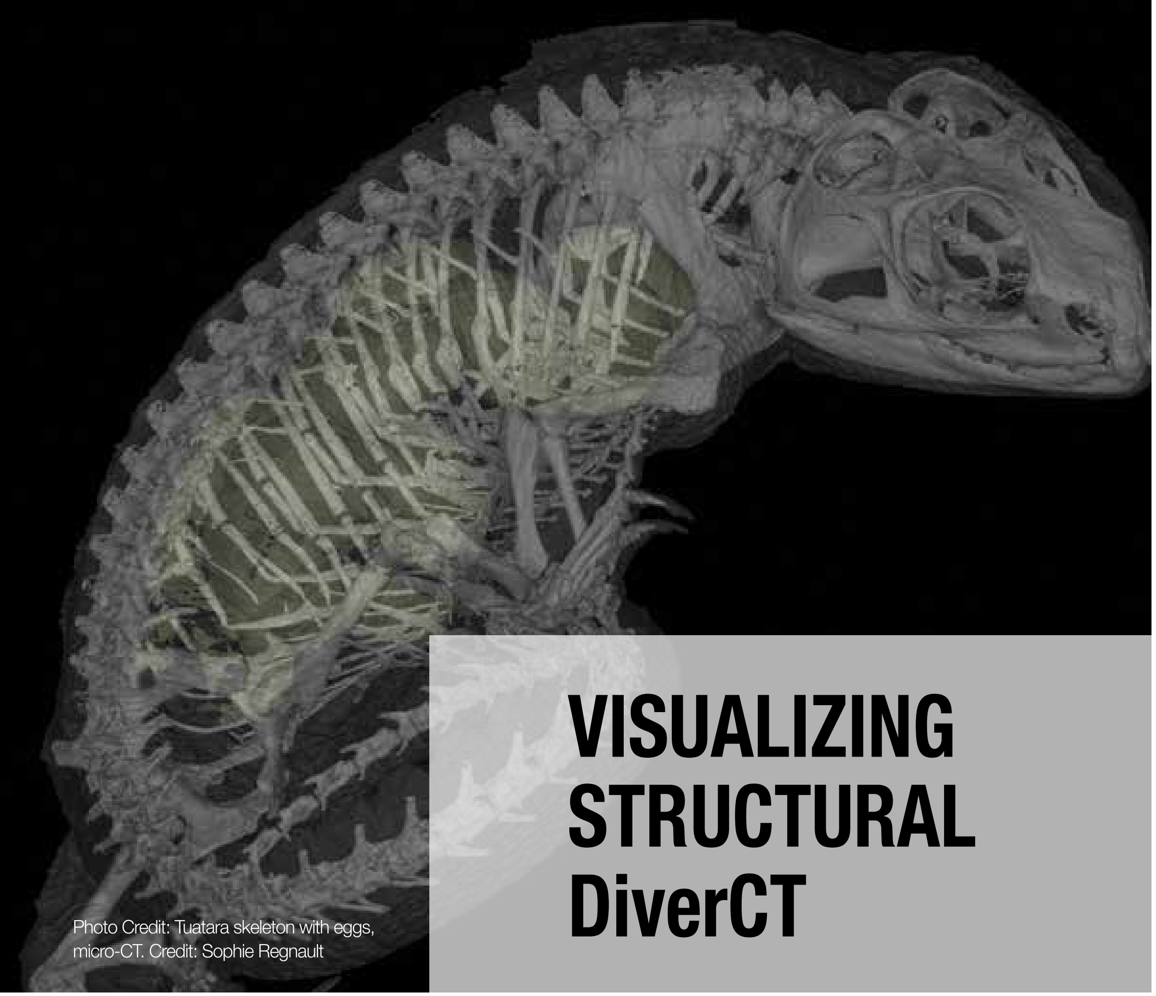


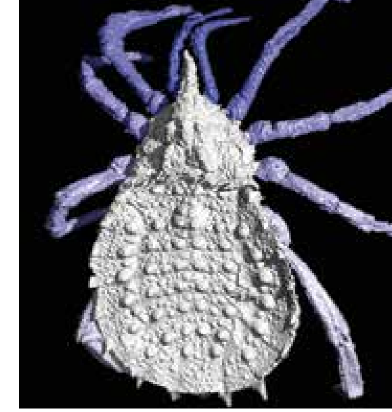
Photo Credit: Tuatara skeleton with eggs, micro-CT. Credit: Sophie Regnault

VISUALIZING STRUCTURAL DiverCT

For most people, computed tomography (CT) scanning is a familiar medical term for a diagnostic x-ray test. They may have even had a CT (or CAT) scan ordered by one of their doctors for investigation of the head, the abdomen, or another part of the body. However, the uses of CT scanning extend well past the medical field. These types of x-ray scans help us visualize the internal features of structures within many solid materials, including their shapes, sizes, and textures.

