

Journal of NATURAL SCIENCE ILLUSTRATION

GUILD OF NATURAL SCIENCE ILLUSTRATORS



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A Note From...

Clara Richardson, GNSI Journal Editor-In-Chief

Your Journal editors are happy to present you, our members, with this issue, which arrives at the time of the 50th Anniversary of the founding of GNSI. We take this unique opportunity to be able to present this issue to participants at the 50th Anniversary Annual Conference in Washington, DC and look forward to seeing as many of you there as possible.

Once again, article diversity reflects the diversity of our members. We have articles on subjects varying from 3-dimensional computer space to watercolor, from tangible to intangible. We are happy to be able to share a considered study of the flight anatomy of both real and imagined creatures, a technical article on the use of 3D modeling in illustration, a book about an extraordinary artist and musician, the real life story of a GNSI member and student artwork from the scientific illustration program at California State University at Monterey Bay. We hope that each of you will celebrate the benefits of our diversity as well.

Occasionally our ship comes in with more pages than usual, and that is certainly so in this case. Some of these articles have been in the works for longer than usual so we also celebrate their arrival and are grateful to their creators. Long development periods are sometimes required for articles for various reasons, from the nature of the subject matter to the schedule of the author.

We hope that some of you will be inspired to present a subject that may take time to develop—your editors would be happy to help you realize such a project. Choose an untraditional subject or style of presentation, we'd be interested. Come talk to us during the conference or email us afterwards.

—Clara Richardson
clara@illustratingforscience.com

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Cover Caption: Long extinct Pterosaurs and flying raptors can help inform us of the requirements for successful flight of creatures that have not yet evolved, and therefore live only in our minds—for now.... © 2018 Terryl Whitlatch

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Wings, Tails, and Real Flying Monsters:

Illustrating Flying Vertebrates

— Dr. Michael Habib, with illustrations
by Terryl Whitlatch

Abstract

Understanding the mechanics of flying creatures is an important skill to have in one's tool kit when you approach the realistic recreation of paleo flyers. These same mechanics can be used to inform the creation of imaginary flying animals. The fossil record, as well as the practical mechanics observable in extant flying animals are most instructive for our recreations.

I am a professional scientist who specializes in the fossil history, mechanics, and anatomy of flying animals. Over the years, I have consulted for a range of natural history exhibits (including the largest pterosaur exhibit ever assembled) and television programs depicting winged animals, both extinct and living. Most of the programs I have worked on or provided data for (such as Dinosaur Revolution, Clash of the Dinosaurs or the film Walking with Dinosaurs) feature animals that really existed, but

many films and television shows depict fantasy creatures inspired by real flying animals (from giant eagles to Avatar's banshees). Seeing well-conceived flying animals in a film can have enormous visual impact and can be among the most inspiring parts of a fantasy film. I am always thrilled to see a well-designed flying monster come to life onscreen.

However, over the past fifteen years that I have been working in the field of flight mechanics, I have seen some consistent problems plague many reconstructions and animations of winged creatures that negatively affect their accuracy or sense of realism. These errors are disappointing, but they are also understandable—very few scientists or artists have ever received instruction on the mechanics of wings or winged animals. I have been working over the last ten years to help address this problem by teaming up with concept artists, museums, animators, and natural history illustrators to present more accurate depictions of flying animals. This article examines some of the most important features of flying vertebrates for artists.

Figure 1: Various flapping winged* vertebrates (not to scale) featuring:

- A. *Pteranodon longiceps*
- B. *Rhamphorhynchus muensteri*
- C. Great Frigate Bird
Frigata minor
- D. *Microraptor* sp.
- E. *Archaeopteryx lithographica*
- F. Barn Swallow
Hirundo rustica
- G. *Confuciusornis sanctus*
- H. Hammerhead Fruit Bat
Hypsignathus monstrosus

*Fore leg powered flight ranging from rapid sequential flapping to soaring.

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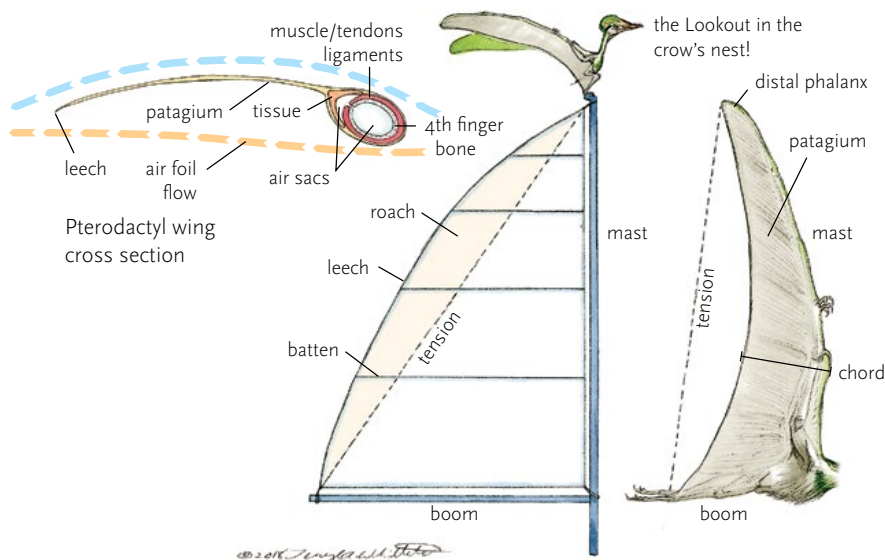


Figure 2: An analogy of a sailboat sail compared with a pterosaur wing concerning roaching. Note curvature of distal phalanx (fingertip) under tension in uplift; hence wing displays concavity in roaching (silhouette of trailing edge). Actinofibrils are actually too thin to act as true battens, and so pterosaur wings would not have the convex trailing edge of some modern sails. Membrane wings must be kept tensioned in flight.

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Top left: Cross section of Pterosaur wing showing interior air sacs. Adapted from Mark Witton, ©2013

We have chosen to emphasize pterosaurs, the flying reptiles known from the Mesozoic fossil record, for two reasons. First, pterosaur reconstructions are particularly challenging, because there are no living pterosaurs. Second, the modern artist has a wealth of recent discoveries in pterosaur paleobiology to tap for creature design that are, at present, underutilized.

Lessons from the living: the fundamentals of wings

Thanks to careful study of living flyers, we observe that animal wings have three primary constraints: they must be properly supported internally, they must articulate correctly for both flight and folding, and they must have enough muscle attached to them to power flight (which is energetically expensive). Flyers in the past, such as pterosaurs, had to abide by the same rules, and we can use that knowledge to improve reconstructions of fossil flyers. Abiding by these rules is also important when creating creatures in the world of fantasy and concept art.

Wings on fantasy creatures (at least those that are supposed to look like vertebrate animals) typically need to do three primary things to appear plausible: they need to have enough surrounding musculature attached for the size of the flyer, they need to be properly supported, and they need to be able to fold and unfold realistically.

For musculature, it's worth keeping in mind that, on average, 15–16% of the mass of a flying bird is flight muscle. For fast flyers like ducks, this can be more like 25%, and for powerful sprint flyers like grouse, it can be nearly 30%. Large pterosaurs probably had even larger flight muscles, comparatively (though, unlike birds, some of this would be on their backs, rather than all being attached to the chest).

Wing support is a complex subject. If the wing is made of stiff components (such as feathers), then the only support system to worry about is the underlying

skeleton. However, membrane wings raise the issue of wing tensioning. A wing cannot work properly if it flutters significantly, so a membrane wing must have a way of staying taut. Bats accomplish this by having four of their five fingers running through the wing on each side and by having the wing run to the hind limb. Pterosaurs only had one finger imbedded in the wing, at the leading edge, and so they would have required stiffening fibers inside the wing and a tougher wing surface. There is direct fossil evidence for both of those features, confirming the expectations from physics and anatomy.

Even with the internal support of fingers and fibers, a membrane wing typically cannot have a convex trailing edge (called roaching) or a forward flexing wing tip. A membrane wing requires a concave trailing edge, unless it has something equivalent to batons running along its full length (as is the case in convex racing sails, for example). A concave trailing edge is particularly important for a wing with a single support, as in pterosaur wings. Illustrations of pterosaur wings with roaching are popular, but they are not anatomically plausible. Showing excessive rippling or distortion of the wing surface is also not realistic—a wing that blows in the breeze like a flag will generate very little lift. If some indication of air movement is desired, then it is more reasonable to show the effects of the wind on other parts of the animal.

The motions of animals in flight obviously differ from the motions of running or swimming animals. A turning motion in flying animals will generally include some degree of roll (rotation about the long axis from the head to the tail). Unlike a running animal, which may lean into a turn for stability reasons, flying animals use banking to *produce* the turn in the first place, so sharper turns will necessitate a greater amount of roll.

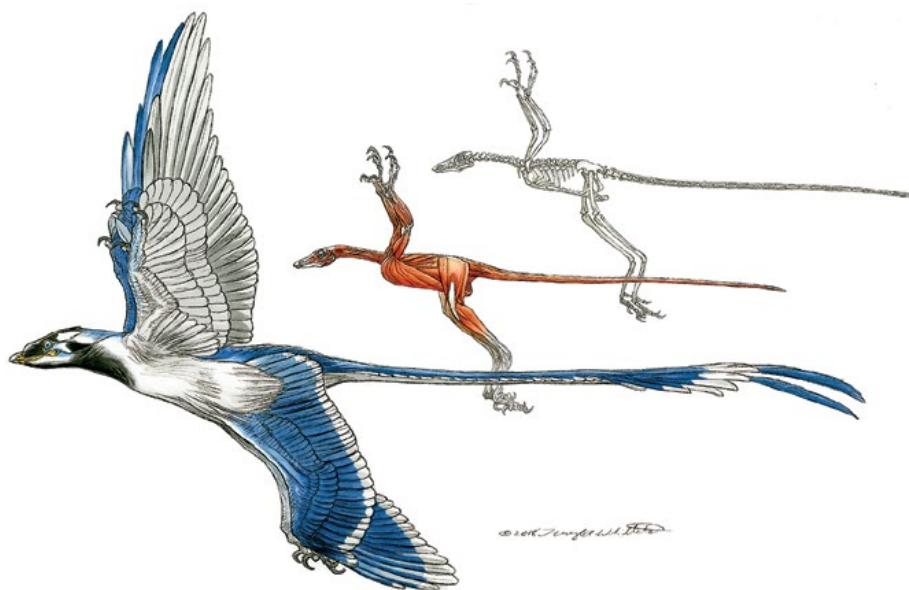
While this article deals mainly with those vertebrate animals capable of flapping, powered flight, there are a great many species that are specialist gliders (including several rodent species, some possums, a few species of snakes, at least one genus of frogs, and multiple species of lizards). These animals use gravity to power their flight, as they do not produce thrust of their own. As a result, gliders will typically take off from an elevated location. Just like powered flyers, gliders use a powerful leap to enter flight.

Birds and their winged relatives

We are fortunate to share our world with thousands of living bird species, and they are our best guide to the anatomy and motion of feather-winged flyers. With about 11,000 living species, birds encompass a tremendous array of lifestyles. Despite this, there are some common themes in how they take off, fly,

and land. Birds take off by using their legs, and most of them prefer to jump into the air (rather than run). A typical launch pose for a bird has the wings elevated as the toes leave the ground, ready for the first downstroke. It is important to note that the first downstroke follows the initial takeoff, rather than being simultaneous with it. In flight, like all powered flyers, birds “slice” their wings down and forward on the downstroke. On the upstroke, the feathers of the wing tips often twist and separate, reducing resistance as the wings are raised. Birds that are flying slowly will usually bend the joints of the wing significantly during the upstroke. In fast flight, the wing is kept more extended during the upstroke. Modern birds display a vast array of wing shapes and feather anatomy, and they can (and do) greatly alter their wing shape during flight, in many cases. In addition to the wings, birds also can use the legs and tail to change the centers of mass and lift, to maneuver, and to stabilize their flight path when faced with gusts or other disturbances.

Many of the flight-related features in living birds can be traced back to their non-avian ancestors, though the exact trajectory by which flight evolved in the bird lineage is uncertain. The origins of birds (and particular, the origins of avian flight) are among the most hotly-debated topics in paleontology, and the subject provides numerous opportunities for visualization of unique winged animals. Among the most exciting discoveries of the early 2000s has been a wide diversity of winged near-bird dinosaurs. These animals had feathered bodies and wings, but they were not birds (though they were closely related to birds). Among the most famous of these feathered dinosaurs were the microraptorines, which ranged from the size of a crow to the size of a



golden eagle. These unique creatures had five wings, in the aerodynamic sense: a pair on the forelimbs, a pair on the hind limbs, and a tail fan. While all three of these feathered surfaces may have been aerodynamically important, the “hindwings” would have been necessarily vertical in flight, rather than held horizontal like the main wings. Vertical wings are not useful for supporting weight, but they can be used for control and/or stability. The hindwings and tail of microraptorines (like *Microraptor* and *Changyuraptor*) may have helped keep them on target when chasing prey or getting in and out of trees. From the standpoint of artistic rendering, these behaviors can be illustrated by using dynamic poses and positions that bring the hindwings or tail into play.

Most extinct birds would have looked quite a bit like living birds. Even in the Mesozoic, there were numerous relatively modern-looking birds, though

Figure 3: *Microraptor* sp. Reconstruction

Ancient birds flew with palms oriented forward—this can be observed in modern birds (*Neornithes*) in the forward-facing alula (which attaches to “thumb” musculature) and in those few birds with claws on the wings—the claws curve forward from the wing. Color is speculative, based on the modern Magpie Jay. While at least some microraptors were primarily black with some iridescence, it is possible that some other microraptorian species displayed more pattern variety in addition to black, as is seen today in various corvids, sturnids (starlings), and icterids. Blue is typically a structural color, backed by black melanins, so the “black” regions on microraptorine feathers might have been blue, in life, just as is the case in living jays.

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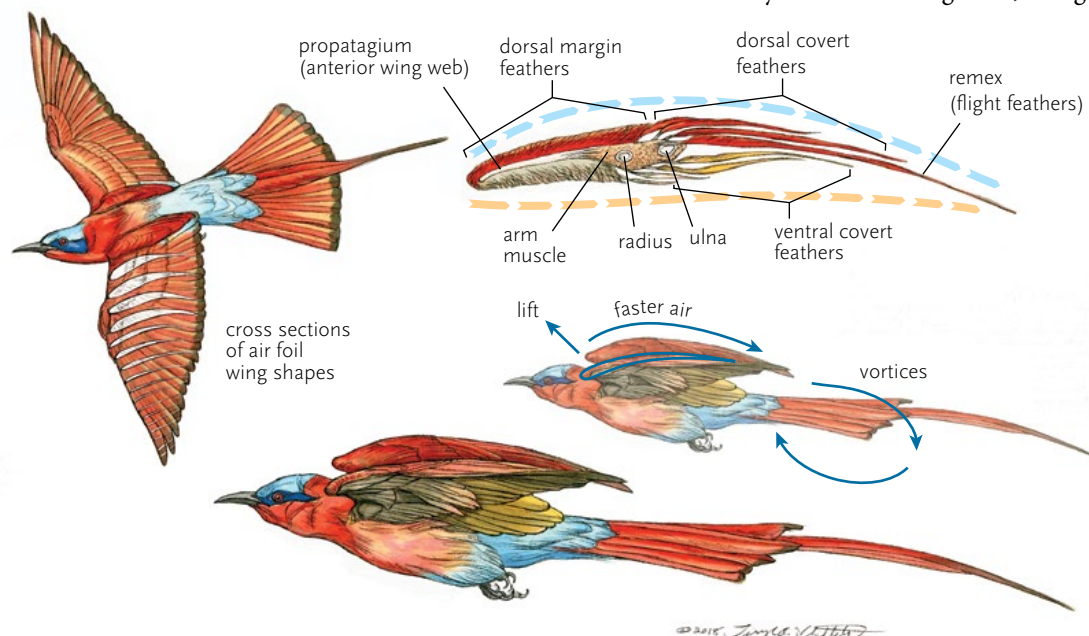


Figure 4: The neornithine Carmine Bee-eater (*Merops nubicoides*) demonstrating the airfoil cross sectional silhouette of modern birds and some ancient bird wings. The wing basically “stirs” the air, making it spin, which speeds up air on top and slows air on the bottom of the wing. It also means that vortices are spinning behind the wing (Newton’s laws)—the air is being pushed down and back. As a result, the bird goes up and forward.

