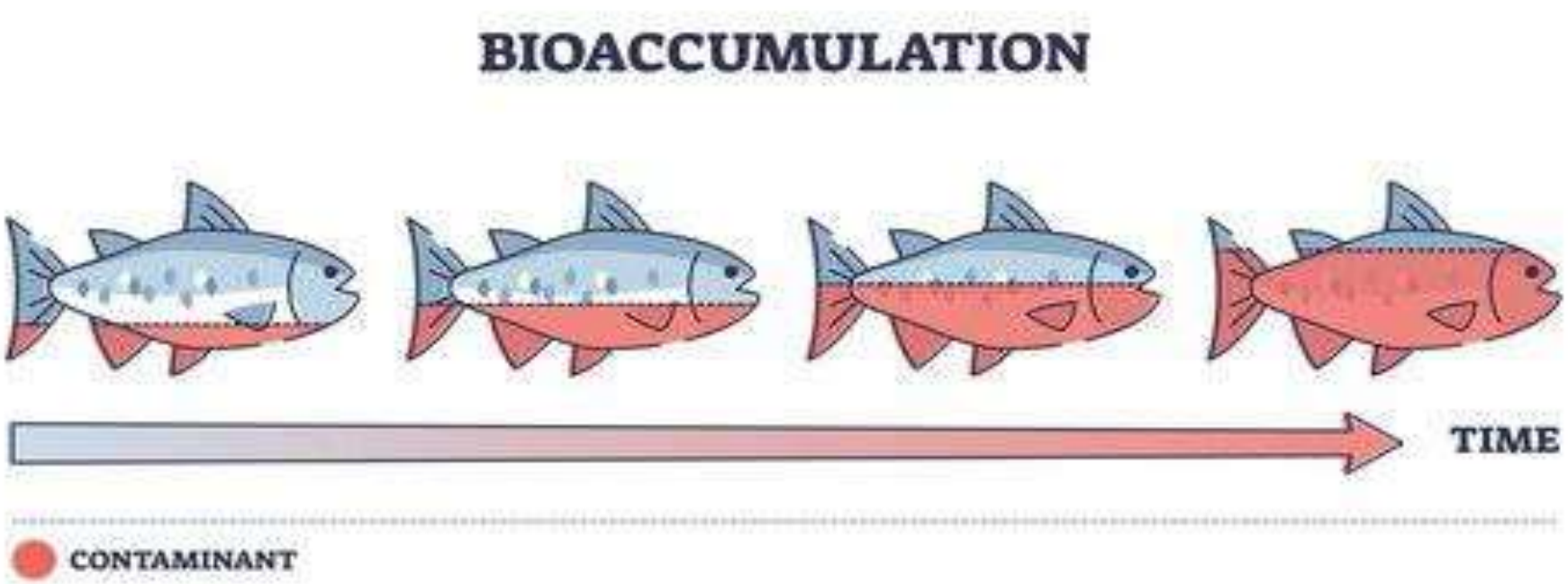
# pesticides

- Are a major source of environmental toxicity.
- These chemically synthesized agents have been known to persist in the environment long after their administration
- The poor bio-degradability of pesticides can result in bio-accumulation of chemicals in various organisms along with bio-magnification within a food web
- Pesticides can be categorized according to the pests they target
- Insecticides are used to eliminate agricultural pests that attack various fruits and crops
- Herbicides target herbal pests such as weeds and other unwanted plants that reduce crop production

# Dichlorodiphenyltrichloroethane DDT

- Is an organochlorine insecticide that has been banned due to its adverse effects on both humans and wildlife
- DDT was widely used by farmers in order to kill agricultural pests
- Large quantities of DDT and its metabolite Dichlorodiphenyldichloroethylene (DDE) that were released into the environment were toxic to both animals and humans
- DDT is not easily biodegradable and thus the chemical accumulates in soil and sediment runoff
- Water systems become polluted and marine life such as fish and shellfish accumulate DDT in their tissues
- This effect is amplified when animals who consume the fish also consume the chemical , demonstrating bio-magnification within the food web


Osprey
Large fish
Small fish
Zooplankton
Water
DDT concentration
(parts per million)
25 ppm
2 ppm
0.5 ppm
0.04 ppm
0.000003 ppm


BIOACCUMULATION
TIME
CONTAMINANT
BIOMAGNIFICATION

# Environmental toxicology

## علوم البيئة\المستوى الثالث

Lab. 4

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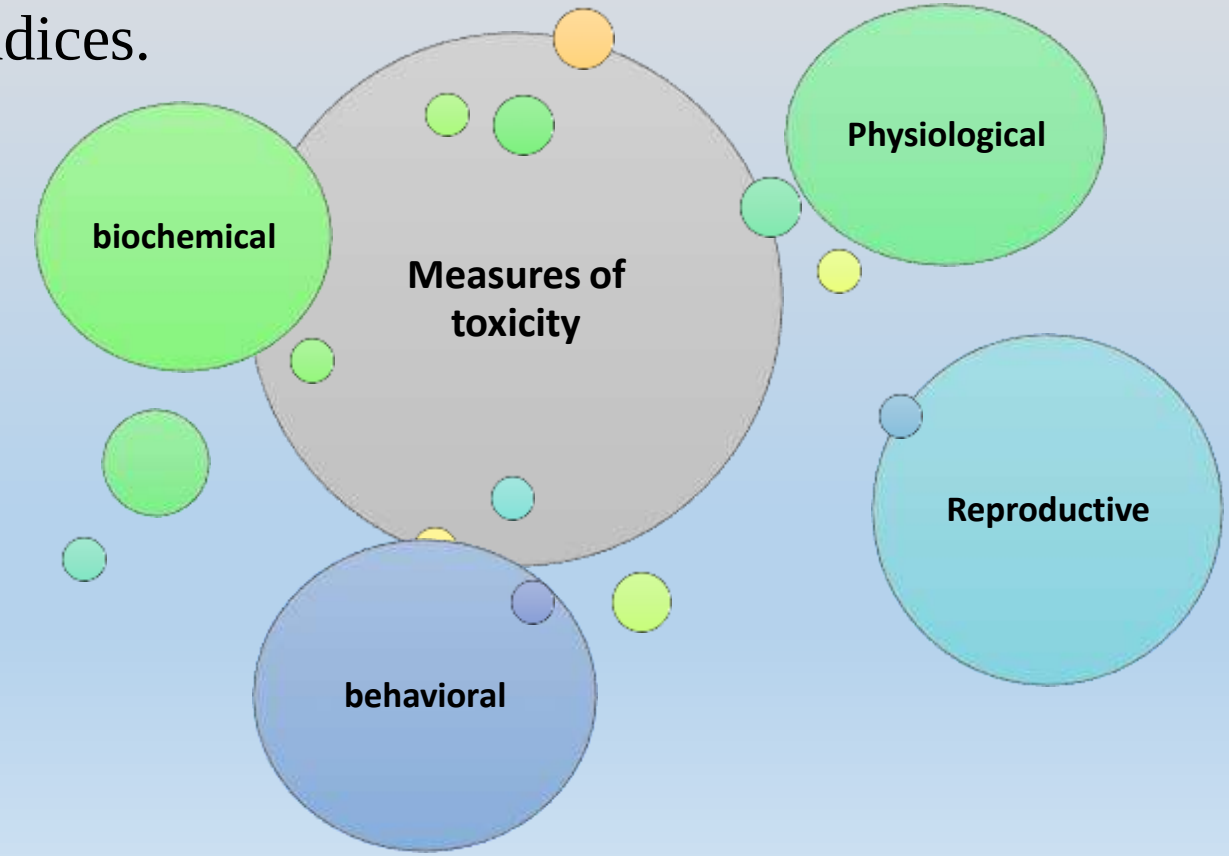
# Effect of pollutants on organisms

