Enabling data interpretability and reuse in light microscopy through consensus building, community engagement, and a next-generation metadata framework

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Why. Microscopy has provided extraordinary insight into the structure and function of human tissues and, with the rate of technical advancements, will undoubtedly lead to further unimaginable biomedical breakthroughs. Yet, although microscopes are a standard fixture in countless research laboratories, progress in the field is greatly hindered by a lack of interoperable hardware, software, and data formats. Images captured by one laboratory cannot be readily interpreted and utilized by others, resulting in a vast waste of time and resources. Establishing community standards that promote the interpretability and reuse of image data will boost economic development in biotechnology, make scientific knowledge and technical advancements more accessible, streamline large-scale experiments across multiple laboratories, and empower artificial intelligence and machine learning to extract crucial insights from combined biomedical imaging data. **Here, we put forth a vision to expedite the establishment and adoption of metadata standards through community and vendor collaboration.**

Who. For the past 15 years, there has been considerable momentum around efforts to foster the adoption of community metadata standards in light microscopy[1–4], including the launch of QUality Assessment and REProducibility for images and instruments in Light Microscopy (QUAREP-LiMi) global community of 600+ scientists and manufacturer representatives[5]. With critical input from nine leading vendors (Andor, Olympus, Roper Teledyne, Scientifica, Hamamatsu, Leica, Nikon, PCO, and Zeiss)[6,7], QUAREP-LiMi recently proposed a first-ever consensus metadata description of scientific-grade cameras to facilitate the transfer of essential hardware information to the community. This work aligns with multiple international efforts, including the NIH-funded 4D Nucleome, HuBMAP, and SenNet projects, ABRF, BioImaging North America (BINA), German BioImaging (GerBI), the Open Microscopy Environment Consortium (OME), and REcommended Metadata for BioImaging (REMBI)[1]. As a result of this concerted effort, a path forward for creating a global microscopy metadata standard is now within reach.

What. We propose to establish a standardized description for all details of microscopy hardware, making rich metadata details widely accessible to all stakeholders, including via automated capture during image acquisition. Thanks to the efforts described above, the time is optimal for the international microscopy community to achieve these goals. Our plan includes (1) the development of a **next-generation framework for metadata**, a composable framework with user-friendly tools, that enable the definition, capture, and exchange of community-specified metadata; (2) the development of **microscopy acquisition metadata descriptions** in close collaboration with instrument manufacturers and providing a complete technical representation of major light-microscope modalities; and (3) a deliberate campaign to drive **community adoption** in imaging facilities to promote the widespread distribution and adoption of image metadata standards and tools.

The vision is to define and take responsibility for a shared standard for the REMBI Image Acquisition module with respect to Light Microscopy in compliance with community requirements. By specifying a way to combine this microscopy acquisition metadata with other types of image metadata, we can associate complete microscope technical descriptions with persistent identifiers and publish them in files such as the related Next-Generation File Format (NGFF)[3,4], enabling their exchange and transfer. With this, it will be possible to share, cite, and find these technical descriptions through centralized registries and web search engines, as well as develop compatible software to facilitate working with them and encourage their adoption. The end effect will fundamentally transform the overall quality and impact of biomedical research. New ways of interpreting, managing, and sharing complex microscopy data will bring academia and industry closer together via mutually agreeable best practices. Upon this solid foundation, future endeavors can specify quality metrics for microscopy images and otherwise drive toward unprecedented reproducibility and reusability.

References

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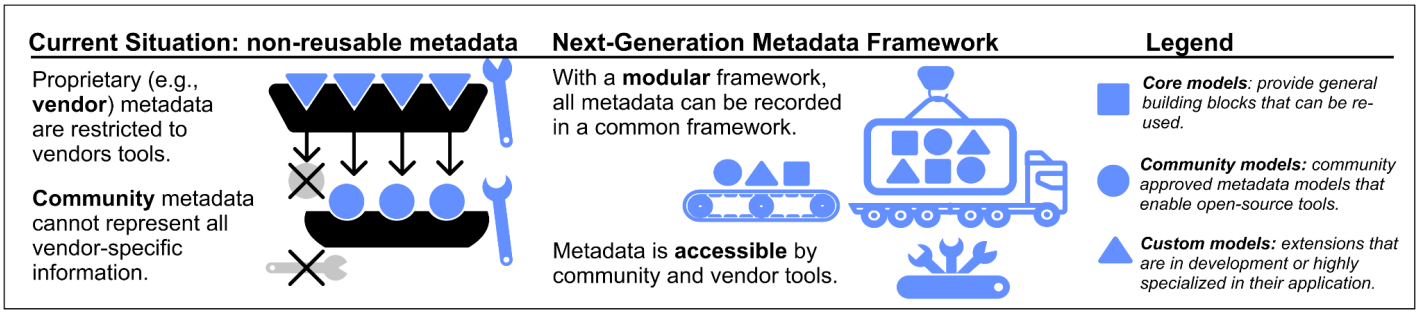

Figure 1 Next-generation metadata will provide the community with a composable collection of metadata schemas to remove barriers to re-use and collaboration.