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Figure 5: Falling with Style
Modern-day Draco lizard, *Draco taeniopterus*, with expandable ribs for gliding.

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Figure 6: Pterosaur Timeline
The Pterosaurs flourished during the three periods (subdivisions) of the Mesozoic Era—the Triassic, Jurassic, and spectacularly during the Cretaceous, where bizarrely-proportioned, jet fighter-sized animals such as the azhdarchid *Quetzalcoatlus* appeared. The wyvern-like long-tailed species lived mainly during the Jurassic period. (Not to scale)

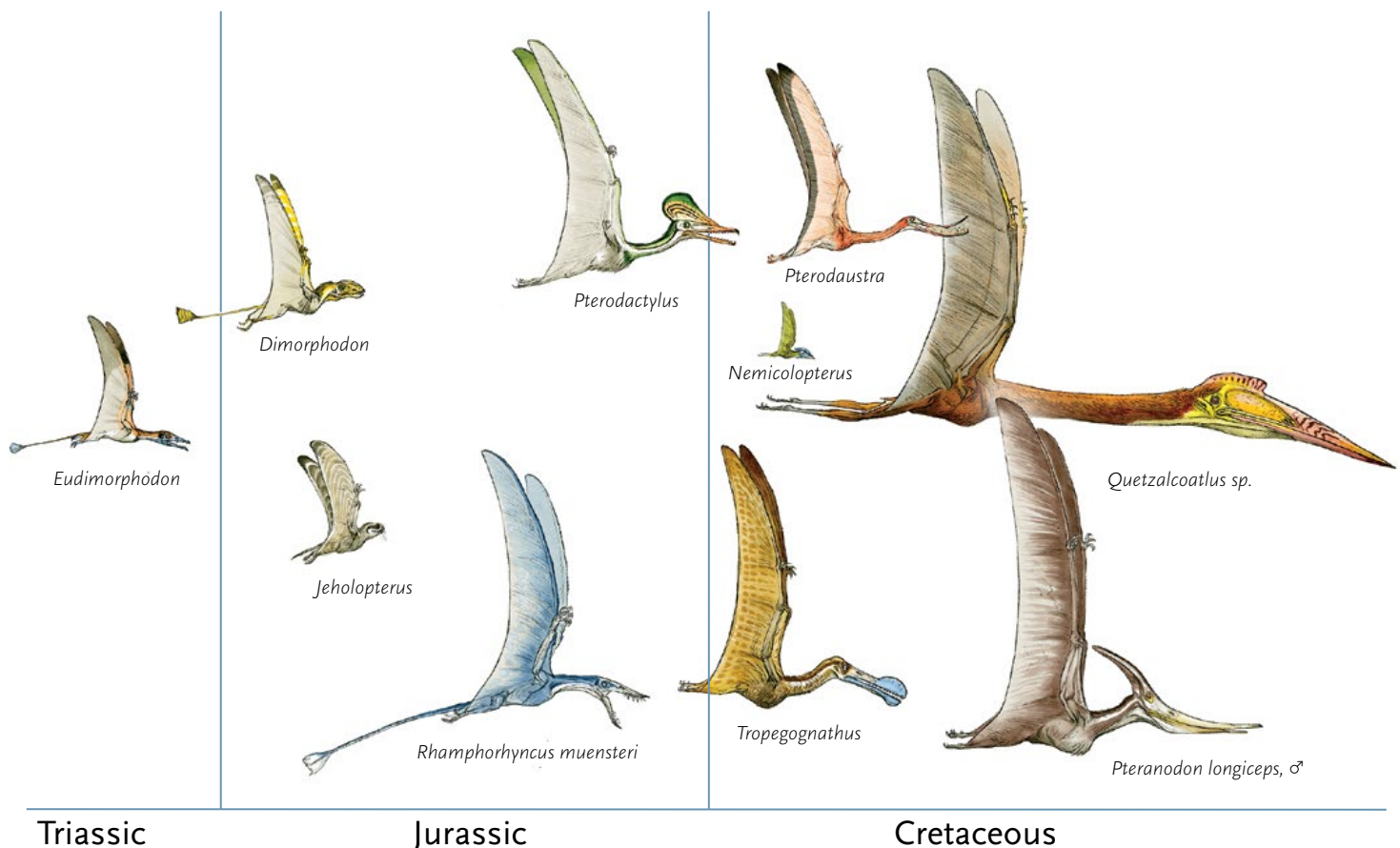
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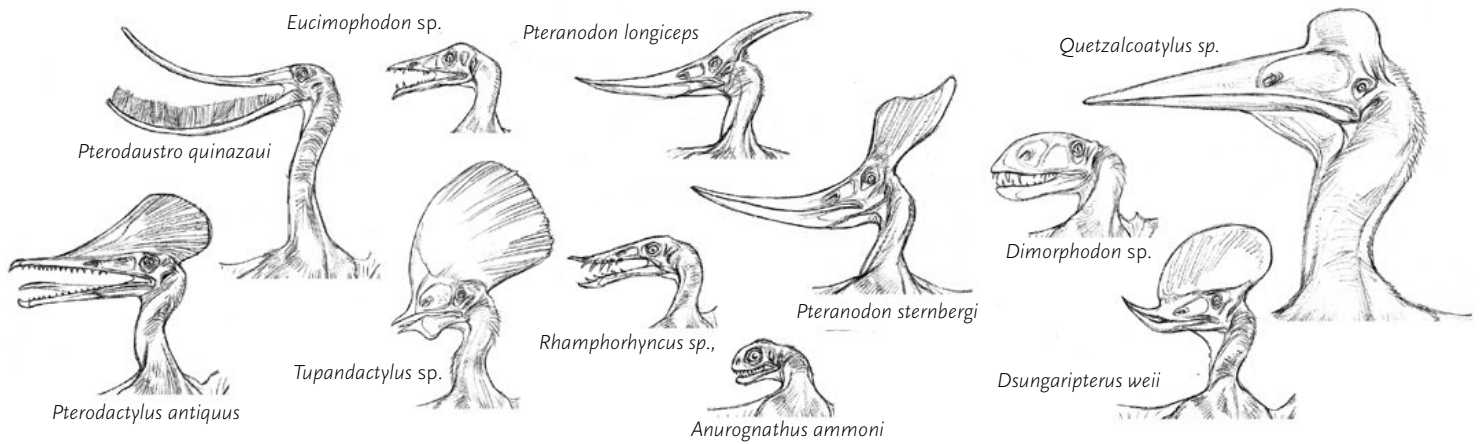
some of these had teeth or clawed hands. It should be noted that the manual claws on extinct birds probably pointed mostly *forward* from the plane of the wing. While we tend to imagine that the palm of a bird's hand is pointed towards the ground in flight, the equivalent of the palmar surface, in fact, points more forward. The wing claws of extinct birds might have helped adjust air flow on the wing (specifically by helping create extra vortices), so it is sensible in animations of these animals to show them adjusting the fingers/claws in flight.

The earliest feathered flyers (microraptorines, early birds, and their kin) may not have had exactly the same kind of feather development and structure as living birds, however. The latest information from feathers preserved in amber suggests that early birds (in the late Jurassic and early Cretaceous, especially) lacked the developmental innovations required to produce feathers that were aerodynamically stable on their own. The evolutionary solution to this problem, in early birds (like *Archaeopteryx*), was to layer the feathers tightly for reinforcement. These birds probably could not separate the primary feathers to create 'slots' the way that many living birds do, because the individual feathers of these earlier flyers would have flexed and twisted in unstable ways if loaded individually.

Falling with Style: Unpowered Flight

Not all flying animals are powered flyers that flap their wings to produce thrust. There is a huge diversity in the living world, and the fossil record of unpowered flyers. These animals are often colloquially referred to in shorthand simply as gliders, even though powered flyers may also spend some time gliding. Gliders are interesting cases studies for the anatomy of living species and the design of fantasy creatures. For gliders, flight is a secondary form of locomotion. They are typically climbing animals that have skeletons and musculature very similar to non-flying leapers and climbers. In fact, from the skeleton alone, it is often difficult to identify animals such as gliding squirrels and possums as flying animals—their proportions are mostly consistent with other climbing animals. There are exceptions, however, as some gliders have truly extreme skeletal alterations associated with the suspension of their wings. Perhaps the best example of these more extreme cases are the lizards in the genus *Draco* (Fig. 5), which have enormously elongated ribs that can be folded away at rest, or extended to stretch a membranous wing into flight position. Some fossil species have similar wings—the gliding reptile *Icarosaurus* (named for the legend of Icarus) also had wings stretched across ribs, rather than the limbs.





Gliders use gravitational energy to power their flight, they must sink relative to the air as they travel—essentially falling with style. They can still rise relative to the ground if there are strong updrafts or other external sources of lift. Just like powered flyers, gliders initiate launch with a powerful leap. Since they use gravity to power their flight, gliders typically jump from an elevated position to enter the air (most gliders are tree-living animals, though one can imagine a myriad of alternative “high points” in a creature design scenario—if cities persist, perhaps someday there will be gliders specialized at leaping from high rise buildings!). One curious feature of gliders is that no particularly large species have been found either in the fossil record or the living world

today. The largest known gliders are the living giant flying squirrels. The red giant flying squirrel can reach about 2.9 kg in mass, a fraction of the size of the largest powered flyers. For comparison, consider that a Canada goose, hardly a giant flyer, can easily be double the mass of a giant flying squirrel. It is not known why gliders are so constrained in size. It could be that living in trees put significant limits on size. It may also be that gliding across gaps in the canopy simply becomes inefficient at large sizes: for animals much above 3–4 kg, the leap needed to initiate flight will probably clear most canopy gaps all on its own, eliminating the advantage of gliding across. Small animals, however, can travel a great deal further by gliding than they can by jumping.

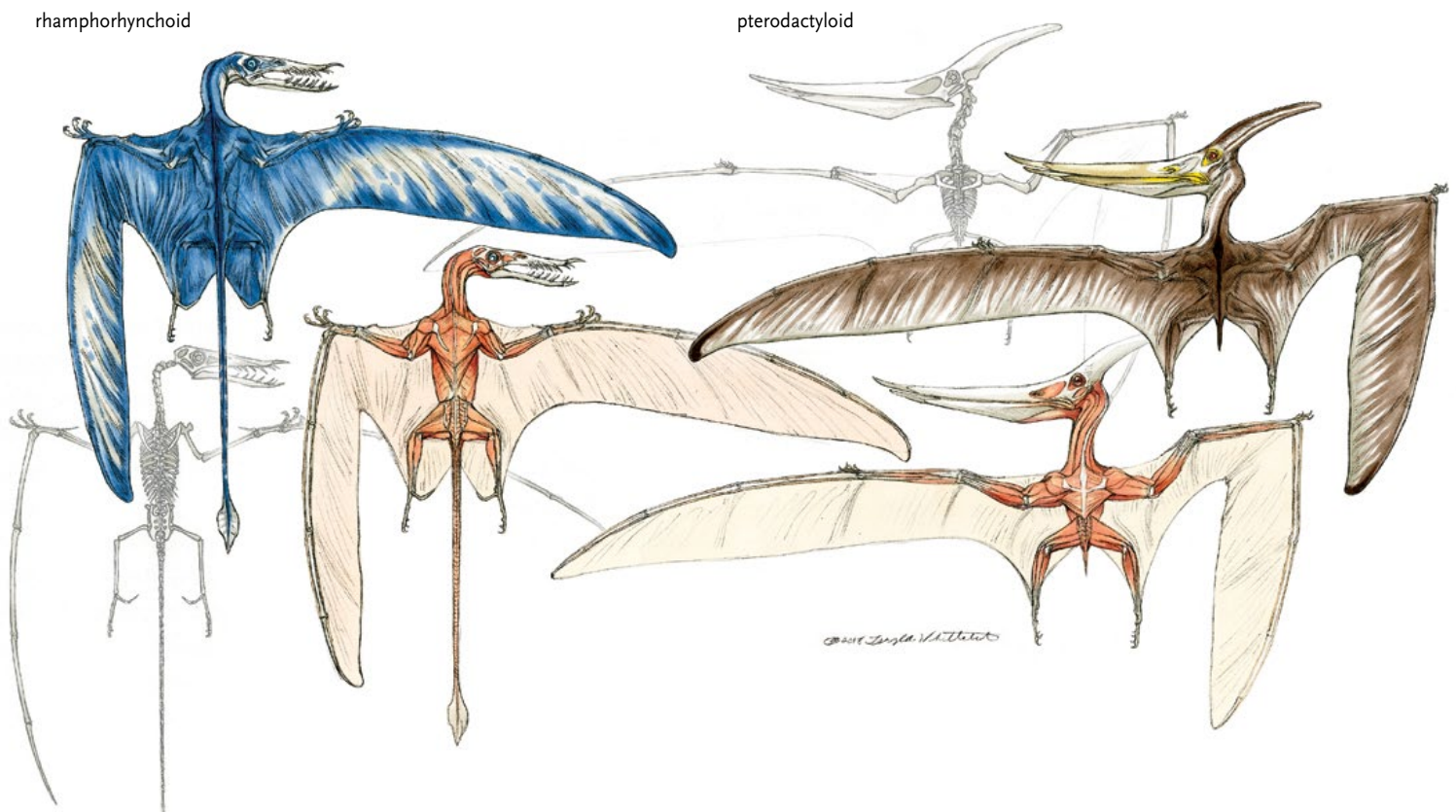
Figure 7: Anatomy

(above): A small sampling of the wide kaleidoscope of Pterosaur heads, some with spectacular casques and crests.

(below): The two main body types of Pterosaurs — **rhamphorhynchoid** (long-tailed and long-toothed) **pterodactyloid** (large-headed, short-bodied, and short-tailed, often toothless).

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Skeletal poses adapted from Mark Witton, ©2013. (Not to scale)



The strange anatomy of pterosaurs

A key element to reconstructing pterosaurs is properly representing their strange proportions. A timeline (Fig. 6) shows earlier pterosaurs (those from the Triassic and Jurassic) tended to have long, relatively stiff tails, broad membranes between their hind limbs, and heads about as long as their shoulder to hip distance. Some early species, such as *Dimorphodon*, had expanded heads that were relatively tall and slightly longer than their shoulder to hip length.

