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Short Commentary

Application Prospects of the *Caenorhabditis Elegans* Model in Toxicology and Forensic Science

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ABSTRACT

This review summarizes the current applications of *Caenorhabditis elegans* (referred to as *C. elegans*) as a model organism in toxicological research and explores its prospects in the field of forensic science. *C. elegans*, with its short life cycle, clear genetic background and highly conserved genome, has demonstrated unique advantages in toxicological studies. Starting from its biological characteristics, this paper introduces the toxicological research methods and progress based on the *C. elegans* model and focuses on its applications in environmental forensic medicine and forensic toxicology.

Keywords: Forensic toxicology; Environmental forensic medicine; *Caenorhabditis elegans*; Model organism

DESCRIPTION

Biological characteristics of *C. elegans*

C. elegans is a nonparasitic, soil-dwelling nematode with the following notable biological characteristics:

Short life cycle: Under laboratory conditions, *C. elegans* can complete a generation turnover in about 4 days, with low maintenance costs [1].

Clear genetic background: The genome of *C. elegans* has been fully sequenced, with 60%-80% of its genes being homologous to those of humans [2]. The experimental data obtained are highly consistent with human detection data.

Complete nervous system: The nervous system of *C. elegans* has been fully mapped, with some neurotransmitters showing high similarity to those in higher mammals [3-7].

Rich behavioral traits: *C. elegans* exhibits clear, diverse, and easily quantifiable behavioral traits.

Transgenic strains: Additionally, since the *C. elegans* genome has been fully annotated, its model has been widely used in genetics, molecular biology and cell biology. Transgenic strains based on the Green Fluorescent Protein (GFP) gene, such as CL2166 (gst4::GFP) and SJ4005 (hsp4::GFP), have been widely used in toxicological research. These strains are mostly preserved in the Caenorhabditis Genetics Center (CGC) and are available for open access, providing convenience for relevant research [8,9].

Toxicological research methods using the *C. elegans* model

Toxicological studies using the *C. elegans* model typically simulate real world exposure patterns of toxicants, including liquid-phase, solid-phase and gas-phase exposures. The toxic effects of substances are assessed through various biological indicators, such as survival rate, reproductive capacity, growth and development and behavioral phenotypes [10-19]. In recent years, the *C. elegans* model, with its unique biological characteristics, has shown high compatibility and synergistic effects with various cutting-edge techniques. These include high-throughput technologies, fluorescence screening, metabolomics, microfluidic chip technology, and gene-editing techniques (such as CRISPR/Cas9) to precisely modify the *C. elegans* genome, thereby revealing the toxic effects of substances at the molecular level [20-22].

Research achievements of the *C. elegans* model in forensic science

Environmental forensic medicine: Significant achievements have been made in environmental toxicology using the *C. elegans*

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model, covering pesticides, nano industrial materials, organic pollutants and heavy metals [14,15,23-36]. These studies provide a scientific basis for environmental risk monitoring and the assessment of the correlation between pollutants and human health. For instance, the toxicity effects of trifluralin, such as increased oxidative stress levels and mitochondrial damage, are evaluated by observing the body length and pharyngeal pumping frequency, as well as the head swing frequency of *C. elegans* exposed to different concentrations of trifluralin [23].

Forensic toxicology: In forensic toxicology, the *C. elegans* model is used to study the molecular mechanisms of toxicant action, such as addiction mechanisms, teratogenic effects on offspring and the impact of neurotoxins on neurodegenerative diseases [37-40]. In recent years, at least 50 genes related to ethanol poisoning have been identified in the *C. elegans* model and some of these homologous genes have been confirmed to be associated with human ethanol addiction and metabolic disorders [41,42]. In addition, the *C. elegans* model is also used in genetic toxicology research to explore the transgenerational and multigenerational toxic effects of heavy metals and organic pollutants. Studies have shown that the mechanism of transgenerational toxic effects induced by heavy metals may be related to the overactivation of oxidative stress [43,44]. Toxicity from multigenerational exposure is often associated with the accumulation of toxicants in the body and phenotypic changes such as growth inhibition, reproductive damage, neuronal injury, and oxidative stress induction can usually be observed in *C. elegans* models exposed to toxicants over multiple generations.

Outlook for the *C. elegans* model in forensic science: The application of the *C. elegans* model in forensic identification faces challenges. In the future, it is necessary to further strengthen the integration with forensic practice. Metabolic mechanism data obtained from *C. elegans* toxicology experimental models should be used to establish open and updated standardized databases of metabolic mechanisms, which should then be correlated with human data from forensic identification. It is also necessary to improve the judicial interpretation rules for toxicological data and the construction of the evidence chain so that research findings can serve forensic identification.

CONCLUSION

As the demand for elucidating the mechanisms of toxicant action and their metabolic pathways in the human body increases in forensic science, toxicological research based on the *C. elegans* model will offer a new perspective for judicial identification. Establishing a comprehensive database of metabolic mechanisms and continuously accumulating and updating relevant toxicological data will provide stronger support for interdisciplinary research in forensic and toxicological sciences.

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