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WP3 DigiOmica collaborative learning in Integrated omics for environmental sustainability

Module 9: *Omics in Aquatic Toxicology*

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- **Educational goals**: the aim of this module is to present knowledge about:
  - To provide background knowledge about utilizing omics techniques in aquatic toxicology including genomics, transcriptomics, proteomics, and metabolomics.
  - To emphasize significant developing the skills to effectively interpreting omics data generated from studies of aquatic toxicology.
  - To highlight the omics approaches to enhance risk assessment strategies with case studies in aquatic toxicology

Summary

Aquatic ecosystems are under increasing pressure from a variety of environmental stressors, including chemical pollutants, habitat degradation, climate change, and invasive species. It is essential to comprehend how aquatic organisms respond molecularly to various stresses in order to evaluate the condition of aquatic ecosystems and create efficient plans for environmental preservation and management. Omics, which includes genomics, transcriptomics, proteomics, and metabolomics, transforms aquatic toxicology by providing thorough understanding of how contaminants affect aquatic life. Evaluation of genomic methods in aquatic toxicology, possibilities and limitations of the microarray and quantitative polymerase chain reaction (PCR) methodologies, proteomics, metabolomics, RNA sequencing, and DNA methylation studies are discussed in details. Together, these omics approaches provide a holistic understanding of the molecular mechanisms underlying toxicity, facilitating the identification of novel biomarkers for early detection of pollution, assessment of environmental risk, and development of more effective mitigation strategies to safeguard aquatic ecosystems and human health. This learning outcome focuses on comprehensive look for omics in aquatic toxicology with approaches of cases studies, covering their principles, applications, challenges, and future directions.

- **Expected learning outcomes**: Upon completion of this Module the learners will be able to:
  - Gain knowledge of how pollutants interact with aquatic organisms at the molecular level through genomics, transcriptomics, proteomics, and metabolomics, elucidating the pathways and processes affected by toxicants.
  - Identify of biomarkers and characterize molecular biomarkers indicative of exposure to aquatic pollutants, enabling more sensitive and reliable monitoring of environmental contamination and early detection of potential risks to aquatic ecosystems.
  - Integrate of omics data into risk assessment frameworks, allowing for a more comprehensive evaluation of the potential impacts of pollutants on aquatic organisms and ecosystems, and informing evidence-based regulatory decisions.
  - Apply of omics in aquatic toxicology with designing and conducting omics-based experiments to investigate the effects of pollutants on aquatic organisms, including the selection of appropriate omics techniques, sample preparation, data analysis, and interpretation.
  - Understand the principles and applications of omics techniques in interdisciplinary research approach with case studies to develop innovative strategies for the protection and conservation of aquatic ecosystems.

Provisional Table of contents:

Presentation of the learning content

1. Introduction

- **Omics** aims to comprehensively analyze biological systems by examining various molecules or components within an organism or ecosystem.
- **Ecotoxicogenomics** describes the studies analyzing the adaptive response to toxic exposure at the transcriptomic, proteomic, and metabolomic levels.
- In aquatic toxicology, omics approaches have become increasingly important for understanding the impacts of contaminants on aquatic organisms and ecosystems.