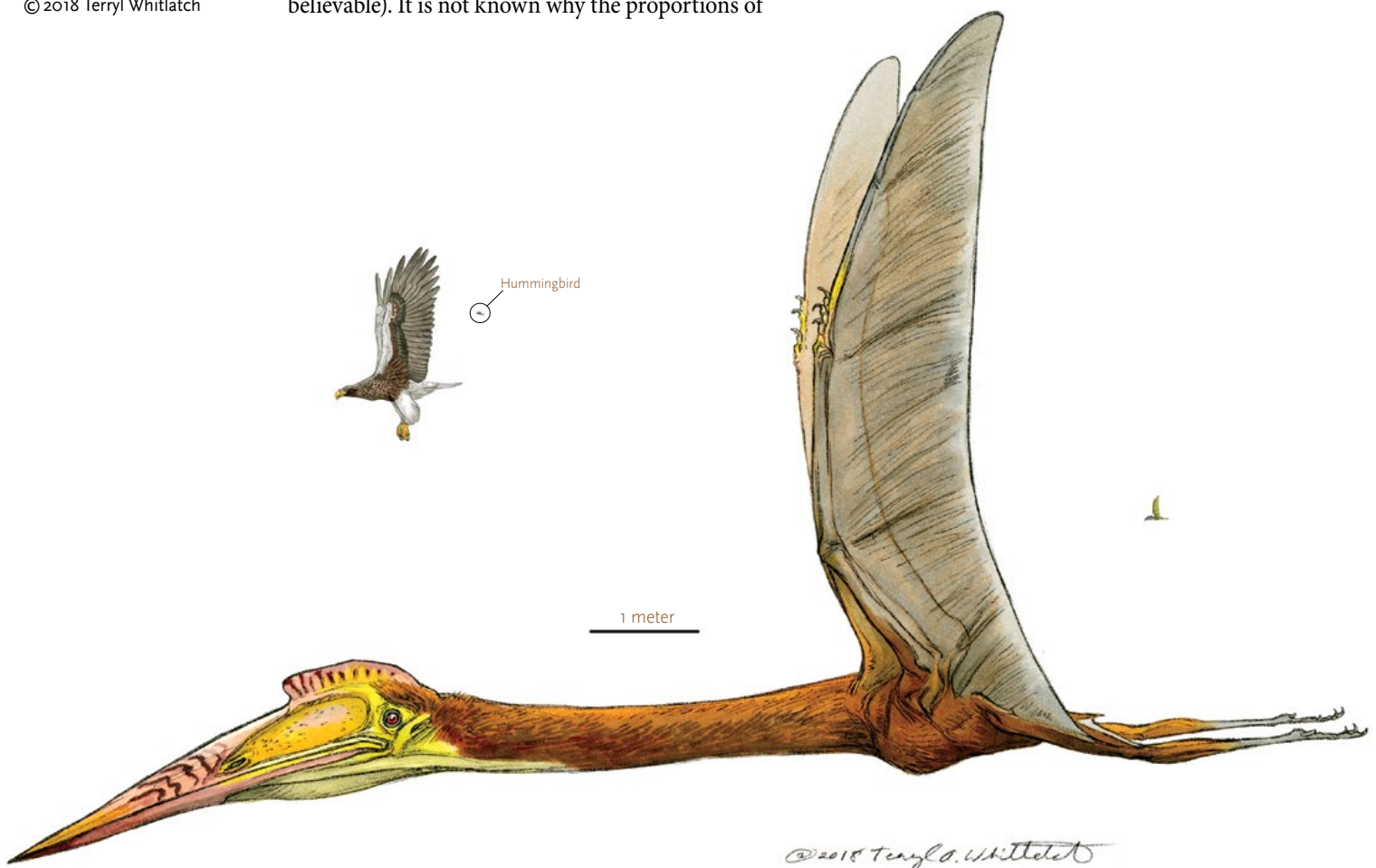
Cretaceous pterosaurs often had truly extreme proportions. Azhdarchids, which included the largest pterosaurs, often had skulls over three times longer than the shoulder to hip distance. The necks on many of the Cretaceous pterosaurs were as long (or longer) than their enormous heads, producing a strangely “front-weighted” look to the animals. When properly illustrated, these animals look almost alien. It might be for this reason that movies have sometimes knowingly changed the proportions of the final look of pterosaurs from more accurate early concept art (Walking with Dinosaurs shrank the heads on the giant azhdarchids, for example, because the producers did not think the real proportions looked believable). It is not known why the proportions of

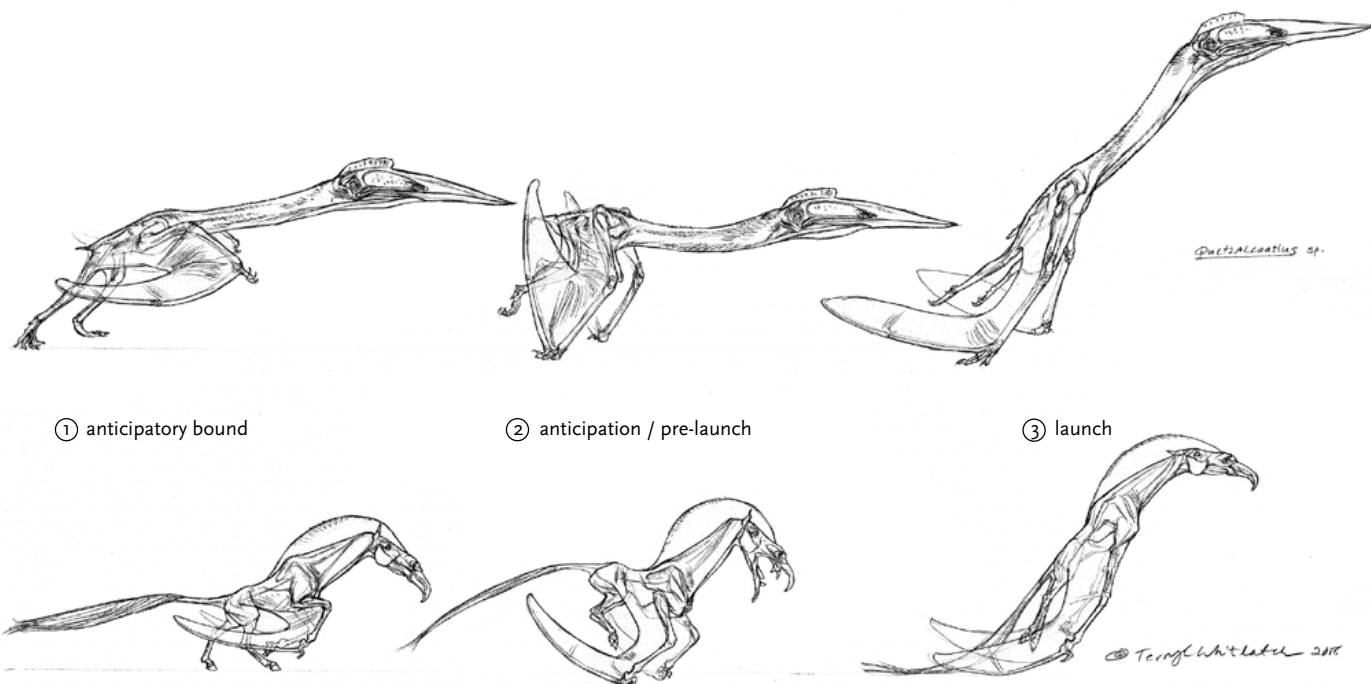
Cretaceous pterosaurs were often so extreme, though it may have been related, in part, to the giant size of many Cretaceous pterosaurs. Many pterosaurs, of all sizes, also had enormous crests that further expanded the size of their heads (Fig 7). The function of these crests is not well understood, though we can be reasonably confident that the crests had a signaling function, and not an aerodynamic one, so bright colors on the crests were likely.

The heads and necks of large pterosaurs had extensive air sacs, which would have helped lessen the load, but ultimately these animals would have required wings that were swept forward in flight to balance the center of lift from the wings with the center of mass from the body. The center of mass in the giant-headed Cretaceous forms was probably just in front of the shoulders. As a good rule of thumb, the center of lift on a wing (animal or machine) can be approximated as being 25% of the chord-wise length of wing behind the leading edge. The chord is the distance from the front of the wing to the trailing edge of the wing (the “front to back” distance—perpendicular to the wingspan). The center of mass and center of lift should always be lined up in any illustration of

Figure 8: Size comparison between two of the largest and smallest of the modern Neornithes, the Steller's Sea Eagle and Ruby-throated Hummingbird—and two of the largest and smallest of the Pterosaurs—*Quetzalcoatlus* and *Nemicolopterus*.

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a flying animal that is supposed to be in level flight. The center of mass is often dominated by the location of the flight muscles, since they are both dense and large. In pterosaurs, for example, the center of mass has been estimated near the shoulders. The center of mass would be a little further forward of the shoulders in those species with very large heads, but thanks to the lightweight skull and large flight muscles, the center of mass wouldn't be as far forward as the overall contour of the animal suggests.

The low density build of pterosaur skeletons should not be taken to mean that they were frail or thin animals, however. All pterosaurs, especially the extreme-proportioned species in the Cretaceous, had highly-expanded processes for muscle attachment throughout much of their skeleton. Pterosaurs should be reconstructed with large chests and muscular backs. Pterosaurs were, anatomically speaking, more “winged bruisers” than fragile organic kites. The contours of the bones in the wings were probably not visible in life. Pterosaur wings were suspended mostly from an elongate finger, and this finger would have had all the same tendons and other tissue around it as in the fingers of other vertebrate animals. The wing membrane itself would not have been flimsy or paper-thin, either. Well preserved wing impressions from pterosaurs demonstrate that they had a significant muscle layer within their wings, and the surface of the wing seems to have been keratinized. The wing therefore may have looked somewhat roughened in texture in life, and the wing was probably relatively opaque (as opposed to bat wings, which are somewhat translucent when back-lit). There are no living

animals with wings of this kind, so we have to imagine what the wing texture would have looked like. However, a reasonable example of the surface texture for pterosaur wings might be the unscaled areas of skin on living reptiles (there are some snakes in the pet trade now that are entirely scale-less, and their skin may be among the best examples of unscaled, keratinized reptile surface texture).

Lessons from pterosaurs: how to be a ridiculously large flying animal

The largest pterosaurs were truly huge by modern standards of flying animals: the heaviest living flying animals are kori bustards, and they can sometimes reach 18 kg. The largest pterosaurs, by contrast, were probably at least 260 kg, and they had wingspans up to 10 meters or so (Fig. 8). To some extent, this comparison is cheating: as recently as 1.8 million years ago, there were flying birds much larger than any living species (with wingspans more than 6 meters and body masses over 30 kg). The largest bird thought to have been flight capable was *Argentavis*, which probably massed 75 kg.

That still leaves a whopping big gap between largest flying pterosaurs and largest flying birds. Just the skull of the largest pterosaurs was roughly the length of the *wingspan* of the largest living flying birds. Pterosaurs are therefore highly informative to understanding what features a flying animal needs to be very large and still fly. All available data indicate that the Late Cretaceous atmosphere was not very different from the modern one: the prerequisites to obtaining giant size lie within the *anatomy* of

Figure 9: Making Horses Fly
Pterosaurs most likely achieved flight by bounding into a launch broadly similar to that of vampire bats (in that they use folded wings for much of the leaping power). A 1200 pound Hippogriff would probably use a similar approach with some variation common to equine locomotion in using its powerful hind limbs for further push off (as in Lippizan horses performing ‘airs above the ground’). A long stiff tail could add further thrust by slamming against the ground. In the air, it would act similar to a rhamphorhynchine tail counterbalance, as well as be visually interesting on the movie screen. On the ground, such a Hippogriff would assume a Chalicotheres stance and locomotion. This is zoologically consistent, as Chalicotheres were ancient relatives of horses.

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Figure 10: Striped Hippogriff (*Equus aquila draco*).

While currently no one has yet documented a substantially large vertebrate employing the gliding methods of the Draco lizard, one could postulate, biologically speaking, a large mammal becoming temporarily airborne in a series of powerful leap-glides augmented in duration by rib webs, as in this carnivorous hippogriff. Horses are already powerful leapers, some able to leap over 6 feet vertically over an arc of 28 feet, and so provide a plausible example.

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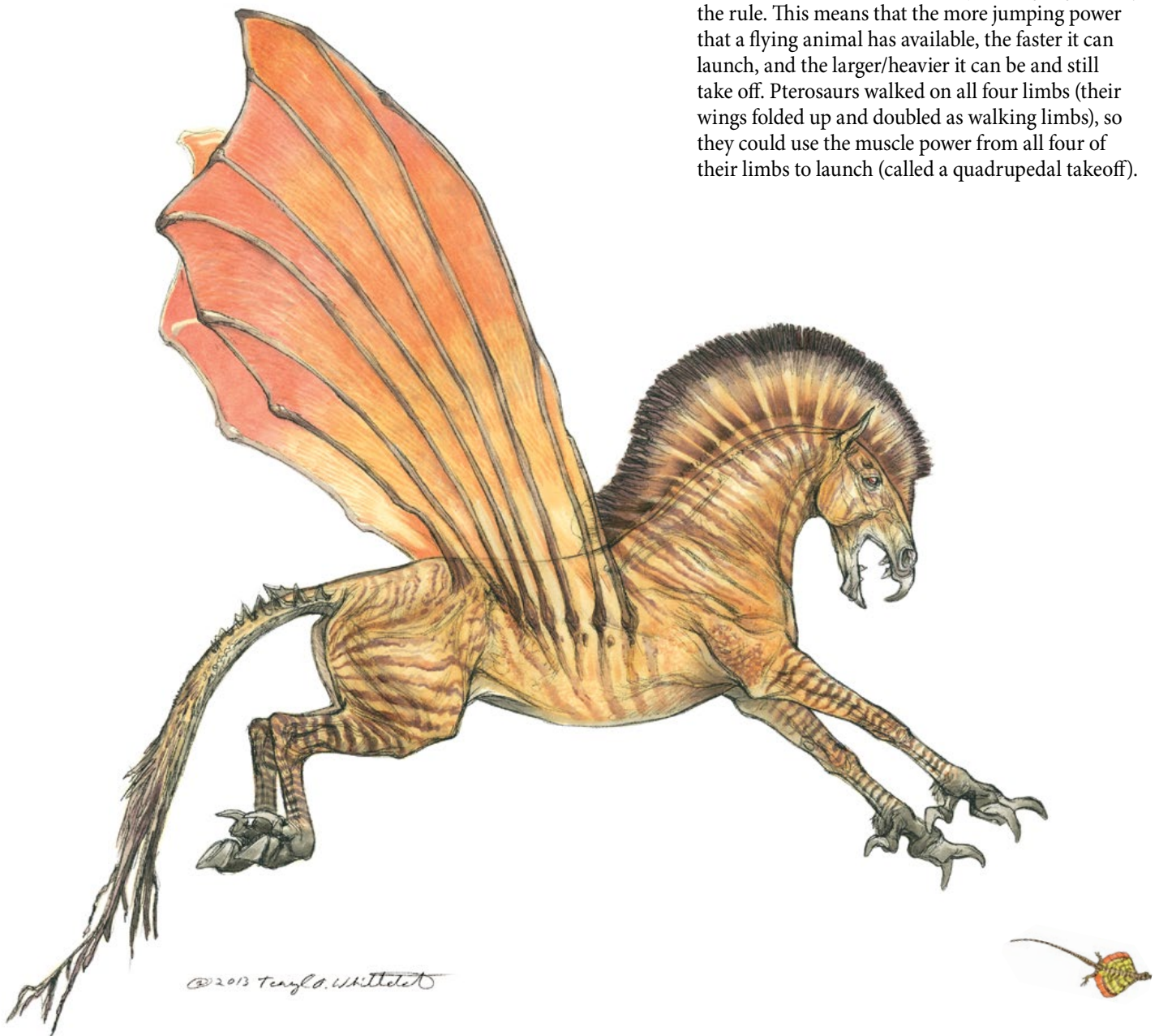
pterosaurs, rather than a quirk of their environment (though the advantages of being large are likely related to the Mesozoic world in which pterosaurs lived).

