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Forum 3: X-ray imaging
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Insights on the fluid transport, geometric scaling, and living architecture of insect physiological systems revealed by x-ray imaging

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Applying imaging technology to novel biological systems is making it possible to make discoveries that break longstanding paradigms in physiology and animal behavior from the microfluidics of respiratory systems to the spatial dynamics of insect societies. Working with collaborators at Argonne National Laboratory, The University of Chicago, Arizona State University, Virginia Tech, Union College, and Providence College, we have spent the last decade using synchrotron x-ray and conventional x-ray imaging to study many different aspects of insect biology that would otherwise not be possible to visualize or study. One of the classic paradigms of insect respiratory physiology is that tracheal systems were supposed to be rigid. These branching and anastomosing networks of thin-walled and air-filled tubes are responsible for providing the conduits for gas exchange throughout the insect body. Synchrotron x-ray phase contrast imaging of live insects has revealed that in many species the tracheal system has evolved into a dynamic organ that inflates and deflates, often in a rhythmic manner that resembles the tidal ventilation patterns characteristic of larger vertebrate organisms. Using the same energy source with immobilized specimens has also made it possible to tomographically reconstruct detailed three-dimensional respiratory system structures down to the micron-scale and quantify the extent to which their geometry is environmentally sensitive to ambient oxygen partial pressures during development. Additional case studies will be presented including the allometric scaling of tracheal system investment and how this relates to Paleozoic gigantism, the pulsatile feeding mechanics exhibited by the insect cibarial pump, and the first study to visualize the explosively foamy defensive secretion of tropical ants. Tabletop microtomography x-ray light sources are also making it possible to study systems at a larger scale, including the spatial organization and interactions between ants within their nests.