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Innovative technologies for monitoring and detection of diseases in aquatic animals

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Innovative Technologies for Monitoring and Detection of Diseases in Aquatic Animals

Aquatic animals, including fish, shellfish, and other marine organisms, play a vital role in global food security and ecosystems. However, diseases in aquatic animals can have devastating effects, causing significant economic losses in aquaculture and threatening the health of wild populations. The development and application of innovative technologies for disease monitoring and detection are crucial for ensuring the sustainability of the aquatic sector. This article explores cutting-edge technologies and their potential to revolutionize aquatic animal health management.

1. Molecular Diagnostics

Molecular diagnostic tools, such as polymerase chain reaction (PCR) and quantitative PCR (qPCR), enable the rapid and accurate detection of pathogens at the genetic level. These techniques can identify specific viruses, bacteria, or parasites in aquatic animals, even at early stages of infection. Recent advancements include:

- **Loop-Mediated Isothermal Amplification (LAMP):** A rapid, cost-effective alternative to PCR that requires minimal equipment, making it suitable for field diagnostics.
- **CRISPR-based Diagnostics:** Utilizing the precision of CRISPR technology to detect pathogen DNA or RNA with high specificity and sensitivity.

2. Biosensors

Biosensors are analytical devices that convert biological responses into measurable signals. They offer real-time monitoring and can detect pathogens, toxins, or environmental stressors. Types of biosensors include:

- **Electrochemical Biosensors:** Used to detect specific microbial pathogens by measuring electrical signals generated upon binding with the target.
- **Optical Biosensors:** Employing fluorescence or surface plasmon resonance (SPR) to monitor disease markers in water samples or animal tissues.



3. Digital Imaging and Machine Learning

Advanced imaging techniques combined with machine learning algorithms provide non-invasive methods for disease detection. These technologies analyze physical and behavioral changes in aquatic animals, such as skin lesions, abnormal swimming patterns, or gill discoloration.

- **Computer Vision Systems:** Automatically detect external signs of disease by analyzing high-resolution images of fish.
- **Deep Learning Models:** Predict disease outbreaks by correlating environmental data with historical disease patterns.

4. Environmental DNA (eDNA) Analysis

eDNA refers to genetic material shed by organisms into their environment. By analyzing water samples for eDNA, researchers can detect the presence of pathogens or infected individuals without direct sampling of animals. Innovations in eDNA technology include:

- Next-Generation Sequencing (NGS): Allows comprehensive analysis of microbial communities and identification of emerging pathogens.
- **Portable eDNA Detectors:** Enabling on-site pathogen detection and real-time decision-making.

5. Internet of Things (IoT) and Smart Sensors

IoT-based systems integrate smart sensors, data analytics, and cloud computing for continuous monitoring of aquatic environments. These technologies provide critical insights into water quality parameters, such as temperature, pH, and dissolved oxygen, which are linked to disease outbreaks.

- **Remote Sensing Devices:** Monitor aquaculture farms remotely, alerting farmers to potential health risks.
- Automated Feeding and Health Monitoring Systems: Detect changes in feeding behavior or metabolic activity, which can indicate disease onset.

6. Immunological Techniques

Innovative immunological methods, such as enzyme-linked immunosorbent assay (ELISA) and lateral flow assays (LFAs), are used to detect specific antigens or antibodies associated with diseases. Recent developments include:

- **Multiplex ELISA:** Capable of detecting multiple pathogens simultaneously, improving efficiency in large-scale operations.
- **Point-of-Care LFAs:** Portable and easy-to-use devices for rapid disease diagnosis in field settings.

7. Artificial Intelligence (AI) and Predictive Analytics



AI-driven predictive models analyze vast datasets to forecast disease outbreaks and inform proactive management strategies. These models consider factors such as water quality, climatic conditions, and historical disease data to identify patterns and trends.

- Early Warning Systems: Provide alerts about potential disease risks, allowing timely intervention.
- **Disease Spread Simulations:** Predict the trajectory of infectious diseases, aiding in containment efforts.

Conclusion

The integration of innovative technologies in monitoring and detecting diseases in aquatic animals represents a transformative shift in aquatic health management. These advancements enhance the early detection of pathogens, reduce economic losses, and improve animal welfare. By adopting these technologies, stakeholders in aquaculture and fisheries can foster sustainable practices and ensure the resilience of aquatic ecosystems. Future research and collaboration between technology developers, researchers, and industry practitioners will further propel this field, paving the way for a healthier and more sustainable aquatic environment.