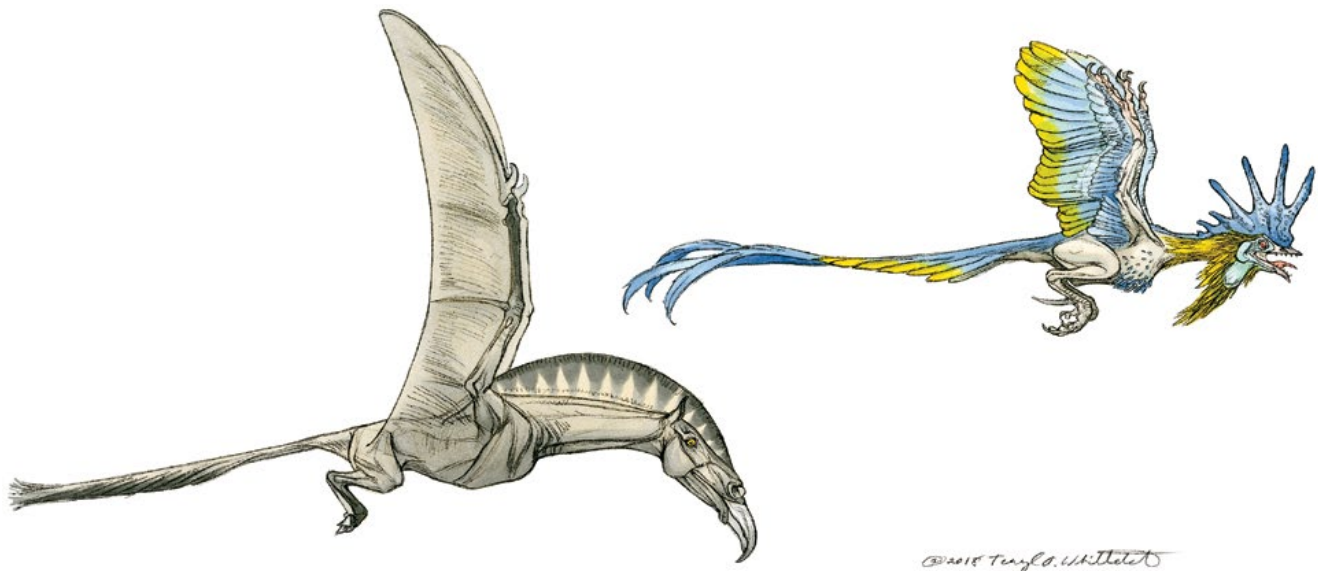
There are three features that really gave pterosaurs an advantage for getting huge, and these same features are useful for consideration when building informative graphics about pterosaurs or in designing giant fantasy flyers. The three features of interest are: membrane wings, pneumaticity, and quadrupedal stance.

Membrane wings can generate more lift at a given speed, especially low speeds, than a thicker wing (such as a feathered dinosaur wing). More lift at low speeds means more weight can be carried into the air or safely landed, and so this is a major advantage to growing large. Pneumaticity refers to the extensive air sac system in birds and pterosaurs. These air sacs

enter the bones, allowing the bones to grow large diameters (making the bones stiff and strong) without adding excessive weight. Fat is the lowest density packing material that a mammal (such as a bat) can utilize in most areas, except perhaps for the paranasal sinuses of the skull. Using air as a space-filling material is much more weight efficient than using fat, and so pneumatic flying animals (birds and pterosaurs) can develop more skeletal stiffness for a given weight of bone, and this allows them to grow larger than the non-pneumatic flying animals (such as bats).

Finally, the primary limitation on size in flying animals is launch (i.e. takeoff). The initial phase of launch in all flying animals (even those that purely glide, such as gliding squirrels) is powered by jumping or running. Running launch is mostly seen in water birds—otherwise, jumping is generally the rule. This means that the more jumping power that a flying animal has available, the faster it can launch, and the larger/heavier it can be and still take off. Pterosaurs walked on all four limbs (their wings folded up and doubled as walking limbs), so they could use the muscle power from all four of their limbs to launch (called a quadrupedal takeoff).





Those bats that can launch from the ground are also quadrupedal launchers. Birds are obligate biped launchers, and this significantly limits the size that birds can obtain and still fly. Birds essentially have two separate motors (one for flight, and one for running, swimming, and takeoff). At large sizes, the tradeoffs between expanding one motor over the other become limiting.

Example Design Challenge: Building a hexapod flyer

With this more complete understanding of the principles and mechanics of flying creatures, we can become intrigued with the possibilities of creating new creatures that use them. Just as we like to run simulations to compare with science data, we can run though experiments on what might be possible on an alternate world or another evolutionary path. One of the most popular types of flying creature anatomy for fantasy and science fiction is that of a vertebrate with four walking limbs and a separate set of wings. Dragons and flying horses are two popular examples. Making the anatomy of such animals plausible is difficult, however, because they would have two pectoral girdles, with the two sets of scapulae either stacked or in series, each of which present significant mechanical problems. To help solve this issue, one option is to create wings that are constructed from some part of the anatomy other than an extra set of limbs. Another option is to avoid the hexapod condition and create flying creatures with forelimbs that double as wings and walking limbs (as in bats and pterosaurs). Having the wings able to fold up and realistically touch the ground also provides the option of designing the creature to launch quadrupedally, as bats do today (and pterosaurs likely did in the past). Quadrupedal launch is a more

realistic option for large flyers, because the powerful wings can double as limbs for leaping, thereby providing a great deal more power. Placing the wings in contact with the ground for takeoff to get double duty out of the wing muscles is the most realistic way to get a 1,200-pound fantasy creature (like Pegasus) to fly (Fig. 9).

If a hexapod is ultimately called for in a creature design problem, time should be given to considering the articulation of the pectoral girdles. Having two large pectoral girdles of a mammalian type stacked on top of each other creates both a potential center of mass problem (potentially solvable with a very large forward sweep of the wings) and a muscle attachment problem (for which it is more difficult to create a visual/anatomical solution). One option is to have the typical mammalian-grade rotating spatulate scapula commanding the forelimbs along the anterior sides of the ribcage, while nearly directly above is located an avian-like thin scapula fused to the back of the ribcage, commanding the wings, to try to keep the center of gravity correct. This creates independent pectoral systems, one layered under the other, and protected from one another and friction via encapsulation by fascia. This articulation prevents an avian-grade musculature (where both upstroke and down stroke muscles are attached to the sternum) from attaching in a realistic way, and so a bat-like or pterosaur-like condition is a more realistic option for “stacked scapula” creature design. In those animals, the upstroke muscles are derived from the back musculature, and the down stroke musculature is associated with the chest.

Using the forelimbs as both wings and walking limbs solves the articulation problems of hexapod

Fantasy Animals: Hippogriff & Cockatrice

The order Perissodactyla (odd-toed hoofed mammals) included many more diverse species than represented today by gracile equines (horses) and their distant relatives, tapirs and rhinos. So, why not several, if not many, species of hippogriffs? Here is a speculative pteromorph hippogriff based on azhdarchid proportions, internally equipped with reinforced brachiocephalic tendons acting as clavicles that allow brachiation and forelimb-powered flight.

The Cockatrice is inspired by any number of ancient frond-tailed avian species.

© 2018 Terry L. Whitlatch

THIS ARTICLE is a taste of the work that Mike Habib and Terryl Whitlatch have embarked upon together. They are creating a new book that more fully explores the current knowledge of fossil flyer morphology and the resulting appearance and ability of these fascinating creatures. The abilities of all flyers give us a window onto other fantastic types of creatures we could invent and get off the ground.

creature design, but this can raise new anatomical challenges. For a winged animal, the shoulder must allow elevation of the wing above the back. This means having a shoulder joint that faces laterally (as in brachiating primates and all flying animals). Such a shoulder is very unlike the condition found in most fast-running mammalian quadrupeds (such as horses). Horses, for example, have no clavicles, and their shoulder blades are located on the sides of their ribcages to promote forward locomotion.

For a winged horse to have folding winged forelimbs, some particularly imaginative anatomy is required. For example, we can imagine the creation of a brachiating horse with strong tendinous bands at the points in the brachiocephalicus that could act as pseudo clavicles, and push the shoulder blades towards the spine. The “horse” could then walk on its forelimbs, like a vampire bat or pterosaur, and use these forelimbs as a major source of launch power (in addition to the hind limbs). Since the forelimbs will also be the source of power for flight itself, it is important to scale the musculature properly for any such flying animal. To make a large flying animal look realistic, it needs to have proportionally more robust flight muscles than a small flying animal. At the same time, reducing mass in other areas (using air sacs, reduced tails, lightened skulls, etc) can make a giant flying animal work more effectively as a mechanically coherent creature design.

There is yet another flight alternative, more properly

a glide alternative, that does not involve traditional wings at all, but rather foldable ribs with patagium that can extend along a horse's body (somewhat akin to a draco lizard's), that the horse can extend and retract at will. Terryl pictures this animal able to perform extended leap glides from a fast gallop (Fig. 10). If it was a carnivorous equine, another type of hippogriff, with physical abilities like this, it would be a dangerous animal indeed.

Fantasy inspired by science

Flying animals, both past and present, can make wonderful sources of creature design inspiration for games, film, and television. Many of the classic creature concepts in fantasy and science fiction genres include physically implausible configurations that can undermine the believability and impact of the creature design. Using real animals as a guide can help solve some of the challenges of designing flying creatures.



Photo: Gus Ruelas/USC

Dr. Michael B. Habib

Assistant Professor, Integrative Anatomical Sciences at University of Southern California; Research Associate, Natural History Museum of Los Angeles County and Carnegie Museum of Natural History

Dr. Michael Habib is a biomechanist and a paleontologist exploring the relationships between animal structure and motion. His work combines comparative anatomy with concepts from modern engineering. In addition to traditional publications in professional journals, his work on pterosaur launch was featured as one of the top 100 science discoveries of 2009 by *Discover Magazine*. Dr. Habib has authored numerous scientific papers, appeared in a diverse array of television specials, and written for *The Conversation UK*, *Scientific American*, and *Universe Today*.

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Photo: Jacob Pace/Imagination International, Inc

Terryl Whitlatch

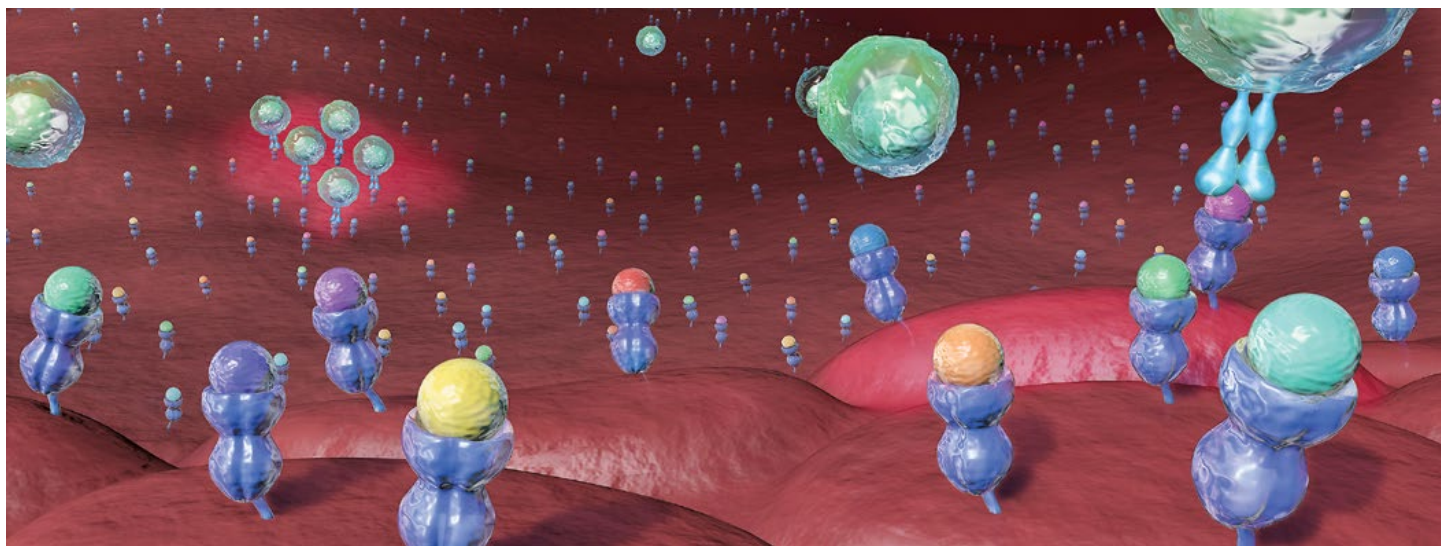
Terryl Whitlatch is a professional Creature designer specializing in Animal Anatomy, Paleontological Reconstruction, and the creation of Imaginary Creatures for the Animation, Publishing, Institutional, Academic, and other Transmedia/Entertainment Industries.

Clients include: Lucasfilm, LTD., Industrial Light & Magic, LucasArts, Walt Disney Feature Animation, Walt Disney Imagineering, Electronic Arts (EA), Paramount Pictures, Sony, Miramax, PDI, Imagination International, Inc.

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Creating a 3D Molecular Landscape

— Layla Lang



Abstract

I will demonstrate a few basic 3D modeling techniques, explain how to add materials to 3D elements, export separate layers from Cinema 4D® to compose a complete illustration, and make color adjustments to achieve the envisioned mood in Adobe® Photoshop®.

3D programs can be a great tool to create realistic and vivid illustrations and interesting perspectives. However, it can be intimidating to start working in 3D if you have mainly worked with 2D programs. Using the best of both worlds does make it easier and saves time. Here I explain my process for creating a 3D molecular illustration of the immuno-peptidome (the collection of peptides displayed on the cell surface by major histocompatibility complex molecules).

The overall process for this project was as follows: After the concept sketch was approved, I used Cinema 4D® to create 3D models for draft one. I then added lighting and basic surface materials to the scene, still in Cinema 4D. At this point I exported the elements from Cinema 4D into a layered Adobe® Photoshop® file for final composition. Colors, contrast and opacity are adjusted in Photoshop to achieve the final look and mood. Other 3D programs and image editing programs can be substituted in this workflow, but Cinema 4D and Photoshop are among the industry standards of our profession.

Figure 1: Final illustration showing the cellular landscape of the human immuno-peptidome. Blue shapes represent MHC molecules, spheres represent peptides that are displayed on the MHC molecules, green cells represent T-cells and the light blue protein represents the T cell receptor. The lighter colored red cell in the foreground represents an abnormal cell, for instance a cancerous cell. Here a T-cell is binding to the MHC peptide complex. There is a second region of abnormal cells and T cells attacking these cells in the background.

All images ©Layla Lang

What is the immuno-peptidome?

To best understand the workflow, it will help readers to have some basics about the immune system and how the immune system protects us from diseased cells.

To protect the organism against viral infections and cancer, the cells in our body display special proteins on their surface, called Major Histocompatibility Complex (MHC, Fig. 3). There are MHC class I and MHC class II molecules (in humans MHC molecules are called HLA). For simplicity only MHC class I is shown here. The main function of these MHC molecules is to display small fragments of proteins, called peptides, on the cell surface. A healthy cell will display peptides from normal cellular protein turnover. However, when an unhealthy cell contains foreign or abnormal proteins, for instance when the cell is infected by a virus or has become cancerous, some of the MHC molecules will display non-self protein fragments from the virus or cancerous cell. All non-self peptides are called antigens. T-cells from our immune system can recognize these antigens and after binding to the MHC antigen complex, the infected cell will be killed.