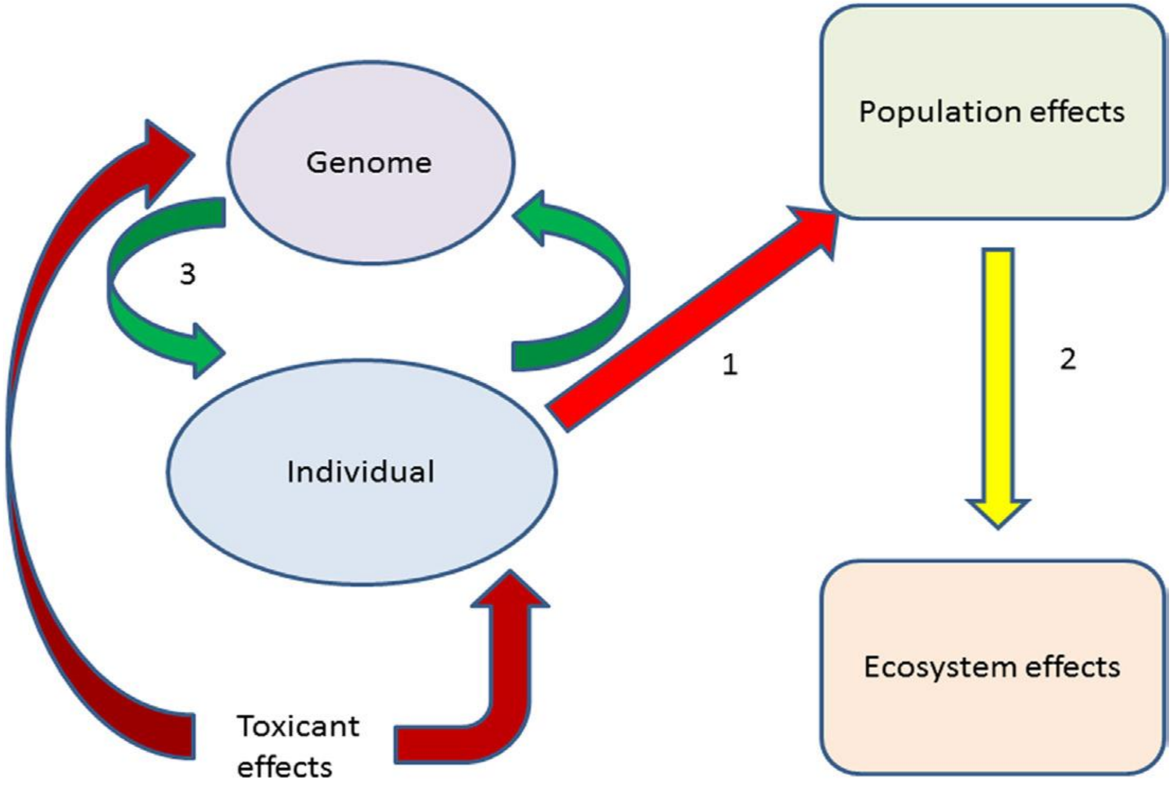


Figure 1. The hierarchy of toxicant actions (Nikinmaa, 2014)

Presentation of the learning content

2. Context (findings)

2.1. Genomics in Aquatic Toxicology

- Genomics can be used to identify the genes in the total genome of an organism function in the life-span of the organism.

2.1.1. Transcriptomics in Aquatic Toxicology

- Transcriptomics focuses on the study of an organism's entire transcriptome, including all the RNA molecules transcribed from its genome.

2.1.2. Proteomics in Aquatic Toxicology

- Proteomic approaches can provide valuable insights into harmful mechanisms and aid in biomarker discovery.
- In aquatic toxicology, particular protein expression profiling is commonly used to monitor exposure and effect.

Context (findings)

2.1.3 Metabolomics in Aquatic Toxicology

- Metabolomic analysis can provide insights into the metabolic pathways perturbed by exposure to contaminants, identify metabolic biomarkers of exposure or effect and gain a better understanding of the physiological responses of organisms to pollutants (Figure 2).

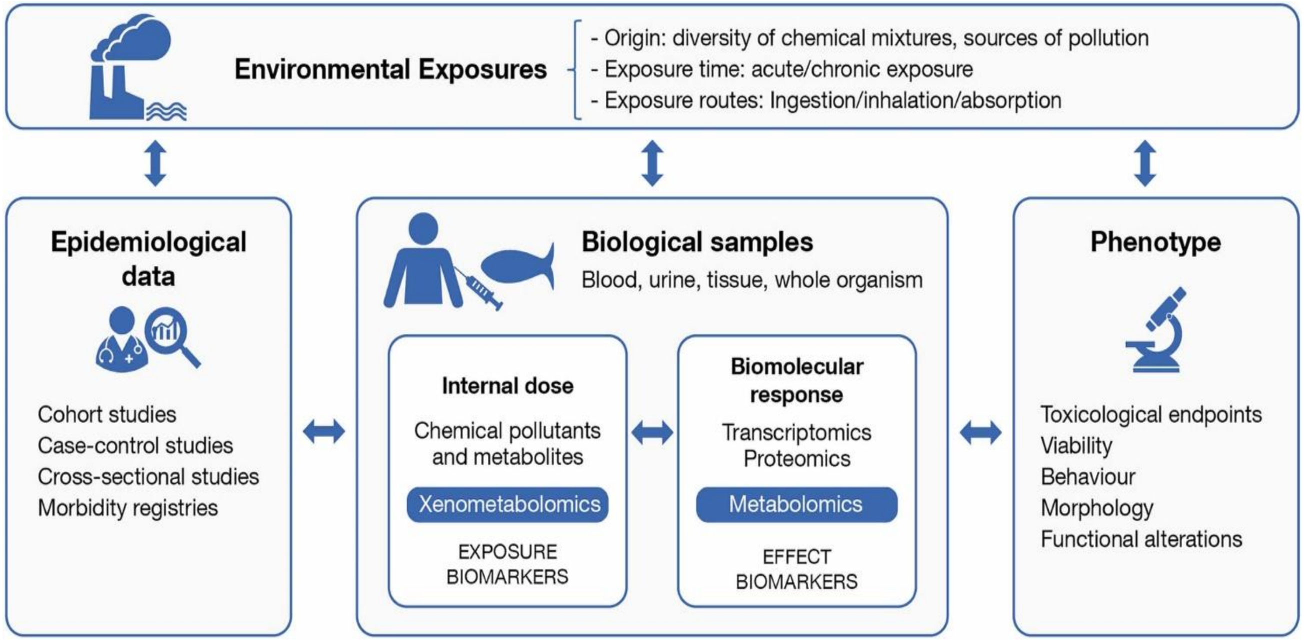


Fig. 2. Schema of the different data associations linking exposures and adverse effect/disease outcomes in exposome studies, with emphasis on the role of metabolomics to investigate the molecular responses to chemical pollutant exposure. (Bedia 2022)