- Toxicity testing: Of central importance in both toxicology and ecotoxicology is the relationship between the **quantity** of chemical to which an organism is exposed and the nature and **degree of consequent harmful (toxic) effects.**
- **Dose response:** relationships provide the basis for assessment of hazards and risks presented by environmental chemicals.
- this simple basic concept immediately raises questions about the definition of poisons because **everything depends on dose**
- **No** chemicals are poisonous **if** the dose is low enough, whereas **all** chemicals are poisonous **if** the dose is high enough

**All substances are poisons; there is none that is not a poison**

# Effect of pollutants on organisms

- There are many different ways in which toxicity can be measured
- Most commonly, the measure (end-point) is death, although there is a growing interest in the use of more sophisticated indices.



# Toxicity tests

- Many toxicity tests provide an estimate of the dose ( or the concentration in food, air or water) which will cause a toxic response at the 50% level

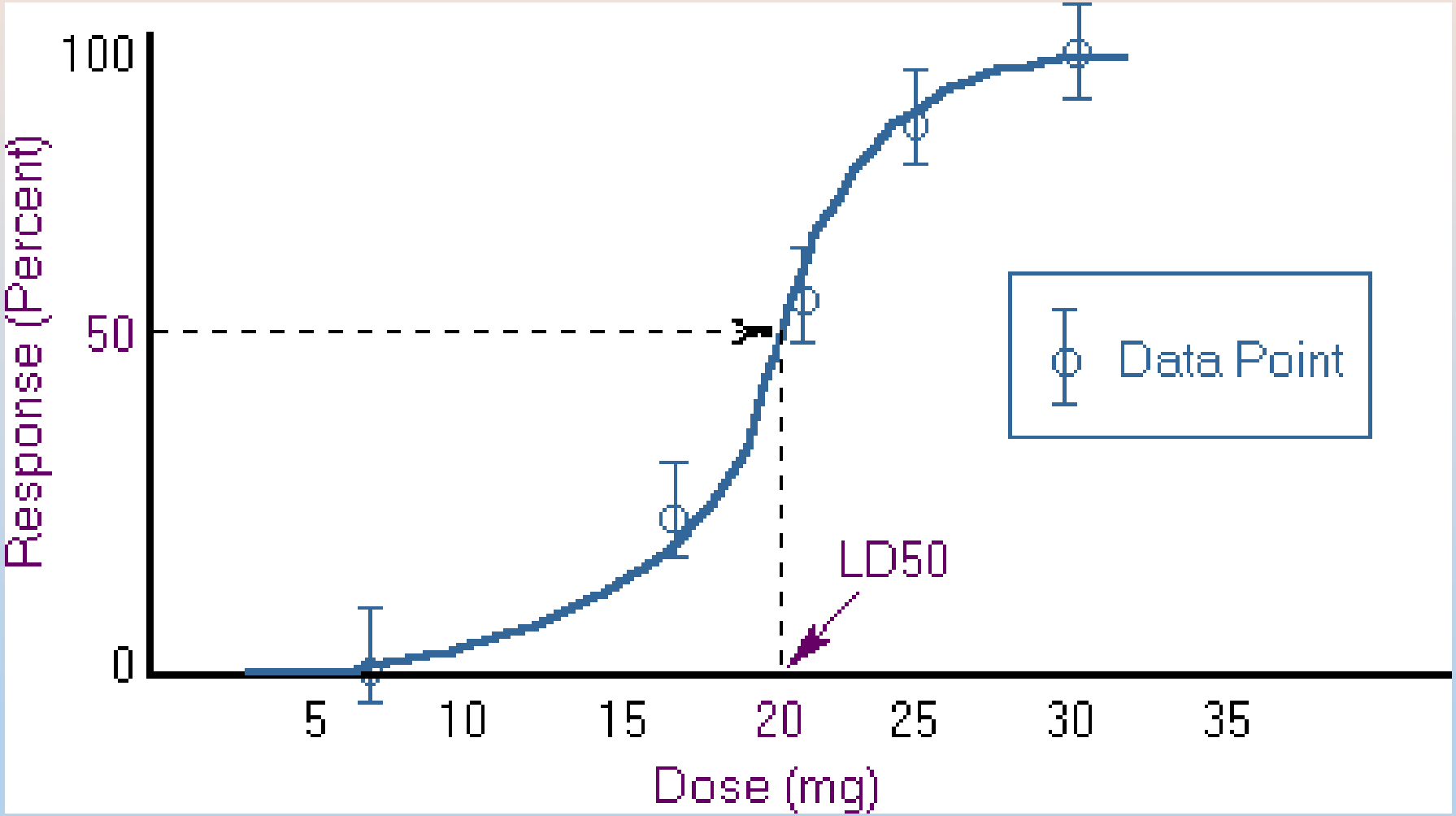
- It is also possible to establish the highest concentration or dose that will not cause an effect

**LD50**= the median lethal dose that kill 50% of a population

# Terms used in relation to toxicity testing

- LD50 = represents the median lethal dose
- LC50 = represents the median lethal concentration
- NOED= represents the no observed dose
- NOEC= represents the no observed concentration


- In practice, the data from toxicity tests usually depart from normal distribution when approaching the extremes of 0% and 100%


100
50
0
Response (Percent)
5
10
15
20
25
30
35
Dose (mg)
LD50
Data Point

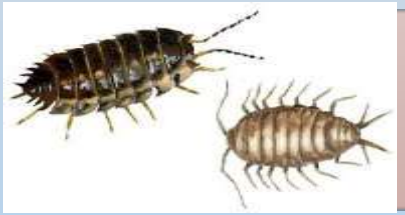
# Toxicity testing with vertebrates

- The toxicity of chemicals to mammals, birds and other vertebrates has commonly been measured as a median lethal dose (LD50).
- The percentage of animals which die in each group over a fixed period following dosing is then plotted against the log of the dose .
- To obtain a straight line relationship between dose and mortality

# Toxicity testing with invertebrates

The **earthworm tests** mainly measure effects of chemicals that pass across the body surface.