Within our bodies there are hundreds of thousands of MHC molecules displaying peptides on the cell surface, and the collection of all of these peptides displayed by HMC molecules is defined as the cellular immuno-peptidome.

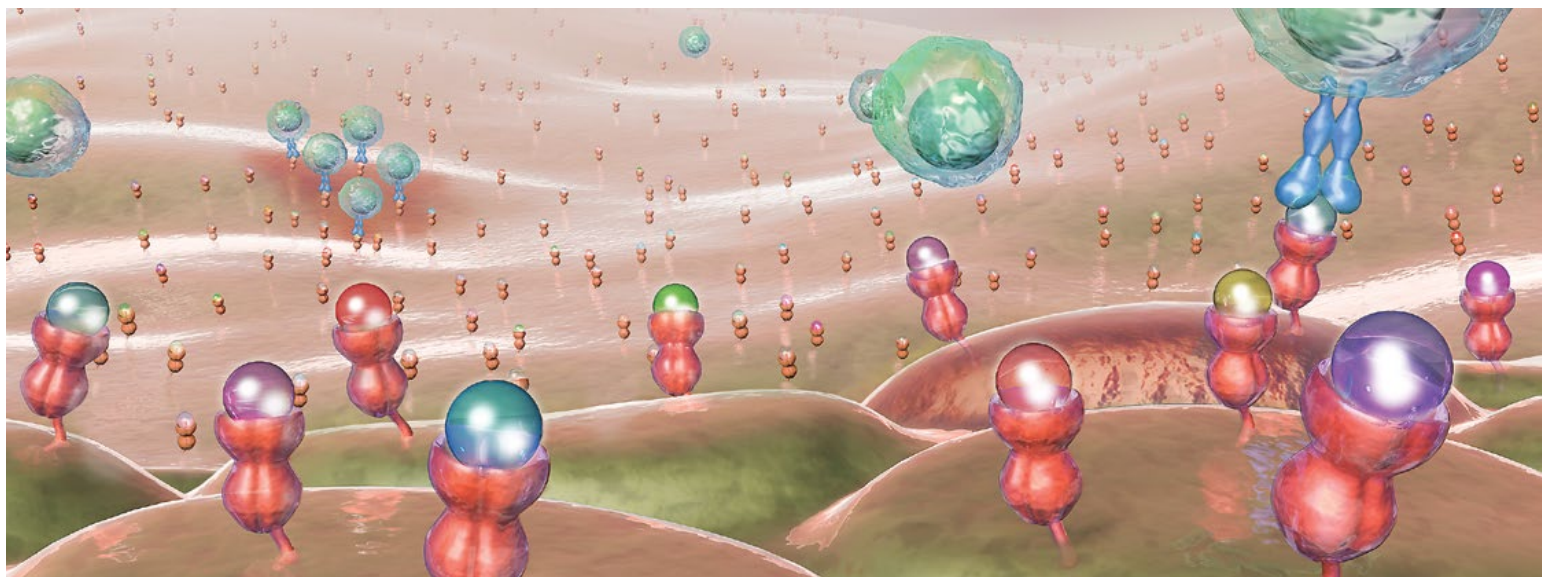


Figure 2 (above): Second color alternate version of final illustration

Figure 3 (right): Major Histocompatibility Complex. A cell that is displaying a foreign peptide is recognized by a T cell. Binding of the T cell receptor to the MHC antigen complex triggers the immune response.

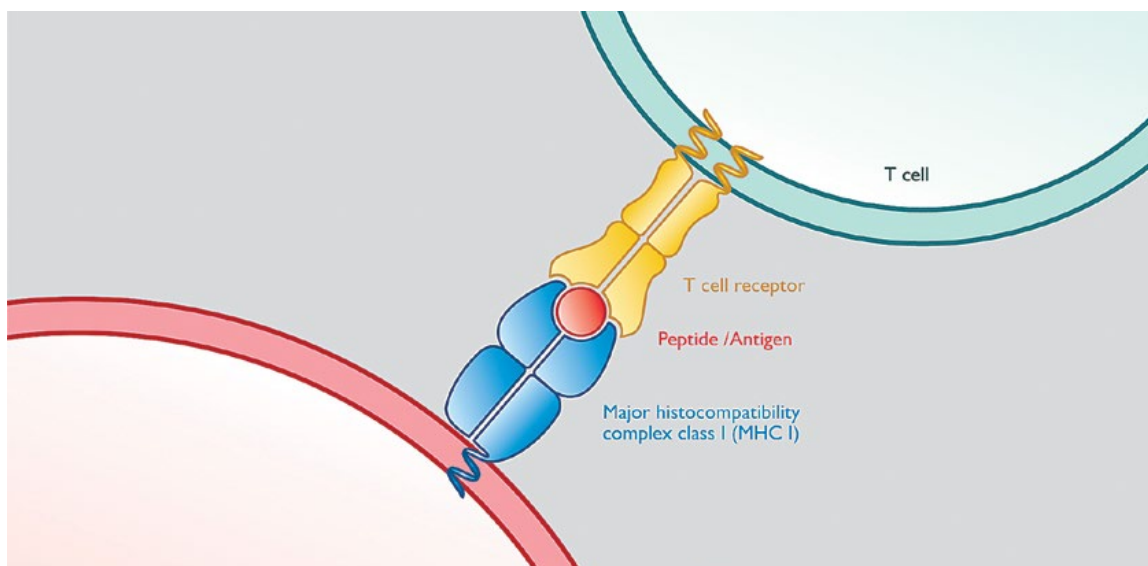
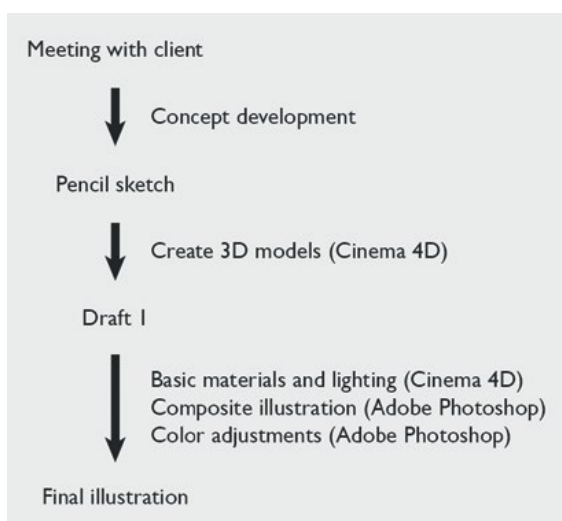


Figure 4: Workflow to create a molecular landscape illustration.



Client Goals

The goal for this illustration was to create an appealing illustration of the immuno-peptidome for multiple uses: for web presentation of the research at the Institute of Molecular Systems Biology at ETH Zürich, to promote the 1st HUPO-HIPP Workshop of the Human Immuno-Peptidome Project, and for use as a potential cover with a scientific research journal. The content goal of the project was to show that there are a huge number and diversity of different MHC peptide complexes; the scientific community has yet to fully appreciate the complexity of the immuno-peptidome. This project was created for Dr. Etienne Caron, Institute of Molecular Systems Biology, ETH Zürich, Switzerland.

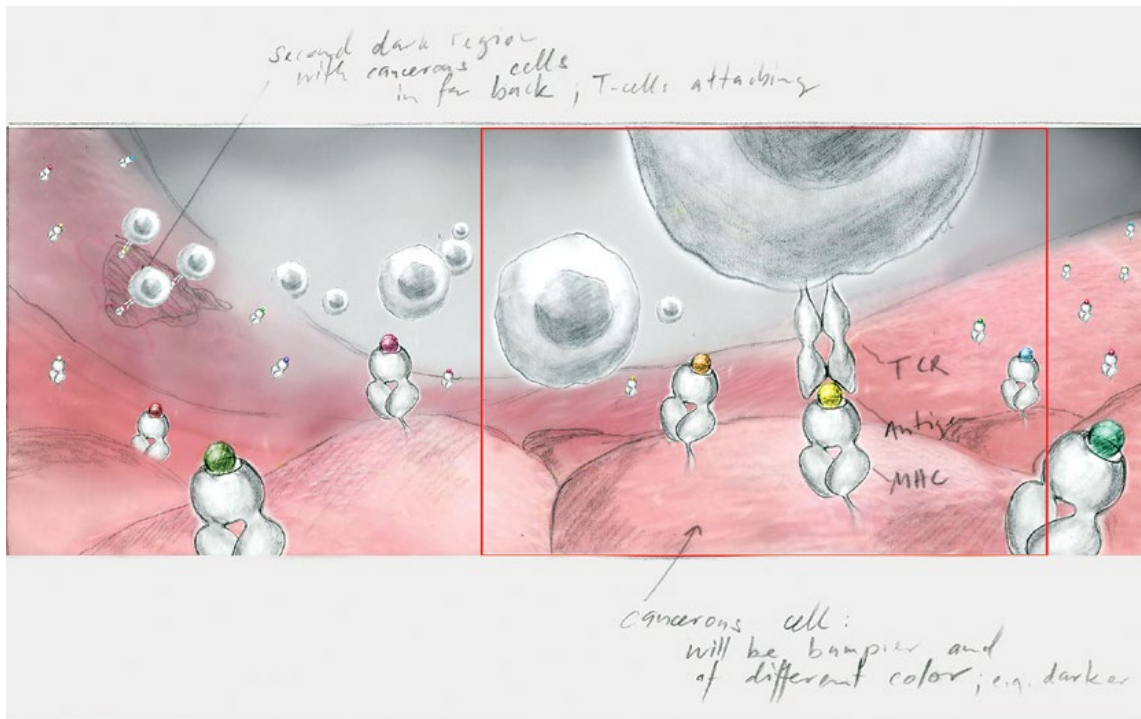


Figure 5: First pencil sketch.

General Process

In order to create a dimensional and realistic landscape feeling in the illustration, my approach (Fig.4) was to create the landscape and the various elements I would need in the 3D program Cinema 4D. I then composited and finalized the illustration in Photoshop as a time-saving technique for quick adjustments.

I started with a detailed pencil sketch (Fig. 5) after my first discussion with the client, choosing an extreme perspective, so a few cells in the foreground are really large and we see a lot of tissue detail. The cells farther back in the landscape are too small to be recognized as individual cells. In this way I am able to show details of the MHC peptide complex and T cell receptor in the foreground, as well as high numbers of the MHC peptide complexes in the background at the same time. I will render all the peptides in different colors to show diversity.

Modeling

Example 1: Create cells in foreground and landscape

I used Cinema 4D to create 3D models of the various elements in the sketch for draft one. At the base is a background landscape of cell surfaces (Fig. 6). Working with the plane shown in Figure 7, I first modified some of its polygons. The triangulate command subdivides the plane, enabling me to use hexagonal shapes that are very similar to the desired cell shape. The hexagons are extruded upward to create three dimensional shapes. All the cells in the foreground were created in the same way.

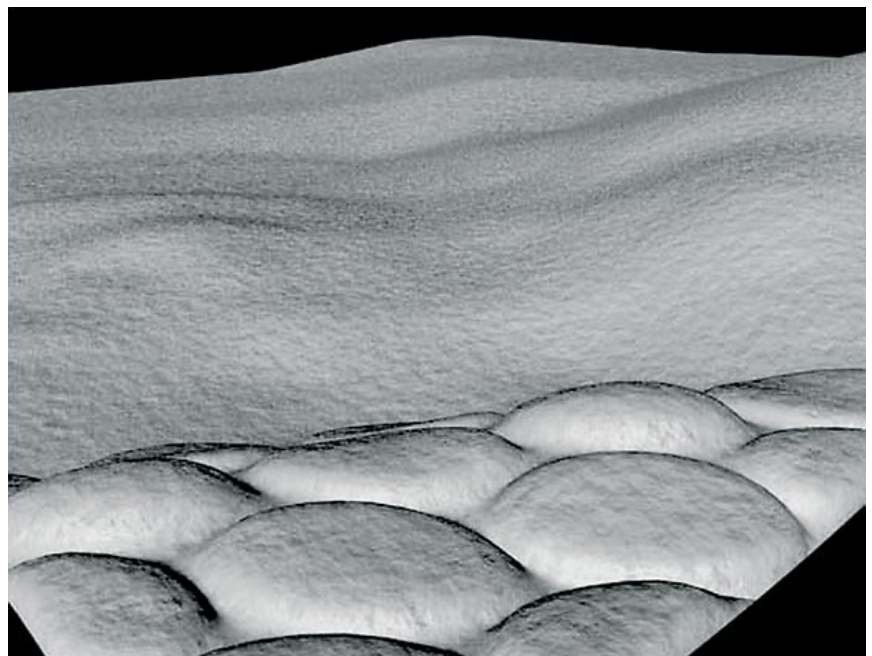


Figure 6: Landscape modeled in Cinema 4D.

To make the edges of these cells smooth, I placed a hypernurbs modifier on top of the plane (hyperNURBs is the Cinema 4D name for the Subdivision Surface technique now common in many 3D programs). The hills in the landscape were created by selecting different areas of polygons and moving them with the move tool using a soft selection to randomize the appearance (Fig. 8).

Figure 7: A plane that has been divided up in to triangle polygons (triangulate command) is our starting point for the landscape. Extruding a hexagonal shape from the plane creates the basic cell shape.