Context (findings)

2.1.4 Applications of Omics in Aquatic Toxicology

2.1.4.1 Genotoxicity/Oxidative stress

- Genotoxicants can cause errors in DNA replication, making DNA repair insufficient to erase all errors, leading to mutation (Figure 3).

2.1.4.2 Other case studies

- The effects of toxicants on reproduction, development, energy metabolism and behavior, neurotoxicity and immunotoxicity, epigenetics will be discussed

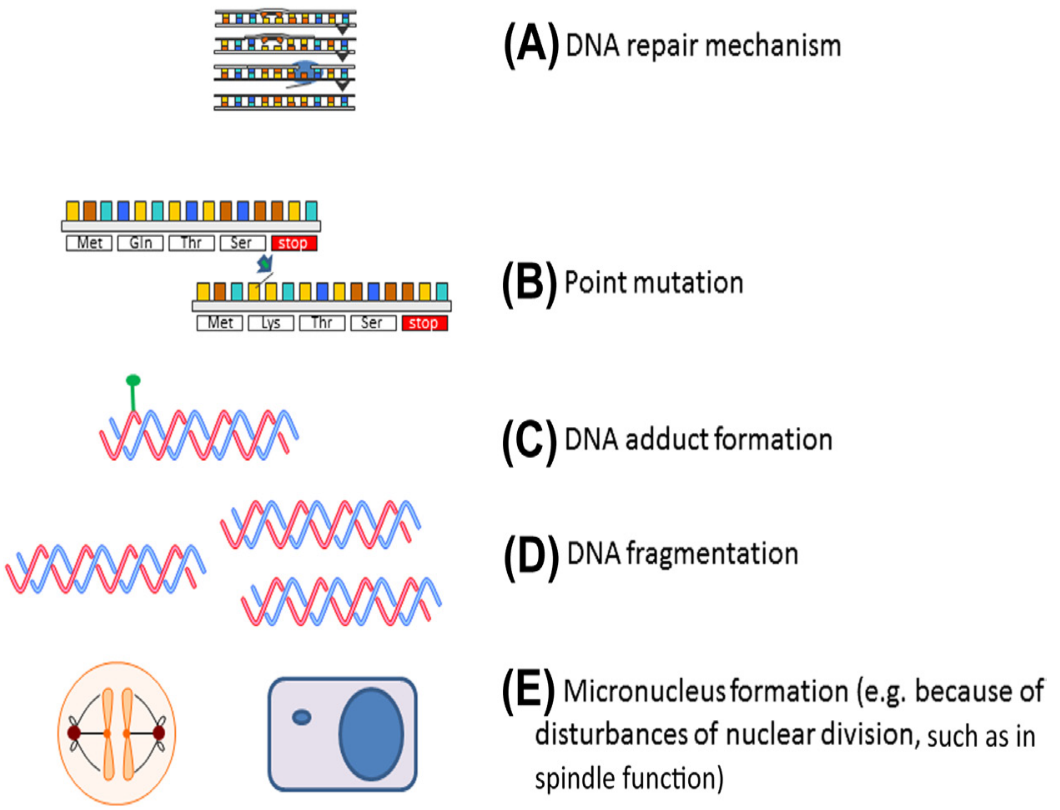


Figure 3. The principles of genotoxic effects (Nikinmaa, 2014).

Presentation of the learning content

3. Alternatives

➢ 3.1. Limitations and challenges of omics in aquatic toxicology

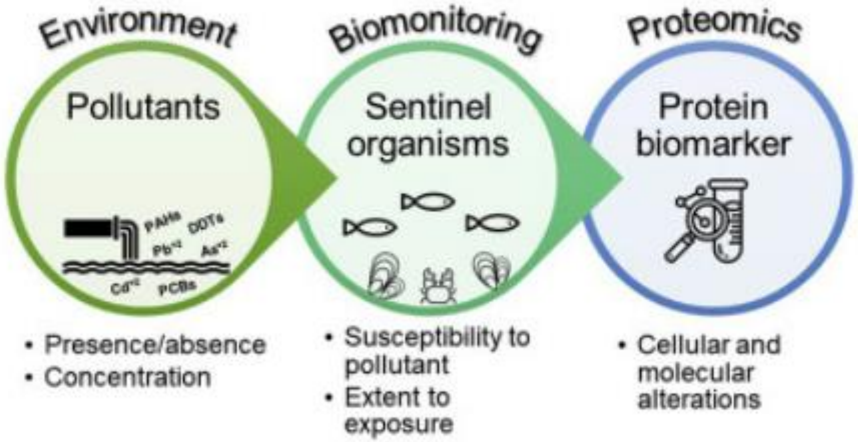
Omic techniques have efficiently used to assess the effects of toxicants on aquatic organisms, however there are still some challenges and needs for improvements that limit the practical use in monitoring programs and in regulatory contexts.