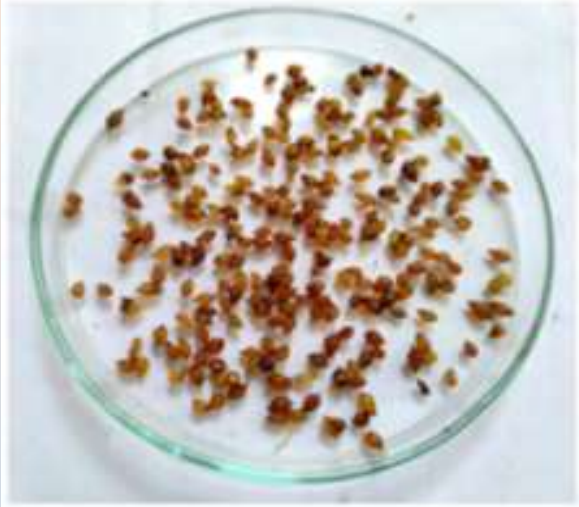
The **springtail test** measures effects on reproduction, again mainly through contact poisoning of the adults, their eggs or juveniles that hatch from the eggs.



The **isopod test** measures the effects of chemicals on feeding rates, mainly through feeding repellence.

The **bee test** is designed to assess the effects of chemicals on ‘beneficial insects

No pesticide exposure



High number of cocoons

More juveniles

Pesticide exposure reduces the reproductive ability of earthworms

Pesticide exposure

Less number of cocoons

Less juveniles

# Toxicity testing with aquatic organisms

- With aquatic organisms, direct uptake from water is a route of major importance (e.g. uptake across the gills of a fish or across the permeable skin of amphibian).
- Uptake can also occur from food during its passage through the alimentary system and bottom-dwelling organisms are exposed to residues in sediment.

# Environmental toxicology

# علوم البيئة\المستوى الثالث

Lab. 5

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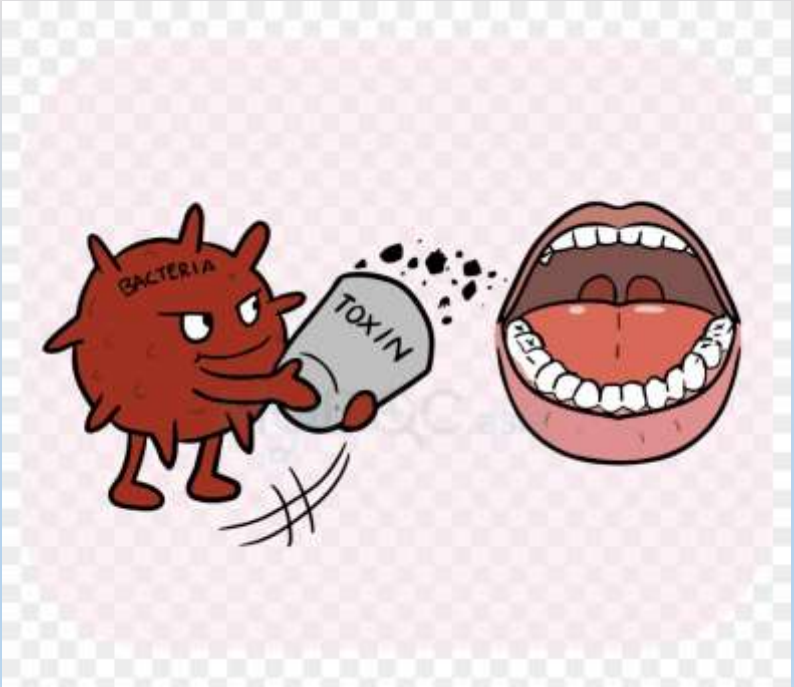
# Microbial toxins

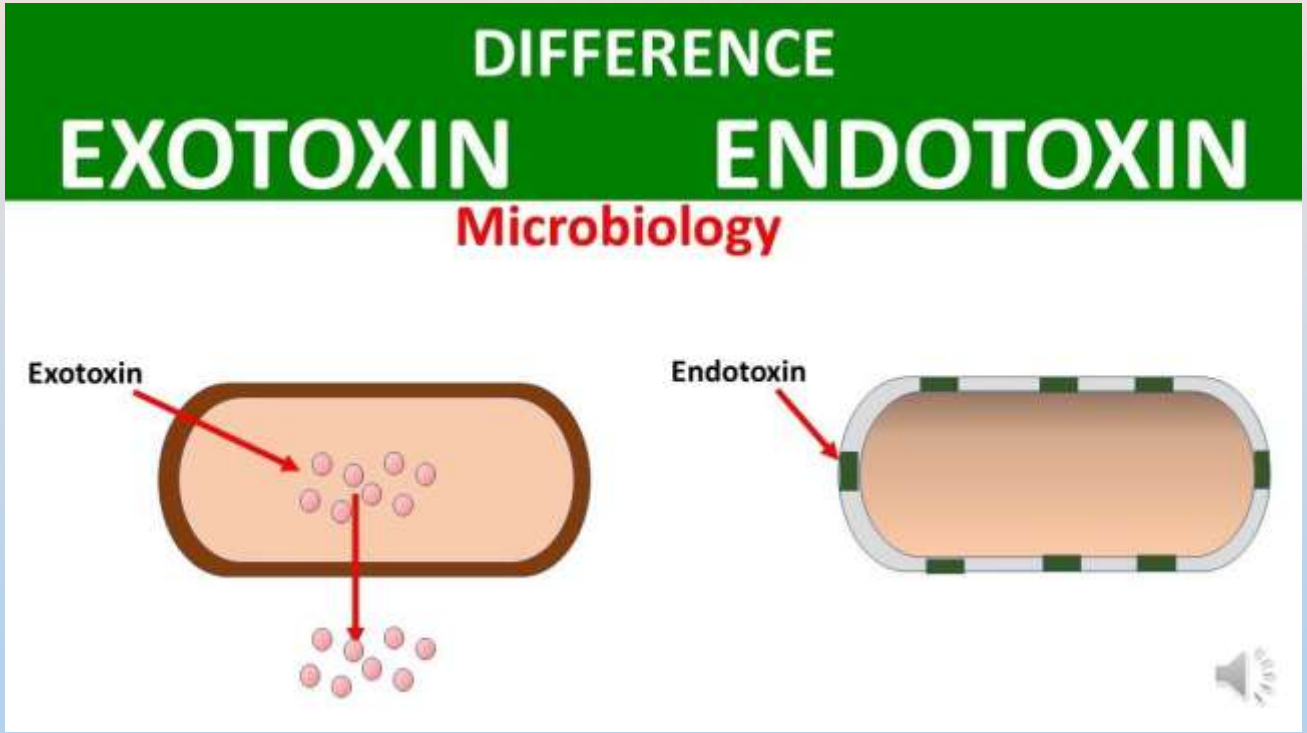
- Are toxins produced by microorganisms, including bacteria, viruses and fungi.
- Ubiquitous distribution



