Unlocking the Future of Toxicology: A Path Forward with Omics and PrecisionTox

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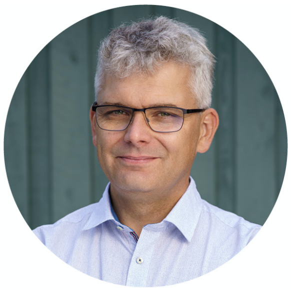

The landscape of toxicology is undergoing a significant transformation, driven by the need to adopt more efficient, human- and environment-relevant approaches and to reduce animal testing. One promising avenue for this shift is the integration of omics technologies—such as transcriptomics, proteomics, and metabolomics—into toxicological research and regulatory decision-making. Dr. Tomasz Sobanski and Prof. Mark Viant came together in a PrecisionTox Webinar to discuss with our stakeholders how these technologies can redefine risk assessment and chemical safety.

Central to the evolution of toxicology is the focus on understanding the molecular mechanisms, or "modes of action," that underlie toxicity, moving beyond traditional methods that measure adverse outcomes. Omics technologies have the potential to provide information to identify chemical hazards early after chemical exposure, providing a deeper understanding of their effects on human health and the environment. By examining the molecular landscape, gene expression, metabolite changes, and protein activity, scientists can gain a more accurate and detailed picture of toxicity, potentially before any harmful effects are seen.

However, integrating omics technologies into regulatory frameworks poses several challenges. One of the key hurdles is the lack of a high-quality, publicly available ‘omics signatures’ database that could be used to reliably interpret how the observed molecular perturbations relate to hazard. To overcome this, we need a collaborative, community-driven approach to generate consistent and reliable datasets. The ongoing development of protocols, such as the OECD’s guidance on omics sampling, will be essential in building a robust database that can support regulatory decision-making. The PrecisionTox initiative, which involves researchers from diverse backgrounds, is an example of how global collaboration can help shape the future of toxicological risk assessment.

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The potential of omics is further enhanced by its intersection with the Adverse Outcome Pathway (AOP) framework. AOPs help map molecular changes to higher-level biological consequences, linking omics data to specific toxicological endpoints. This combination promises to create more comprehensive and flexible risk assessment models. Although AOPs have been successful for certain endpoints, the broad nature of systemic toxicity may require more generalized, omics-based approaches, making the integration of both strategies essential for future regulatory science.

Moving forward it is necessary to evaluate and discuss how the sensitivity of omics data fits in practical regulatory considerations. For example, while transcriptomic-based Points of Departure (PoDs) are more conservative than traditional animal studies, a blanket application of such PoDs may overprotect human health to the point of restricting essential chemicals. A balanced approach is needed, one that incorporates the sensitivity of omics while addressing the realities of chemical use in society.

Looking ahead, we want to emphasize the importance of moving away from animal-based hazard identification and toward regulatory systems that focus on the molecular pathways affected by chemicals. Such a paradigm shift would require a deeper understanding of toxicity mechanisms and the ability to reliably measure systemic exposure, ultimately phasing out the need for animal testing. This vision can become a reality through continued research, collaboration, and the gradual integration of omics technologies and AOPs into regulatory frameworks.

In conclusion, the future of toxicology and chemical safety lies at the intersection of innovative technologies, collaboration, and a willingness to embrace new approaches. While challenges remain in data generation, regulatory integration, and practical application, the potential rewards such as safer chemicals, fewer animals used in testing, and more accurate risk assessments, are well worth the effort. Through community-driven initiatives, transparency, and a focus on the molecular mechanisms of toxicity, we can build a safer, more sustainable future for human health and the environment.

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