- Natural variability
- Interpretation of data

Presentation of the learning content

4. Solutions

- Omics technologies have many uses in aquatic toxicology, such as identifying biomarkers for environmental monitoring, understanding species-specific responses to contaminants, and analyzing the effects of complicated pollutant combinations.

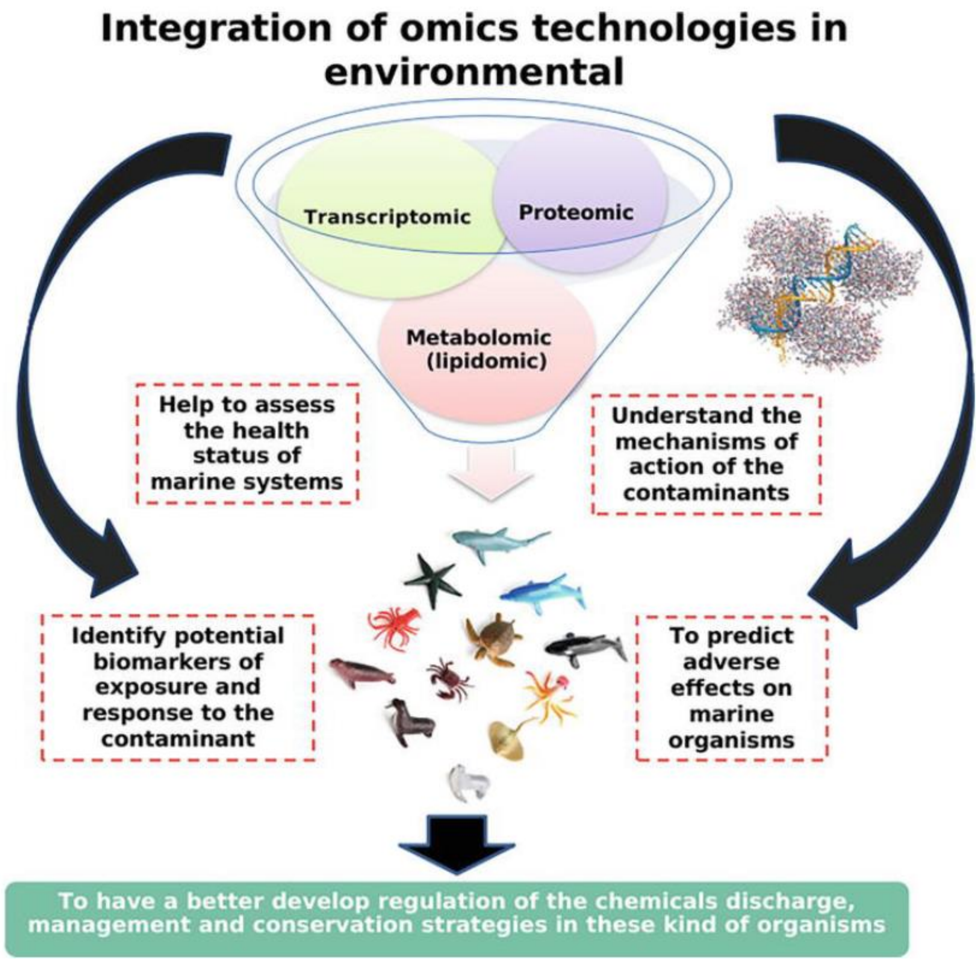


Source: López-Pedrouso, et al. (2020). *Environmental Pollution*, *267*, 115473.

Presentation of the learning content

4. Solutions

- Omics data can be utilized to build predictive models that assess the dangers of new and existing pollutants.



Source: Cristina Collí-Dulá and Mariel Ruiz-Hernández, (2022). IntechOpen. doi: 10.5772/intechopen.102424

Presentation of the learning content

5. Recommendations (Conclusions)

- Advances in sequencing technologies and bioinformatics tools are making omics analyses more accessible and cost-effective.

- The integration of omics data with other environmental data, such as water quality parameters and ecological assessments, will enhance our ability to predict and mitigate the impacts of pollutants on aquatic ecosystems.

- Advances in omics have important implications for risk assessment practice and regulatory decision-making.

- The usage of genomics technology generates a vast amount of data, and bioinformatics is fast growing to fulfill data analysis requirements.

Presentation of the learning content

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