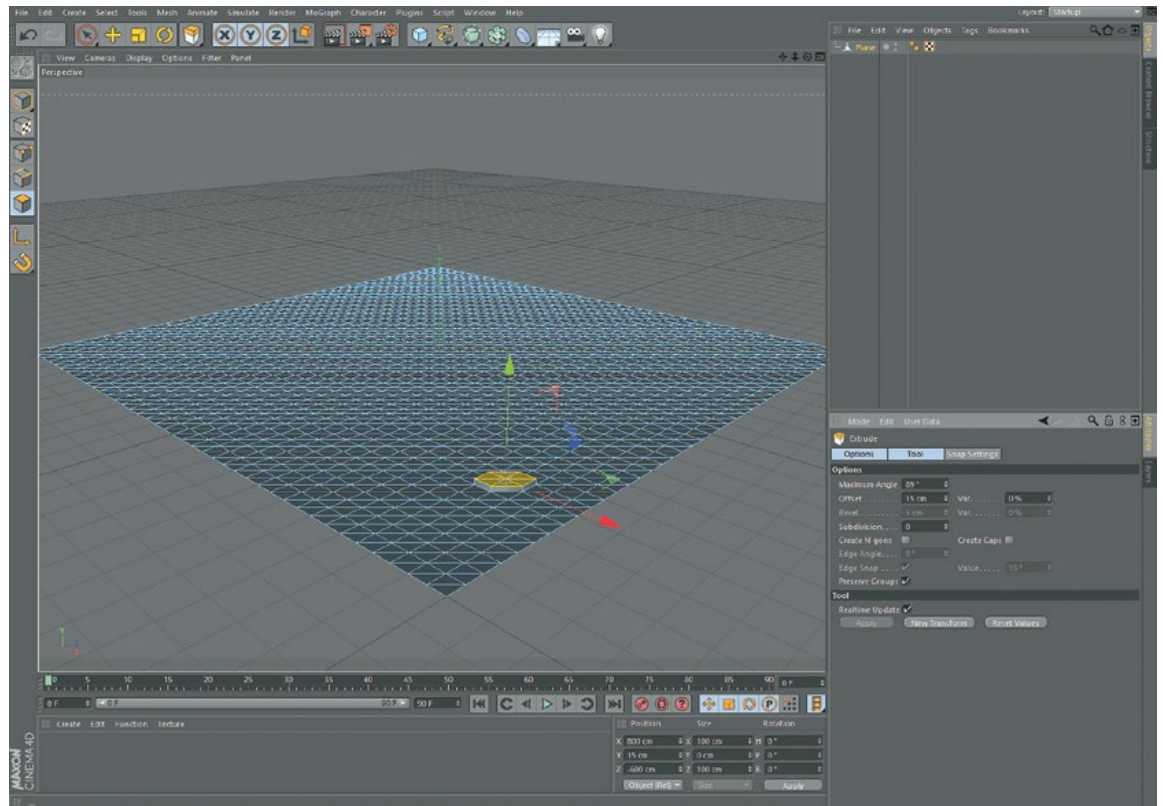
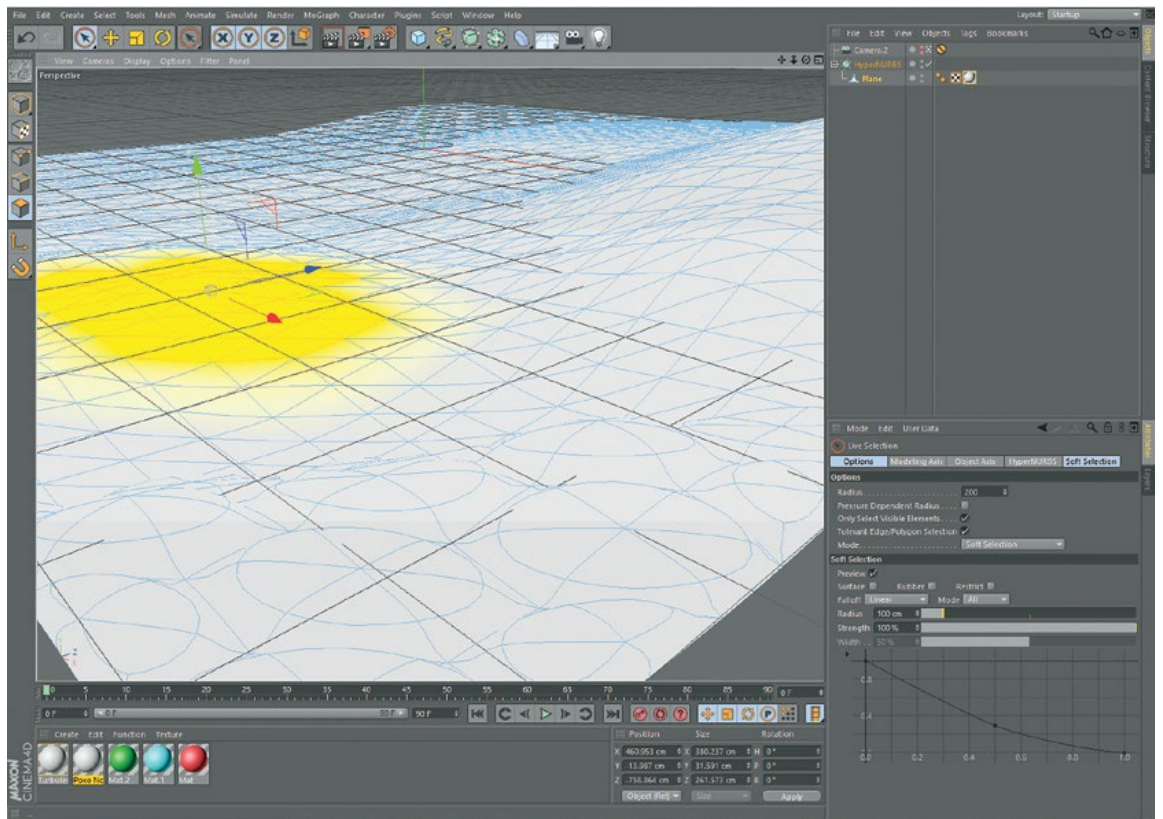


Figure 8: Creating hills in the landscape. By using a soft selection different areas of the plane can be moved with the move tool.



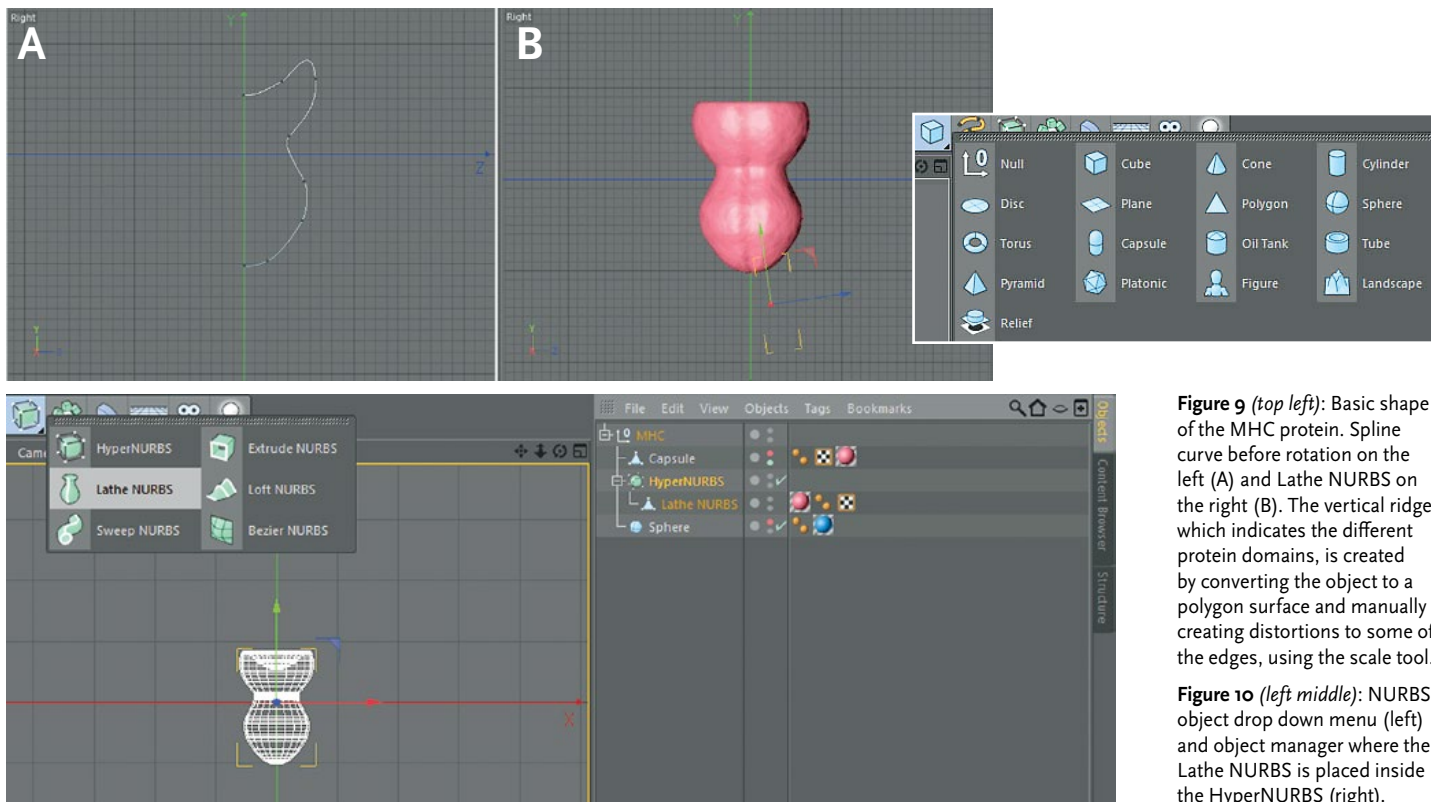


Figure 9 (top left): Basic shape of the MHC protein. Spline curve before rotation on the left (A) and Lathe NURBS on the right (B). The vertical ridge, which indicates the different protein domains, is created by converting the object to a polygon surface and manually creating distortions to some of the edges, using the scale tool.

Figure 10 (left middle): NURBS object drop down menu (left) and object manager where the Lathe NURBS is placed inside the HyperNURBS (right).

Figure 11 (top right): Polygonal primitive drop down menu.

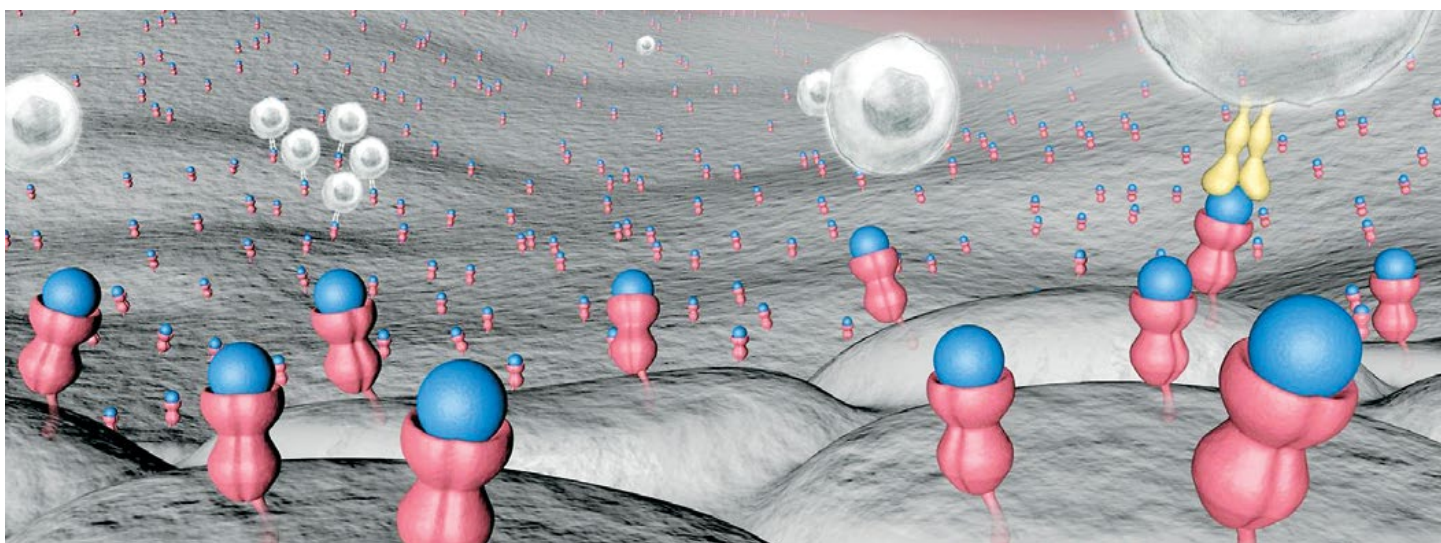
Figure 12 (bottom): Draft one for client. Cells in the foreground and landscape created as described in text. The T cells above are still at a sketch stage here.

Example 2: Create MHC molecules and peptides

Figure 9 illustrates how the MHC protein elements were created using a Non-Uniform Rational Basis Spline (NURBS) object. NURBS are a modeling technique similar to the vector art methods we use in a program like Adobe® Illustrator® except that they work in three dimensions. A simple spline curve (Fig. 9A) is drawn in two dimensions and is then placed within a “Lathe NURBS” envelope (Fig. 10). This rotates the curve to create the 3D object (Fig. 9B). To finalize the MHC molecule, the transmembrane “tail” of the protein at the bottom was added as

a separate *capsule primitive* from the polygonal primitive drop down menu (Fig. 11). I modified the capsule primitive shape slightly to get the desired appearance and then chose a simple *sphere primitive* to represent the peptide, placed on top.

The spline curve can be edited even after being placed into the Lathe NURBS, e.g. points of the spline can be moved, spline can be scaled etc. Changing the shape of the spline will automatically change the shape of the Lathe NURBS symmetrically.



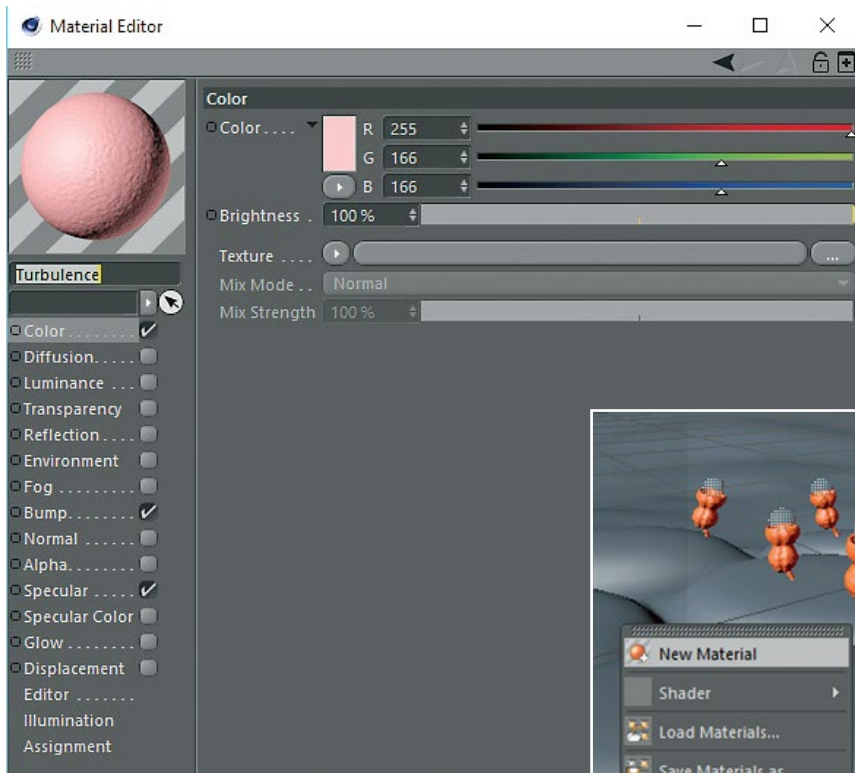
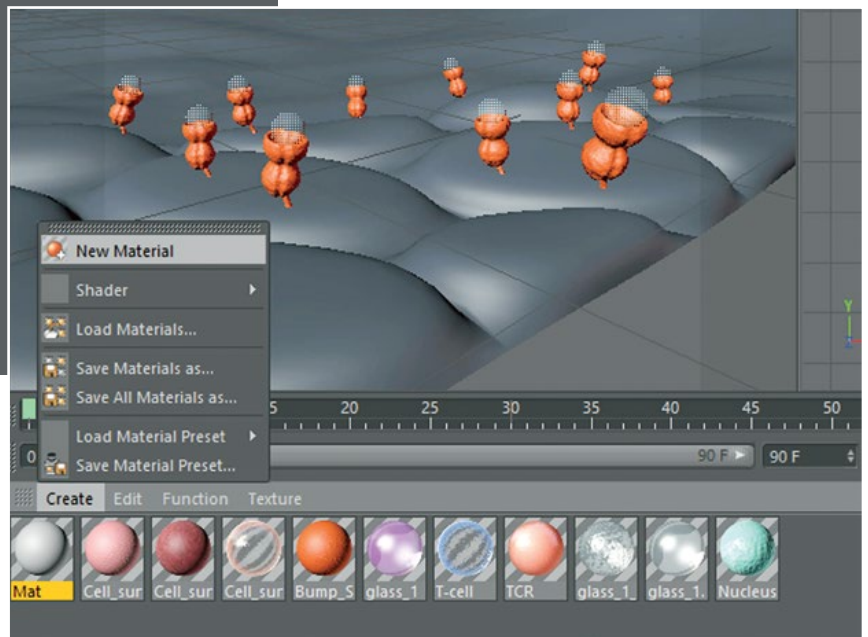


Figure 13 (top left): Material editor in Cinema 4D where all the properties of a material can be defined.