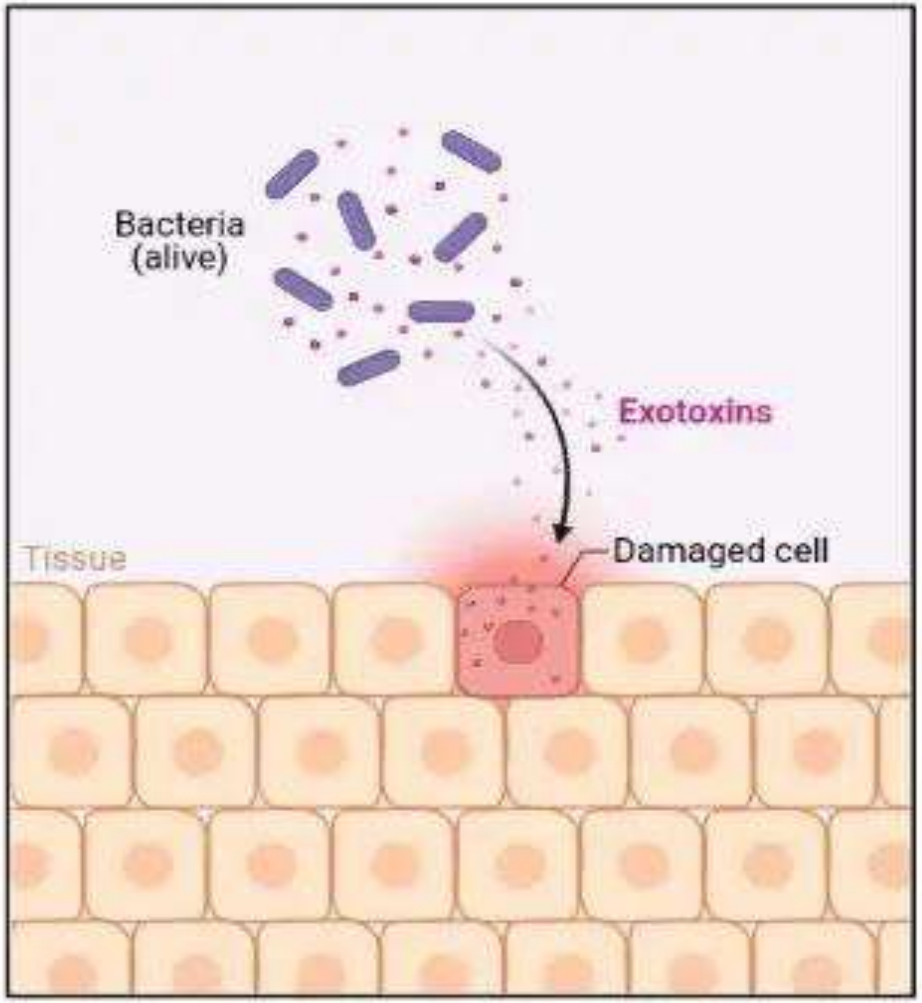
# Different types of microbial toxins

- **Bacterial toxins**

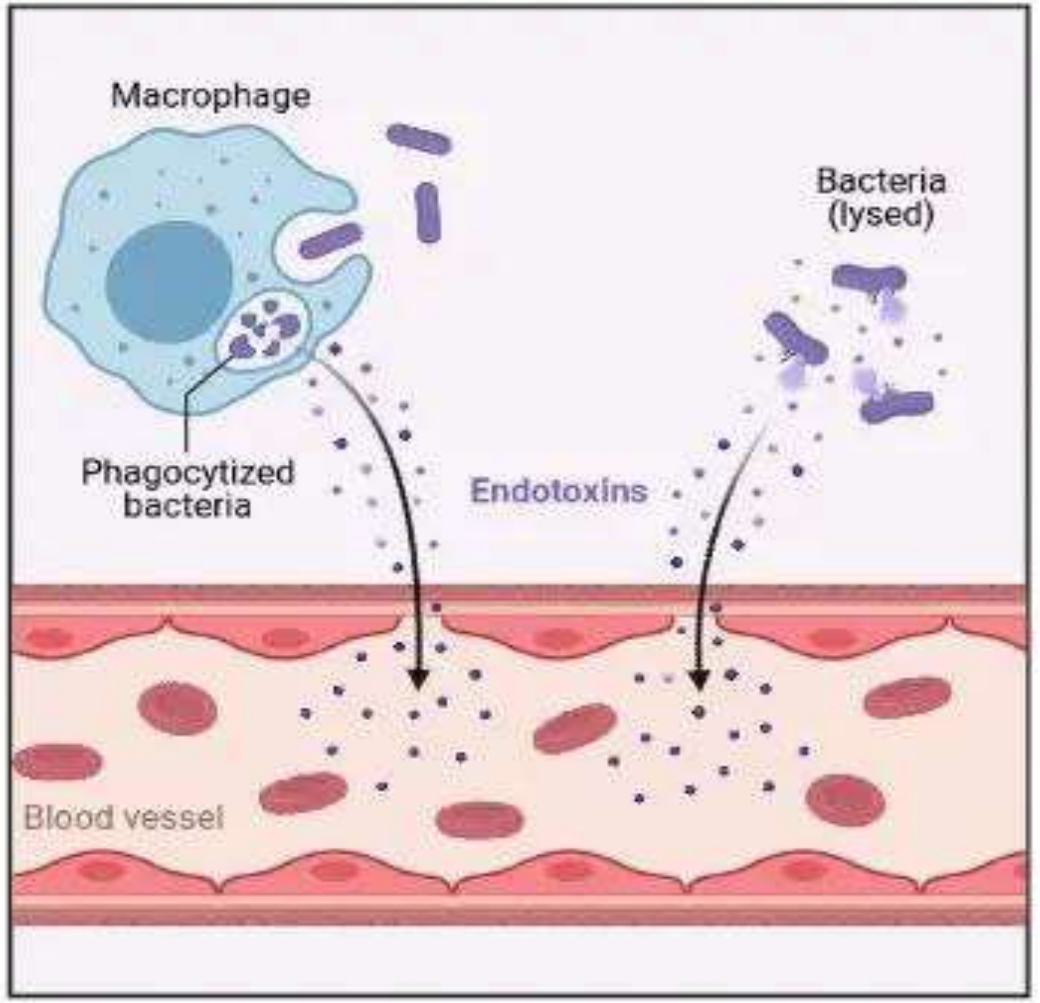
1. **Exotoxins**: generated by the bacteria and actively secreted
2. **Endotoxins**: are part of the bacteria itself (bacteria outer membrane) And in is not released until the bacteria is killed by the immune system



