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Pushing the limits of fluorescence microscopy with adaptive imaging and deep learning

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Fluorescence microscopy lets biologist see and understand the intricate machinery at the heart of living systems and has led to numerous discoveries. Any technological progress towards improving image quality would extend the range of possible observations and would consequently open up the path to new findings. I will show how modern machine learning and smart robotic microscopes can push the boundaries of observability. One fundamental obstacle in microscopy takes the form of an experiment design trade-offs between imaging speed, spatial resolution, light exposure, imaging depth, and live versus fixed imaging. State of the art machine learning — Deep Learning — can circumvent these limitations: microscopy images can be restored even if 60-fold fewer photons are used during acquisition, isotropic resolution can be achieved even with a 10-fold under-sampling along the axial direction, and diffraction-limited structures can be resolved at 20-times higher frame-rates compared to state-of- the-art methods. Moreover, I will demonstrate how smart microscopy techniques can attain the full optical resolution of light-sheet microscopes — instruments capable of capturing the entire developmental arch of an embryo from a single cell to a fully formed motile organism. Our adaptive light-sheet microscope improves spatial resolution and signal strength two to five-fold, recovers cellular and sub-cellular structures in many regions otherwise not resolved, adapts to spatiotemporal dynamics of genetically encoded fluorescent markers and robustly optimises imaging performance during large-scale morphogenetic changes in living organisms.

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