A single x-ray photograph is often taken to see into an object, with the resulting image being an average of the density of the material, a 3D object flattened into 2D. However, CT scanning involves a series of x-ray photographs being taken rotationally around an object, which can then be used to generate a 3D image. Conventional CT typically scans large areas, so the resolution is limited to about 1 millimeter due to limitations in the number of pixels on the x-ray detector; however, by scanning a smaller area, micro-CT scanners can provide much higher resolution – about 1000 times higher (1 micron). This level of detail is often needed to image small, complex structures, allowing researchers to make important discoveries in a variety of fields.

When fossilized segments of dinosaur tail were recently recovered in present-day Alberta, Canada, the scientists at Tel Aviv University noted cavities on the vertebrae that resembled a rare human cancer called Langerhans cell histiocytosis (LCH). By micro-CT scanning the tumor and surrounding blood vessels, they were able to confirm that the lesions present were a result of LCH. LCH results in distinctly shaped bone defects, and when the spine is involved, it typically affects the thoracic vertebral bodies (the oval bones between discs), which could cause anterior wedging and compression fractures. The researchers observed this pattern, identified LCH as the cause, and thereby concluded that LCH has existed for approximately 66 million years. The disease had never before been identified in a dinosaur or in a fossil. Thanks to studies like these, we are one step closer to determining the causes of certain illnesses, as



Computed tomography (CT) scan reconstruction of a 312-million-year-old arachnid fossil. The original Plesiosiro madeleyi represents the only known specimen of the order Haptopoda, an extinct branch of the arachnids class. (Colourized)

well as the evolutionary conditions that enabled their development and survival.

Not only are micro-CT scans useful for identifying diseases, they can also reveal key information about the historic timeline of various animals. Researchers at the University of Missouri recently analyzed tubular fossils and discovered the world's oldest-known digestive tract. This 550-million-year-old fossil from the Nevada desert could be an important piece of the evolutionary puzzle, as the micro-CT imaging allowed for visualization of its small internal structures and revealed its anatomical similarity to worms; the organism, from the ***cloudinid family***, was previously thought to bear more anatomical

WHAT IS THE CLOUDINID FAMILY?

The cloudinids lived during the final 10 to 15 million years of the Ediacaran Period, which is the period that preceded the Cambrian Explosion. Since scientists believe that the Cambrian Explosion is the period in which an influx of complex animals suddenly appeared in the fossil record, discoveries from the Ediacaran Period have special phylogenetic significance (i.e., they can shed light on evolutionary relationships).

WHAT IS REFRACTION

When an x-ray wave interacts with matter, it is slowed down. Since the frequency of a wave always stays the same, the wavelength must decrease, and thus a phase shift (shift in wave peak positions) occurs relative to the original wave before it entered the medium.

similarity to corals. Because of technological advances in imaging, particularly micro-CT imaging, scientists can view 3D images of fossils and identify internal structures without destroying the sample.

Given the important and diverse applications of micro-CT, there has been a big push for researchers to develop improved equipment with which to image samples. A company that is pushing the boundaries of micro-CT technology is KA Imaging, a spin-off from the University of Waterloo. Proto recently partnered with KA Imaging to develop their latest micro-CT scanner, the inCiTe, in which images are taken continuously while x-rays impinge upon a rotating sample. This system is the first commercial CT scanner to feature KA Imaging's unique, high-spatial-resolution amorphous-selenium (a-Se) detector. The compact benchtop design makes it possible to perform micro-CT scans without extensive space requirements. In addition, the a-Se detector has an 8-micron pixel size, which is much smaller than typical Si-based flat panels. This detector allows for direct conversion of x-ray photons into electrical charge. This direct conversion coupled with a high detective quantum efficiency (DQE) enables efficient imaging at low flux and high energy, making the inCiTe a very versatile machine.

Because of the detector's small pixel size, this system has the added advantage of phase-contrast imaging, which allows for the investigation of materials that cannot be visualized with conventional x-ray imaging. For example, soft biological tissues and polymers typically have poor absorption; however, when an x-ray passes through these materials, it is also ***refracted***. After leaving the object, the refracted (phase shifted) x-rays can start to interfere with each other, and when given a long enough propagation distance, the interference effects can be observed on an x-ray detector. The effect is most pronounced when there is an abrupt change in refractive index – for instance, at boundaries and edges within a material. Phase shifts' effects are typically 100 to 1000 times stronger than effects from absorption, thereby improving the

visibility of samples that typically have weak x-ray absorption. However, the interference effects occur over very small distances, so a high-resolution detector is needed in order to observe this edge enhancement.

For example, using the inCiTe system, tissues can be visualized with high contrast, such as in the mouse knee shown below (left), enabling the cartilage to be examined in great detail. The composite material pictured below (center) is a piece of Kevlar. With the help of phase-contrast imaging, individual fibers sized 10-20 μm can be seen within the material. The third CT image below is an LED. Phase-contrast capabilities allowed its substrate layers to be identified, and the wire bond shapes can be seen clearly thanks to the system's high-resolution detector.

The inCiTe system is ideal for analyzing fine structures in materials such as polymer composites and biomaterials but can be used in various fields and applications, including non-destructive testing (NDT), electronics, additive manufacturing, geology, and agriculture.