**Exotoxins** are proteins produced inside pathogenic bacteria which are secreted into the surrounding medium.

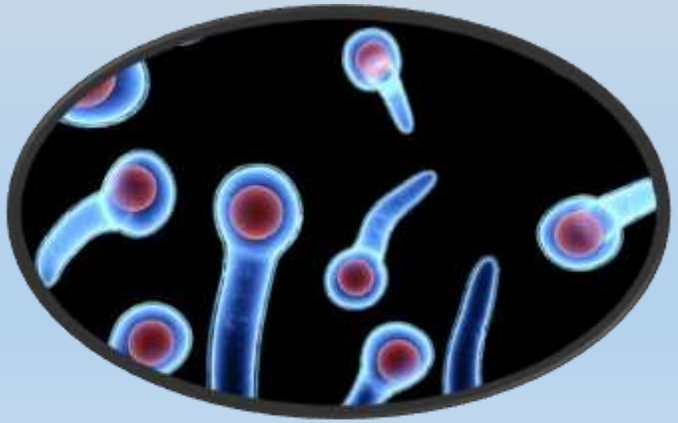


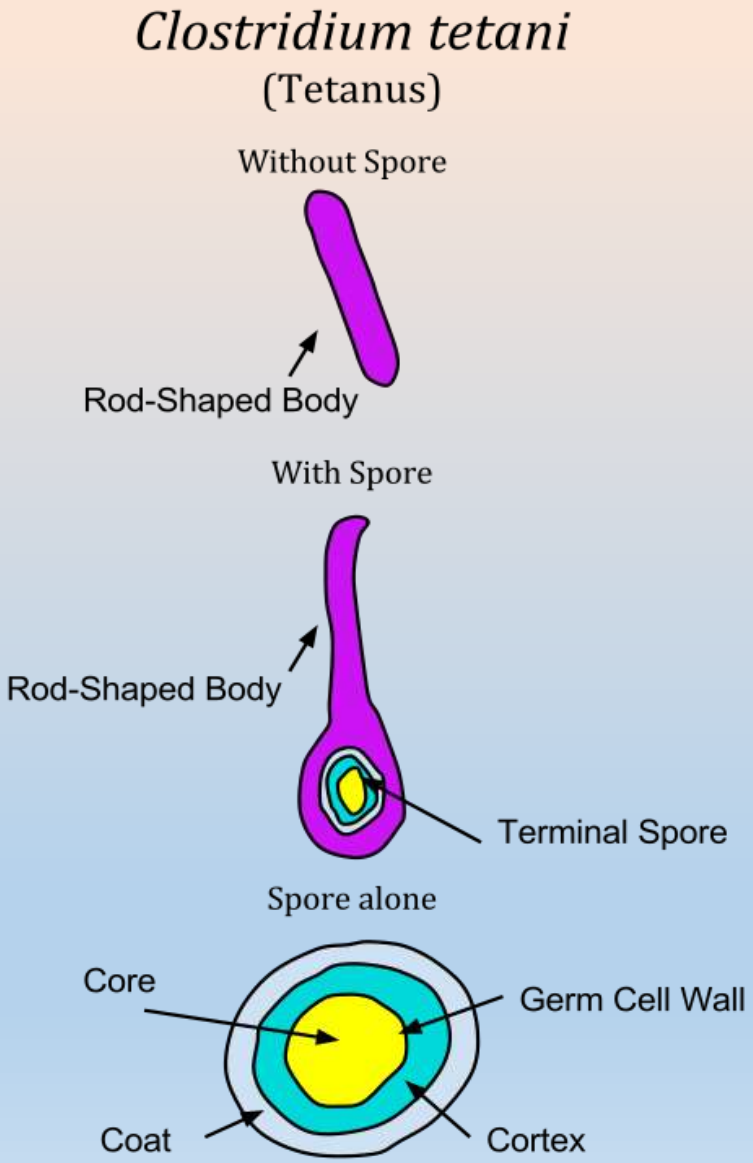

**Endotoxins** are constitutive elements of the bacteria membrane. They are only liberated when the bacteria die.