Figure 14 (right): Collection of all materials created for this scene.



To edit the parameters of the Lathe object that are not defined mathematically, the LatheNURBS object has to be made editable by conversion to a polygon surface. We can now select and modify polygon faces, edges, and points. As soon as we convert the NURBS object to polygons, the initial spline shape is no longer available.

For the proteins in the background, a clone function in Cinema 4D duplicates the objects just created and distributes them randomly on the background plane. The program can follow the distortion I have made to the plane, automatically!

Materials, Lighting and Finish Materials

In 3D parlance, surface *materials* are 2-dimensional images wrapped onto the surface of a 3D object. Materials are what objects are wrapped in. By creating a material and applying it to an object, we can change all the surface properties of an object—for instance, color, reflection, transparency and surface structure (e.g. bumpiness).

Cinema 4D includes a large list of material presets. These can be a good starting point, or you can create your own materials from scratch.

I created several materials for each object, applying them to the objects (landscape, MHC proteins, peptides, T cells and T cell receptor) to create a series of appearances for each object. In the material editor I adjusted the properties for all these materials (Fig. 13) The bottom of Figure 14 shows the material manager, where all the materials that I created for my scene are displayed.

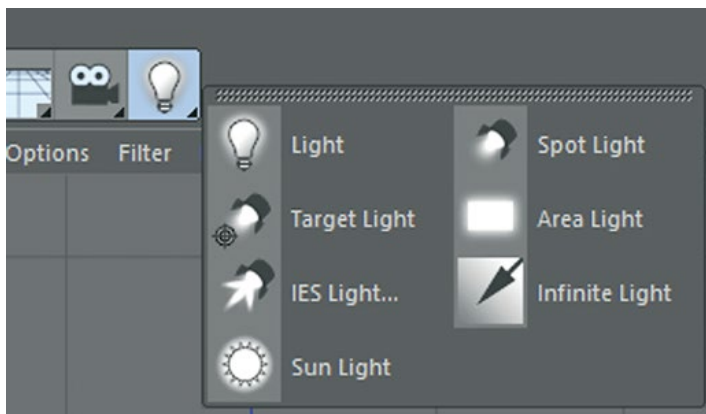


Figure 15 (top left): Light drop down menu.

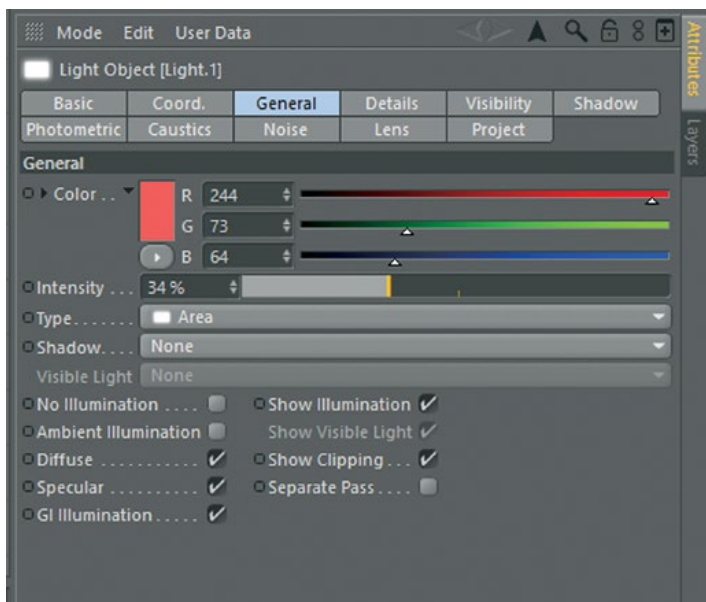


Figure 16 (bottom left): Attributes editor where the properties of the area light are adjusted.

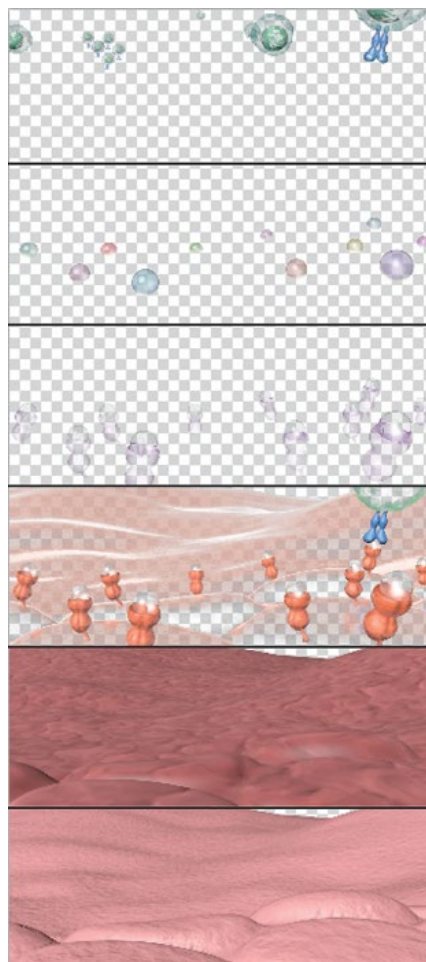


Figure 17 (right): Different elements exported from Cinema 4D and imported into different layers in Adobe Photoshop.

Lighting

Adding lights to the scene enhances spatial depth cues, influences materials and colors, draws the viewer's eye to specific focal points, and is also instrumental in creating mood.

In the light drop down menu (Fig. 15) you can select from a number of different lights. You can use these lights to illuminate objects in the 3D software similar to how you would illuminate an object in real life.

To illuminate my scene I used two different lights, one regular light and one area light. I placed the regular light on the top left of the scene and the area light to the right side of the scene. I also adjusted the properties of the area light in the attributes editor and changed the color to red and turned down the intensity (Fig. 16), in order to add some warmth to the scene.

Finishing in Photoshop

Before leaving Cinema 4D, I rendered images of the various objects in my 3D scene and then exported each element separately. Examples of the elements are the landscape with cell surfaces (in two different materials), MHC proteins in two different materials, peptides and t-cells. The different elements that I exported from Cinema 4D are shown in Figure 17 for the second color version of the illustration.

Photoshop process

I then imported the various objects/elements (shown in Fig. 17) into separate standard 2D layers in Photoshop. The layers function in Photoshop enabled me to create the desired composition and mood by overlaying them, choosing different blend modes, and adjusting colors, contrast and opacity. Photoshop offers great flexibility in this part of the job, making it

unnecessary to create perfect renders of the Cinema 4D models. While it is possible to export 3D elements from Cinema 4D and recreate the scene directly in Photoshop's 3D environment, the tools and lighting now available in recent versions of Photoshop are minimal and a bit clumsy by comparison to a fully

built-out program like Cinema 4D, so that route is not normally used.

The final illustration was published at systemhcatlas.org. It was used to create a poster for the HUPO-HIPP Workshop 2017 (Fig.18).



Figure 18: Poster designs using final illustration.



About the Author

Layla Lang is interested in visualizing complex scientific processes and topics and taking the viewer to the world of molecules and viruses. As in this example, illustrations can have a big impact on imagination and foster understanding. Layla has an extensive scientific background, has specialized in molecular- and microbiology (Master of Science, ETH Zürich, Switzerland) and has been trained as a scientific illustrator at California State University Monterey Bay (CSUMB). Layla not only strives to bring visual clarity to complex subjects, but hopes that her passion as an artist is apparent in her work. Layla works as an independent contractor for a wide variety of clients including publishers, research institutes, biotech and pharmaceutical companies.

www.laylalang.com

Book Review:

— Frank Ippolito

First it is the artwork. Always we will come back to the artwork. It is introduced boldly on the front cover with a striking rendering of a single leaf, *Viburnum x carlcephalum*. The artist has captured a moment in transition; the leaf sits at the cusp between summer and fall. Greens give way to reds and purples. There are signs that the leaf is losing its battle with tiny creatures, who leave behind trace indications of their passage. The northern light, soft and cool, catches a few areas of smooth, waxy texture and invites our touch. The rendering is achieved through use of watercolor on vellum. Like so much of this artist's work employing this medium, the resulting image is filled with nuanced detail that seems to sit atop the very page it is printed on. This leaf has given up its story under the watchful eye of an artist who is clearly trained in the highest order of observational drawing. We run our finger over the image (how can we not?) and we open the book.

The artist's name is Rory McEwen; for many readers in the US, this may be the first time we will have heard his name. This fact is as startling as anything one will come to learn in this beautifully printed overview of Mr. McEwen's life and work. Perhaps this is due, in part, to the fact that Mr. McEwen's



RORY MCEWEN THE COLOURS OF REALITY



botanical illustration career flourished in the UK over 30 years ago. Thumb through the volume and prepare to be engaged by the range of subject and impressed by the treatment that appears under one's fingers.

Holding a book in one's right hand, it is natural to thumb through the pages of an oversized paperback from back to front. My first perusal of this volume was filled with many detours, as I stopped and explored random pages while fanning through the chapters. Here, a wild tangle of grasses rendered in loose watercolor strokes captures the unruly nature of nature itself. Here, a study of a yellow onion sits on the page, layers of translucent skin peeling off into the northern light, as 3-dimensional as it would be if sitting upon the kitchen cutting board. Here, a full habit of a Crown Imperial that would not look out of place in a gallery featuring art from the Age of Enlightenment.

By the time I reached the middle of the book, I was forming a first impression of perhaps who

Rory McEwen, *The Colours of Reality*, Martyn Rix, editor, was published by The Board of Trustees of The Royal Botanic Gardens, Kew in 2013 in association with an exhibit of Rory McEwen's work. A revised edition with additional plates and sections was published in 2015. This review references the later edition.

Your *Journal* editors are extremely grateful to Kew Publishing for permission to reproduce these images from the book for this review.

The book is currently out of stock at Kew Publishing but is being reprinted and will be available in the Fall 2018. shop.kew.org/kewbooksonline

All images © (the estate of) Rory McEwen, as dated in captions.

Above: The book cover, featuring *Kensington Gardens 1*

Left: Onion (detail) 1971, watercolor on vellum 22.3 x 25.1 cm



Fritillary 'Crown Imperial'
1965, *Fritillaria imperialis*,
watercolor on vellum, 78.1 x
56.5 cm

this fellow might be: an artist, steeped in a pursuit of botanical studies, taking his skills to a level only possible through a lifetime of singular focus. Then, as I continued leafing towards the front cover, I came across the scattering of vintage photographs that fill the opening chapters. In one, Rory plays an acoustic guitar with a band on a soundstage of a television studio. In another Rory is posing with Ravi Shankar, the maestro of Indian sitar. (There are more pictures of him performing music in this book than there are of him at a drawing table.) Scanning the captions, I can see sentence fragments that mention Rory in

association with Beatle George Harrison, American blues legend Lead Belly, and the Irish singer-songwriter Van Morrison.

Who WAS this guy? Pulled away from the pages of artwork, I began to read the opening chapters of the book and came to learn about a most fascinating life.

Rory McEwen (1932-1982) was a Scottish artist and musician. Home-schooled in the Palladian mansion of Marchmont House in the Scottish Borders area of Scotland, he went on to earn a degree from Trinity College Cambridge, which holds among its alumni such luminaries as Sir Isaac Newton, Ernest Rutherford and Niels Bohr.

By all accounts, Rory was inspired by his forays into nature from a young age, after a French governess taught Rory and his siblings the art of observational drawing. He channeled that fascination into "painting flowers" from about the age of 8. His great-grandfather was noted botanical illustrator John Lindley, so the seed for this interest may have been planted generations earlier. But his creative endeavors were manifold, and he was soon pulled away from rendering plants by his deeper love for music.

At Cambridge, his skills as a botanical artist were known by those around him. But then, until the mid '60s', McEwen's life and career were centered solidly around music. He and his brother Alexander carved

out a musical niche in the UK, having embraced and mastered what was, at the time, the obscure music of American R&B (rhythm and blues.) In particular, Rory had found a deep connection to the songs of the blues guitarist Huddie "Lead Belly" Leadbetter, whose powerful rhythm and slide work on the acoustic 12-string is the stuff of legend. In the decades to follow, bands as diverse as the Rolling Stones, Led Zeppelin, and Nirvana would cover his music. But in the 1950s UK, Leadbetter's sound was a complete outlier.

Leadbetter's raw blues and Woody Guthrie's depression era folk songs might have seemed an odd fit for a well-to-do Scot. However Rory and his brother would regularly perform them all, along with a mix of Scottish ballads, on a nightly BBC showcase *Tonight*. Rory's passion for his art and his attention to nuances of technique, all that would later serve to elevate his botanical artwork to a higher plane, disarmed those who might be struck by his lack of self-irony in delivery. Reading about the arc of his life, it is clear that he always had each foot planted solidly in two or more very different worlds.

A further example of this dichotomy could be seen in the McEwen Brothers' trip to the US in 1956. While in New York City, they stayed uptown in the posh home of one of the Astors. At the same time they reached out to—and were welcomed by—the burgeoning blues scene downtown. Rory and his brother “Eck” would venture by subway down to the East Village and spend long evenings jamming around smoky kitchen tables with future blues legends, such as Sonny Terry and Brownie McGhee. Their US road trip culminated months later back in NYC with performances by the McEwen Brothers on none other than the Ed Sullivan Show.

Van Morrison would later cite Rory as a huge influence on his playing, as did Eric Clapton and others. But the most fascinating details about this aspect of McEwen's life emerge when looking at the community of artists and musicians that he and his wife, Romana, fostered when they essentially turned their London home into an artist salon. The book mentions, in passing, a party that they threw for Bob Dylan during Dylan's first visit to the UK in early 1963. A short vignette sits the Everly Brothers down with John Lennon, trading blues riffs

in the drawing room. However the friendship and collaboration between George Harrison and Ravi Shankar may well be the most far reaching cross-pollination that the McEwens' home engendered. George and Ravi sat long hours on the living room rug, student and teacher. It was in this rarified and electric atmosphere that Rory passed through Zelig-like. He had left the world of London folk music when it became polarized by politics. By the time the waves of British Invasions crashed upon the US

Flowering Artichoke (detail),
1971, watercolor on vellum,
52.7 x 73 cm





Above: *Auricula* 'S.G. Holden' White Edge), 1963, watercolor on vellum, 42 x 31.8 cm

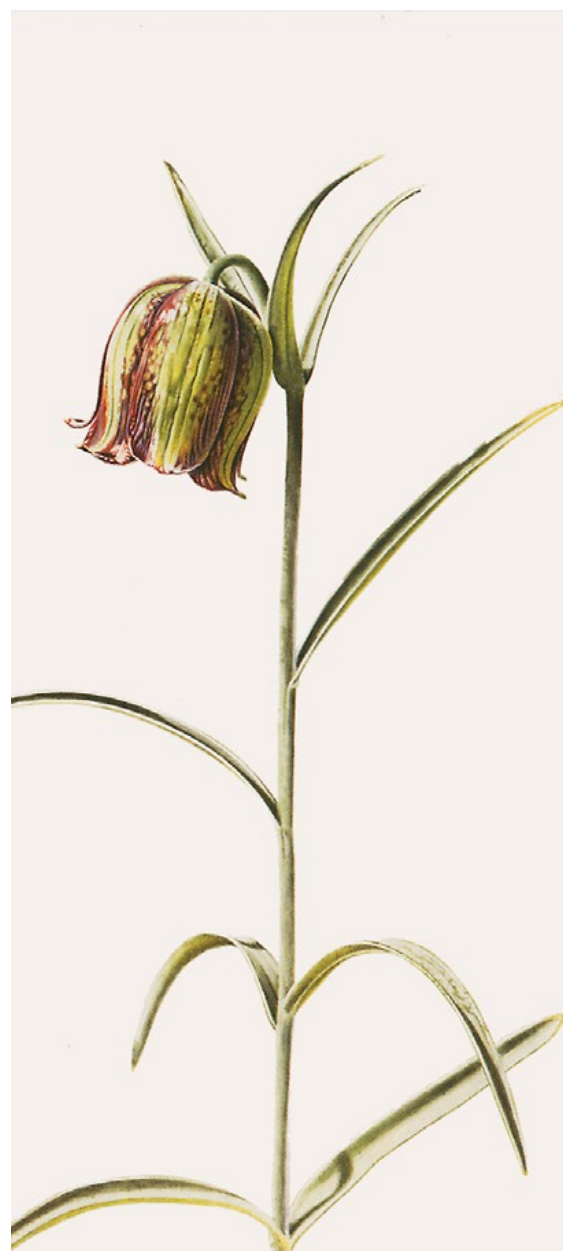
Right: *Fritillaria messanensis* (detail), 1977, watercolor on vellum, 45 x 34 cm

shore, Rory was remembered mostly by those whom he had influenced. The music scene had moved on.

