Past, Present, and Future of Electron Microscopy Chemical Processing Workflows

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Electron microscopy of biological specimens began with the development of room temperature chemical preparation methods for TEM, receiving the 1974 Nobel Prize for Physiology or Medicine [1]. The workflow to prepare specimens required invention of ultramicrotomes and knifes for ultrathin sectioning, other apparatus, and especially preparative chemistries to stabilize specimens for microtomy, vacuum, and for electron-beam irradiation, and to provide image contrast. These chemical workflows are routine today, including aldehyde fixation, OsO4 post fixation, graded solvent dehydration, serial infiltration in epoxy resins, and metal stains.

Since the 1974 Nobel Prize, there have been remarkable workflow improvements in TEM instruments. These now include automated image acquisition and analysis, and the advent of 3D Electron Microscopies (3DEM) including serial block face, array tomography, and FIB SEM. There have also been major improvements in microtomy and other tools that reduce the time and effort for specimen preparation and improve upon the workflows developed in the 1970s.

Despite instrumentation workflow improvements, there has been much less change in the lab processes to deliver the specimen preparation chemicals. Most specimens are still processed as they were decades ago: by immersion in vials with manual reagent exchanges every few minutes or hours. Typical protocol times are 1-2 days for TEM, plus an additional day for immunogold labeling (IGL), while 3DEM requires 4-5 days (Fig. 1). Hands-on effort is also significant, and is required sporadically, making it problematic to perform other tasks. Microwave processing substantially decreases total preparation times, but requires nearly continuous hands-on effort with manual reagent exchanges every few minutes. Tissue auto-processors can prepare large numbers of specimens with less labor. These, however, are not suitable for the more complex and longer IGL or 3DEM protocols. As a result, time-consuming manual effort is required, preventing personnel from performing other work for long periods.

Around the time the 1974 Nobel was awarded for biological EM, a revolution was occurring in the apparatus used for molecular and cell biology. This was the advent of multi-channel pipettors, microwell plates and, somewhat later, fluid handling "robots." In 2010, the mPrep system was introduced to leverage these tools for the EM lab. The mPrep System entraps individual specimens or grids in flow-through capsules that attach to pipettors or to the purpose-built EM preparation "robot", the ASP-1000. The mPrep System enables nearly any protocol, including standard TEM preparation [2], both pre- and post-embedding IGL [3], and 3DEM preparation [4]. Automation enables a protocol to be programmed, set-up, and "run" without human intervention for hours or days, or to include automated prompts when interventions are required, such as adding a fresh reagent. Further, near continuous reagent flow can be programmed to accelerate diffusion into specimens. This enables renal biopsy TEM specimens to be ready for resin curing in 2 hrs, including en bloc Ur staining [2], and to prepare 3DEM specimens as rapidly as one day [4]. Automatic operation and increased processing speed improves workflow by freeing personnel (Fig. 1), and also by reducing the potential for human error.

Where can we look to future workflow enhancements for chemical preparation? EM labs spend considerable time preparing reagents from raw chemicals. Workflows would be improved with easier-to-use reagent "kits and new formulations. These would save time, improve reproducibility, and could lead



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Table of Contents Past Present And Future Of Electron Microscopy In Agricultural Research

- 1. Understanding the eBook Past Present And Future Of Electron Microscopy In Agricultural Research
 - The Rise of Digital Reading Past Present And Future Of Electron Microscopy In Agricultural Research
 - Advantages of eBooks Over Traditional Books
- 2. Identifying Past Present And Future Of Electron Microscopy In Agricultural Research
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
- 3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Past Present And Future Of Electron Microscopy In Agricultural Research
 - User-Friendly Interface
- 4. Exploring eBook Recommendations from Past Present And Future Of Electron Microscopy In Agricultural Research
 - Personalized Recommendations
 - $\circ\,$ Past Present And Future Of Electron Microscopy In Agricultural Research User Reviews and Ratings
 - Past Present And Future Of Electron Microscopy In Agricultural Research and Bestseller Lists
- 5. Accessing Past Present And Future Of Electron Microscopy In Agricultural Research Free and Paid eBooks
 - Past Present And Future Of Electron Microscopy In Agricultural Research Public Domain eBooks
 - Past Present And Future Of Electron Microscopy In Agricultural Research eBook Subscription Services
 - Past Present And Future Of Electron Microscopy In Agricultural Research Budget-Friendly Options

- 6. Navigating Past Present And Future Of Electron Microscopy In Agricultural Research eBook Formats
 - ∘ ePub, PDF, MOBI, and More
 - Past Present And Future Of Electron Microscopy In Agricultural Research Compatibility with Devices
 - Past Present And Future Of Electron Microscopy In Agricultural Research Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - o Adjustable Fonts and Text Sizes of Past Present And Future Of Electron Microscopy In Agricultural Research
 - Highlighting and Note-Taking Past Present And Future Of Electron Microscopy In Agricultural Research
 - o Interactive Elements Past Present And Future Of Electron Microscopy In Agricultural Research
- 8. Staying Engaged with Past Present And Future Of Electron Microscopy In Agricultural Research
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Past Present And Future Of Electron Microscopy In Agricultural Research
- 9. Balancing eBooks and Physical Books Past Present And Future Of Electron Microscopy In Agricultural Research
 - Benefits of a Digital Library
 - o Creating a Diverse Reading Collection Past Present And Future Of Electron Microscopy In Agricultural Research
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Past Present And Future Of Electron Microscopy In Agricultural Research
 - Setting Reading Goals Past Present And Future Of Electron Microscopy In Agricultural Research
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Past Present And Future Of Electron Microscopy In Agricultural Research
 - Fact-Checking eBook Content of Past Present And Future Of Electron Microscopy In Agricultural Research
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements

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web oct 1 2014 fiscal calendars 2015 in other file formats word excel pdf financial calendars 2015 16 for the united kingdom running from april 2015 to april 2016 13 months other multi year calendars for 2014 15 split year calendars 2014 15 july 2014 to june 2015 school calendars 2014 15 august 2014 to july 2015 academic calendars excel formula get fiscal year from date extendoffice - Jan 29 2022

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