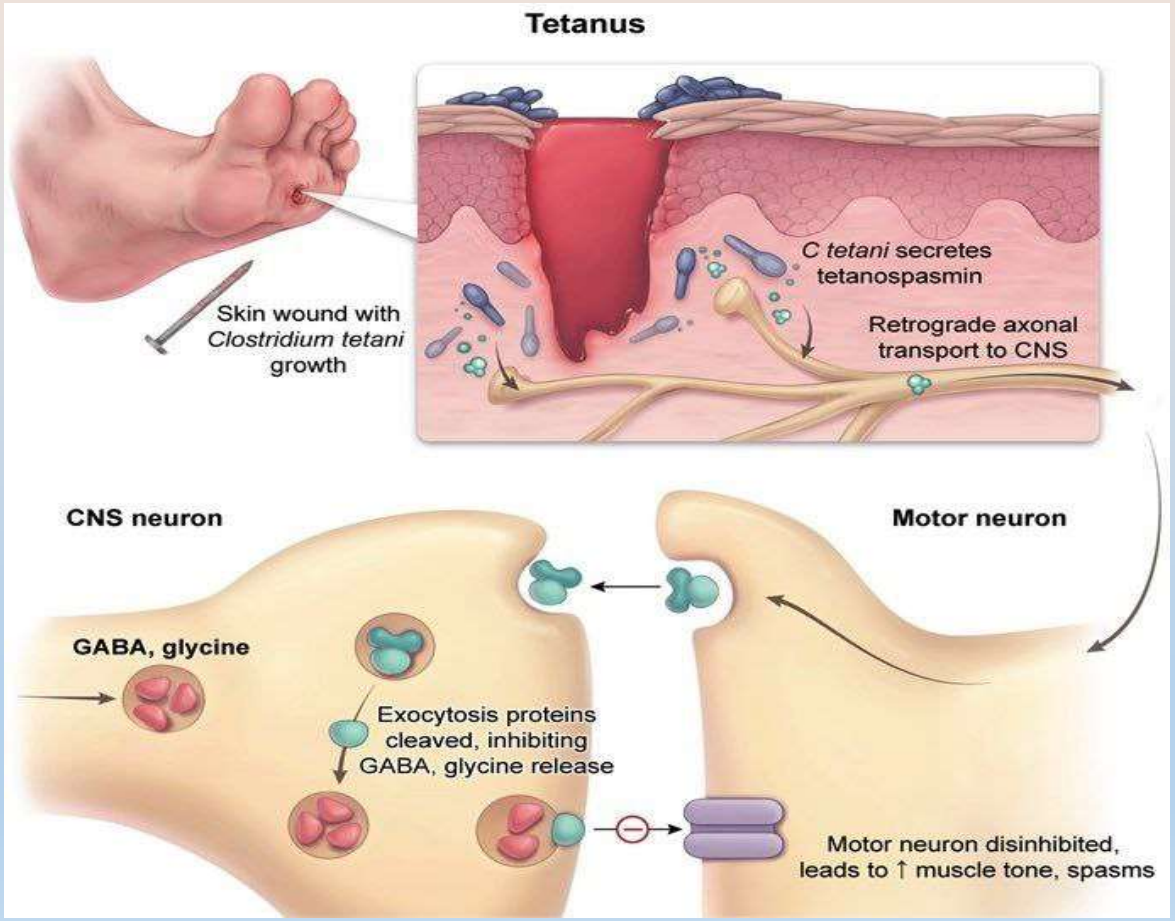
# Bacterial toxins

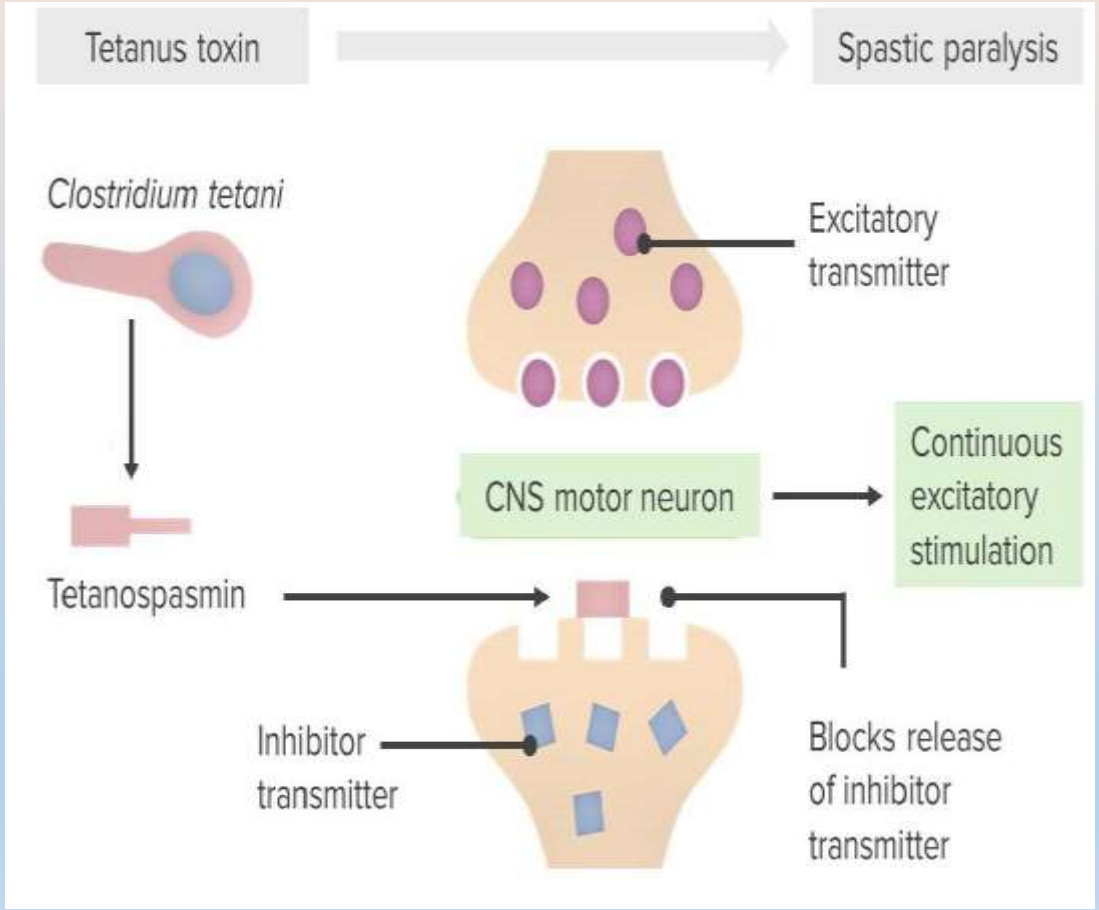
- ***Clostridium tetani*** :
- Rod-shaped, anaerobic, gram- positive
- Found as spores in soil
- Biological toxin: **tetanospasmin**





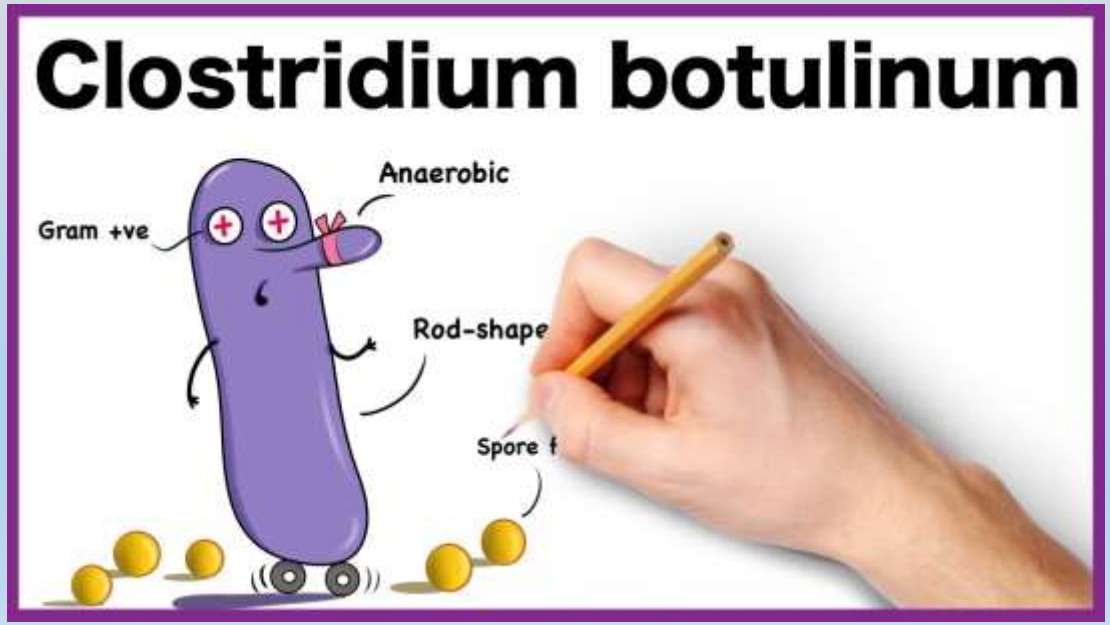
# tetanospasmin



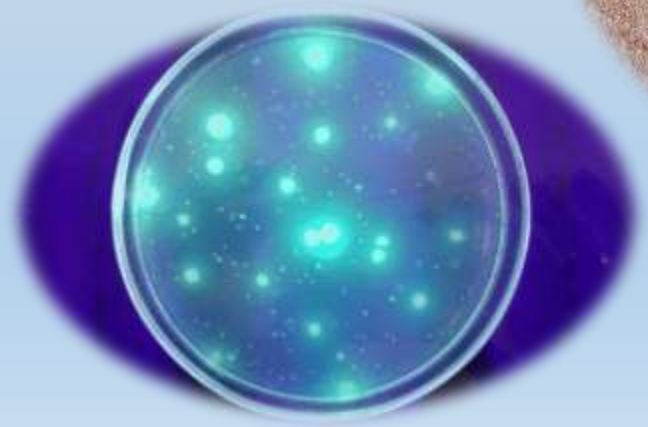
# Bacterial toxins

- ***Clostridium botulinum***
- Gram-positive, rod-shaped
- Produces neurotoxins, known as **botulinum neurotoxins**
- Obligate anaerobic, spore-former
- Commonly found in soil



# Bacterial toxins

- *Pseudomonas fluorescens*
- Gram-negative, rod-shaped
- An obligate aerobe
- Has multiple flagella
- Found in the soil and in water



# mycotoxin

## Fungi produces two categories of toxins

- One of those produced by some **mushrooms** which are consumed directly as food. The poisoning caused by mushrooms is called ”**mycetismus**”

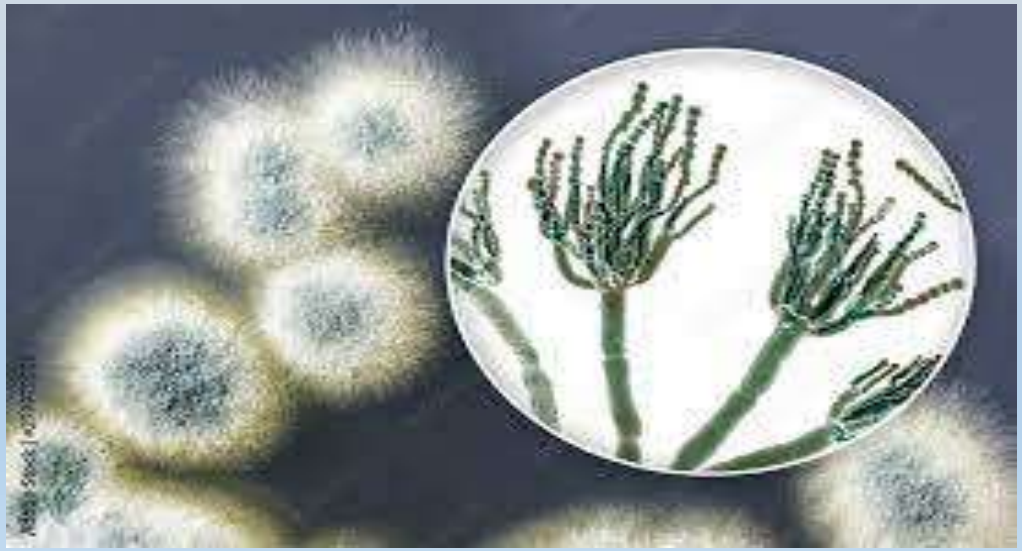
- Second type of toxins is those produced by certain **molds**, which grow on other food products

# mycotoxin

- Mycotoxins are produced by fungi as secondary metabolites at the end of the exponential phase
- Induction of **mycotoxicoses** i.e. disease of animals and human caused by the consumption of feed and food invaded by toxin producing fungi, thus pose serious threat to human and animal health
- Most mycotoxicoses are caused by common and wide spread fungi as aspergillus, fusarium, and penicilllium
- Aspergillus and penicillium produces toxins mostly in **stored seeds**, **hay or commercially processed food and feeds**
- Fusarium produces toxins on corn and other **stored grains**

Fusarium

Aspergillus



penicillium

# Environmental toxicology

# علوم البيئة\المستوى الثالث

Lab. 6

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# environmental impact of pesticides

- The environmental impact of pesticides is greater than what is intended by those who use them
- Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than there target species, including non target species, air, water, and food
- Pesticide can contribute to air pollution
- The biochemical effects of pesticides involves the effects in water, soil, plants, animals, birds, aquatic life, amphibians and human

# water

- Pesticides were found to pollute every streams
- Pesticides residues have also been found in rain and ground water
- There are major routes through which pesticides reach the water:
- It may drift outsides of the intended area when it is sprayed, it percolate, or leach, through the soil, it may carried to the water as runoff, or it may be spilled
- They may also be carried to water by eroding soil
- Factors that affect pesticide’s ability to contaminate water include its solubility

# soil

- Many of the chemicals used in pesticides are persistent soil contamination, whose impact may endure for decades and adversely affect soil conservation
- The use of pesticides decreases the general biodiversity in the soil
- Depending on the chemical nature of the pesticide, such processes control directly the transportation from soil to water, and in turn to air and our food

# plants

- Nitrogen fixation, which is required for growth of higher plants, is hindered by pesticides in soil
- The insecticides DDT, methyl parathion, and especially pentachlorophenol have been shown to interfere with chemical signaling
- Reduction of these chemical signaling results in reduced nitrogen fixation and thus reduced crop yields

- Pesticides can kill bees and are strongly implicated in pollinator decline, the loss of species that pollinate plants, including through the mechanism of colony collapse disorder, in which worker bees from a beehive or western honey colony abruptly disappear
- Application of pesticides to crops that are in bloom can kill honeybees, which act as pollinators

# animal

- Pesticides inflict extremely widespread damage to biota, and many countries have acted to discourage pesticide usage through their Biodiversity Action Plans.
- Animals may be poisoned by pesticide residues that remain on food after spraying
- Widespread application of pesticides can eliminate food sources that certain types of animals need, causing the animals to relocate, change their diet, or starve.

- Poisoning from pesticides can travel up the food chain; for example, birds can be harmed when they eat insects and worms that have consumed pesticides
- Earthworms digest organic matter and increase nutrient content in the top layer of soil.
- They aid in protecting human health by ingesting decomposing litter and serving as bio indicators in soil activity while creating a richer environment

- A number of studies have shown that pesticides have harmful effect on growth and reproduction on earthworms, which are in term consumed while terrestrial vertebrates such as birds and animals small mammals
- Some pesticides can bio accumulate or build up to toxic levels in the bodies of organisms that consume them over time, a phenomenon that impacts species high on the food chain especially hard.

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# Environmental toxicology

# علوم البيئة\المستوى الثالث

Lab. 7

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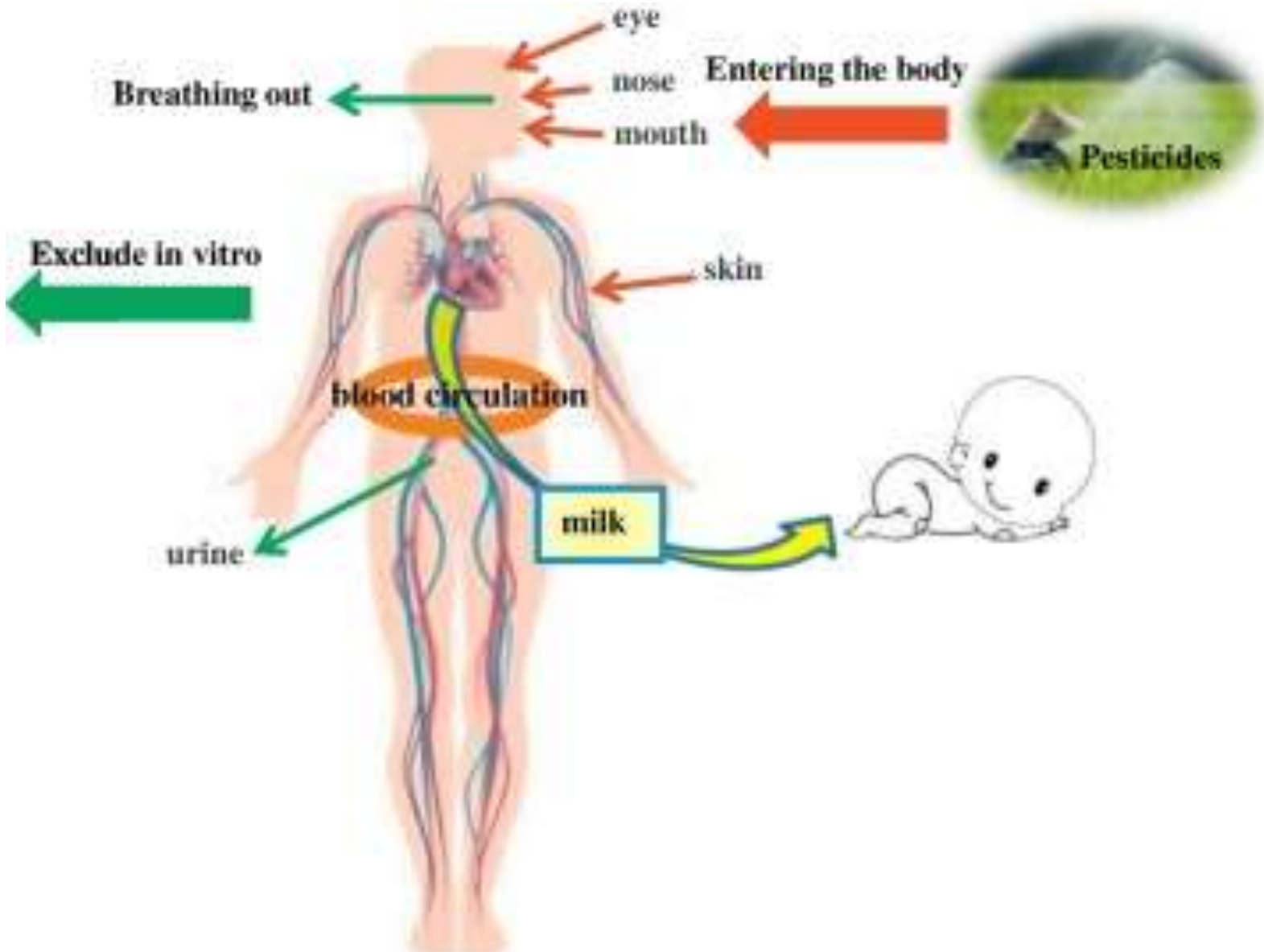
# Pesticides effect on human

- Pesticides can enter the human body through inhalation of aerosols, dust and vapor that contained pesticides, through oral exposure by consuming food and water, and through dermal exposure by direct contact of pesticides with skin.

- Pesticides are sprayed on to food, especially fruits and vegetables, they secrete into soils and ground water which can end up in drinking water, and pesticides spray can drift and pollute the air


eye
nose
mouth
Breathing out
Entering the body
Pesticides
Exclude in vitro
skin
blood circulation
milk
urine

- The effect of pesticides on human health are more harmful based on the toxicity of the chemical and the length and magnitude of exposure
- Farm workers and their families experience the greatest exposure to agricultural pesticides through direct contact with the chemicals
- But every human contains a percentage of pesticides found in fat samples in their body

- Exposure to pesticides can range from mild skin irritation to birth defects, tumors, genetic changes, blood and nerve disorders, endocrine disruption, and even coma or death

- Developmental effect have been associated with pesticides

- Recent increases in childhood cancer, such as leukemia, may be result of genotoxic and non-genotoxic pesticides due to somatic cell mutations

- Insecticides targeted to disrupt insects can have harmful effects on the nervous systems of mammals, due to basic similarities in system structure
- Both chronic and acute alterations have been observed in those who are exposed
- Pesticides can act in the promotion and proliferation of cancer while causing hormone imbalance
- DDT and its breakdown product DDE, with levels still present in the environment, despite its ban, are known to disturb estrogenic activity and possibly lead to breast cancer