While he was hosting parties for rock stars and playwrights, he was forging deeper connections to his other love. Rory had never stopped painting botanical subjects, and he now returned to this endeavor with renewed passion. Paintings from this period reveal an artist pushing his technique while also pushing the boundaries of convention. Indeed, his social circle also brought him into the orbit of London's avant-garde art scene, where he was welcomed, albeit as a quirky painter of old-school subject matter. Experimenting with light, Rory also began to break beyond 2 dimensions and developed a series of sculptures made of glass, steel, and polymer.

A spirit of experimentation rubbed off as Rory began to explore placing his botanical subjects off-center, using negative space in far more creative and dramatic ways. In 1972 McEwen's botanicals were exhibited at London's Redfern Gallery (of contemporary British art). This show is cited by many botanical artists as the show that opened the door to a more progressive approach to the depiction of plants.

While Rory explored watercolor on a variety of substrates, it is his work on vellum that is by far the high point of his career and examples of these stand out across the pages of this book. As a number of our readers may know, vellum is made of calf skin. Water-based media will sit atop its surface upon drying. This offers the artist an opportunity to develop a series of layers that can impart depth. The





Grasses, 1975, watercolor on paper, 56 x 78.6 cm

vellum itself is translucent and McEwen seemed to delight in teasing out a sense of luminosity in his botanical studies.

Renderings of onions (see p. 21) and red peppers, found within the vegetable series, seem to glow from the inside out. It is not hard to draw a direct line between the modern sculpture he created, with light passing through selected areas, and his use of sheets of vellum. Although this luminous quality would be all but impossible to reproduce photo-mechanically, this book does a wonderful job presenting McEwen's work, with many of the plates filling its oversized pages.

This book was produced in conjunction with a retrospective exhibition that was mounted in 2013 at Royal Botanic Gardens, Kew. The Kew show was the second major retrospective of McEwen's botanical work, the first being held 25 years earlier in 1988. The printing quality is top notch; the colors are rich and nuanced.

Chapter 3: *Rory McEwen as a Botanical Painter*, by Martyn Rix, is comprised of 15 sections filled with color plates that are arranged mostly by subject

matter. The chapter runs well over 150 pages and covers McEwen's most prolific stretch from the mid-sixties to his untimely death in 1982.

If I have one criticism of the book, it would be how the writers each spoke of Rory McEwen as if the reader already knew of their subject. It created a certain disconnect in this reader that took repeated visits to the various chapters—all written by separate authors adding their personal perspective to the overall portrait—to see the consensus of the many narratives that are woven together here. As I would come to learn, the superlatives used early and often were more than warranted in describing McEwen's unique mix of talents. But in my first pass through the pages of *The Colours of Reality*, I would scratch my head about how someone of this pedigree—both musical and artistic—could have passed so thoroughly under my radar.

And so again we come back to the cover artwork *Viburnum x carlcephalum*. It can be found inside the book within Section 13. The "leaf series" has been acknowledged by many as some of McEwen's strongest work. In the heart of the book there are 18



Above: *Fritillaria messanensis*
petal, 1981, watercolor on vellum,
25.4 x 20.3 cm

Right: Kensington Gardens 1
(detail without background),
1979, *Viburnum x carlcephalum*,
watercolor on vellum, 21 x 18 cm

ABOUT THE AUTHOR:
Frank Ippolito worked
as scientific illustrator in
the Division of Vertebrate
Paleontology at the American
Museum of Natural History
in New York City for three
decades. His illustration
clients include Scientific
American, Natural History
Magazine, The NYT/Science
Times, and The National
Zoological Park. Over the
years, Frank has also fostered
a parallel career as a musician
and composer, producing
a number of soundtracks
for New York's Hayden
Planetarium. He released his
first solo CD, *The Watermark
Project*, in September 2014.



plates of individual leaves in various stages of decomposition. Each rendering seems to be suspended in time. Rather than lament the degraded state of the subject, the artist has elevated the moment of struggle to one of celebration. It is interesting to note that the paintings in this series are named for the location of where each was found rather than the species of plant being rendered. This suggests that the location—and perhaps associated memories—were being revisited one by one.

It was after internalizing these ideas about McEwen's later work that I learned that in the months before he had begun the series, he was diagnosed with cancer. The series itself was produced during two years of remission and was cut short by the recurrence of the disease. I am reminded of David Bowie's final works, which were written and recorded as Bowie was coming to terms with his own mortality. In both cases, a great artist had chosen to explore, in the last days of his life, a greater truth through an art process that had sustained him across a long and varied career. In each case, the artist produced what was arguably his highest achievement.

Member Spotlight:

MESA SCHUMACHER



My artist origin story takes a form I think is fairly common for scientific illustrators. I grew up in Seattle with parents who didn't study science, and knew little about art, but encouraged my interest in both. In our household, you could maintain a concentrated area of chaos in some corner by saying "don't touch that, I'm in the middle of a project," and my brothers and I usually each had several projects going at any given time, ranging from painting to rebuilding machines bought from the thrift store.

My family loved nature, and we enjoyed camping, hiking and outdoor sports. Travel was also a priority, and a few times during childhood we were pulled out of school for months at a time for "sabbaticals," which profoundly impacted my goals for adult life.

I think at heart I have always been a scientific illustrator. My mom saved crayon drawings with titles like "passenger pigeon, extinct bird" and a high school project comparing the morphology of the extinct primate *Notharctus*. Illustrations and Larry Gonick-inspired comic explanations were incorporated into every school notebook, and visual explanations were the way I learned to process information. In college I finally realized that this obsession could become my career.

After my sophomore year studying science at Stanford, I was lucky to receive a scholarship to spend the summer at an archaeological dig in the Peruvian Andes. There I was taught how to illustrate lithic tools, a task in pen and ink where length and closeness of hatching communicated how deep impressions were on tools; something that photographs of shiny obsidian can't capture. I realized science visualization was necessary to communicating information, not just elective decoration, and I was hooked. I started soaking in any formal or informal study that could make me a better science artist. It was around this time I joined the GNSI, which has provided me with an amazing community of colleagues and friends, without many of whom my career would not be where it is today.

After college, I wanted to see the world, and I took a job in the kitchen at the South Pole Station in Antarctica. There I met my future husband, who quickly became my traveling companion, and

we spent a few years wandering, and one teaching English in South Korea. These years were punctuated by summers working at archaeological dig sites, notably three years at Çatalhöyük in Turkey with illustrator Kathryn Killackey and doing some part time science illustration for some clients remotely.

In 2011 I returned to the US to "get serious" about my career, and I spent a year in Seattle at the University of Washington Graduate Certificate program in Scientific Illustration, with fantastic instructors and a group of varied and enthusiastic students. I also took supplemental biology coursework, and classical art courses at Gage Academy of Art in Seattle. The year after, we moved to DC, and I interned with Taina Litwak in entomological illustration at the Smithsonian National Museum of Natural History, and then in the National Geographic Magazine Art Department, where I fell in love with scientific editorial art, and the world of infographics.

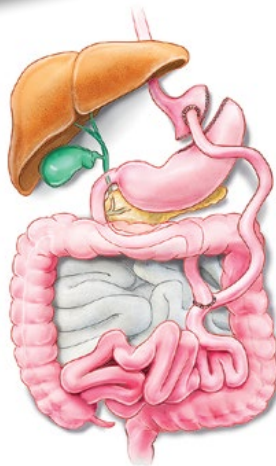
At the end of the year, I had been accepted to the Medical and Biological Illustration Master's Program at Johns Hopkins, and I had my first big illustration job, 65 fish in two months for National Geographic Books. My mom sent me some of my early work

All art © Mesa Schumacher unless noted



Above and pages 28, 29:
Bumble bee species © Koppert Biological Systems.

Below: Drawing archaeological excavation profiles in Chavin de Huantar, Peru



Top: Cover of *Cardiology Today* depicting an aortic valve replacement surgery.

Above: Roux-en-Y gastric bypass operation illustration for *Scientific American Magazine* (July 2017).

Left: Pacific Northwest tidal zone featuring ochre sea stars (*Pisaster ochraceus*), their major predator and prey, glaucous gulls and pacific blue mussels. This piece was inspired by my childhood in Washington state nature.

to congratulate me. It was a piece titled “different kinds of fishes” medium: crayon, from my preschool years. It sat on my desk as I worked day and night to meet my short deadline. It was good training for the following two exhausting but amazing years in Baltimore, where I learned traditional and digital media, and built skills in scientific visual storytelling and translation.

Upon graduating, fate and my husband’s good test scores forced me into freelance illustration under exciting circumstances. He had just entered the US Foreign Service and was posted as a diplomat to Guatemala. We were thrilled, as travel is a shared passion and this was the life we had hoped for. But I was also very nervous, because I had hoped to spend a few years in a medical illustration studio, hospital, or museum before branching out on my own again full time.

Though it has at times been difficult and tiring, three years into my life as an independent science artist, I am very glad this was the path I was forced to take. I have been involved in a wide variety of projects. Thus far, I’ve worked a lot for other popular science editorials, illustrated signs for the National Zoo, and work in illustration and animation for many research, clinical, and education clients.

I’ve also been able to continue my relationship with National Geographic, working as a researcher and sometimes artist. As someone who generally spends the day in her studio solo, it is nice to work with teams of talented people and amazing scientists on large-scale projects for a great platform. In the last year, I am very proud of my work on Pterosaurs (November 2017) a project with Editor Fernando Baptista, and Hummingbirds (June 2017) with Editor Monica Serrano, which were honored Gold for a magazine infographic, and Best of Show for a digital infographic respectively. Finding novel ways to approach subjects in popular science press that incorporate data, mapping, and art is always a challenge, and I feel I am constantly being pushed to improve my work.

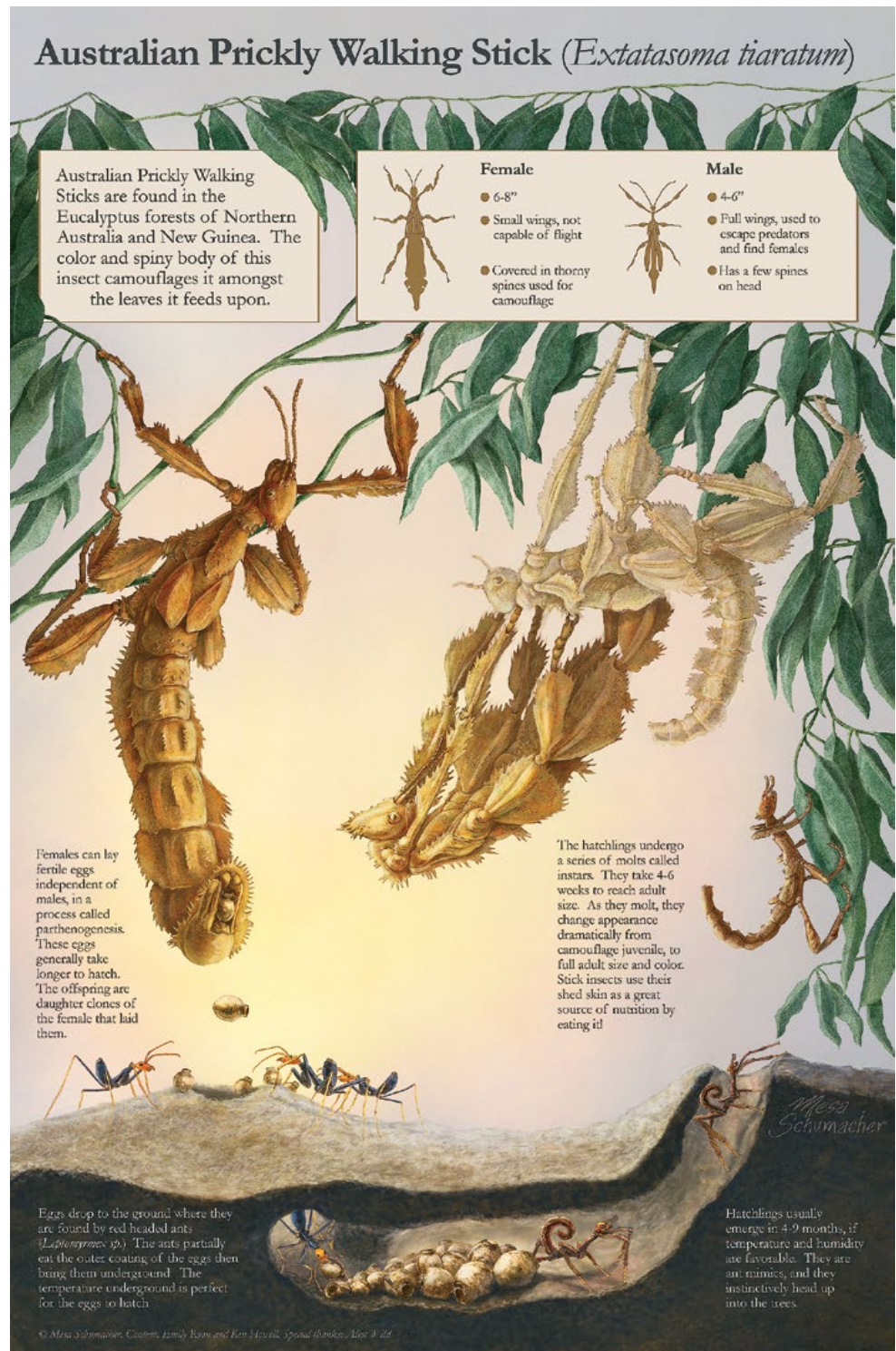
In hopes of improving, I am constantly trying new things, which results in my not really having one style, but rather an overarching mission statement of communication that guides my work. I enjoy changing my stylistic approach or materials to create art that I think fits the needs and audience of my projects, experimentation that sometimes results in happy artistic accidents.

I was fortunate to start learning digital techniques early in my career and develop them as I improved my traditional art skills. I am passionate about the digital space, where media incompatible with the

“real world” can come together to create interesting art. When I work digitally I often use a combination of software in my work, making some elements in 3D, digitally painting others, and sometimes using photography. For example, I love incorporating the digital sculpting program ZBrush into my work, and keeping libraries of watercolor, ink and paper scans to work into my illustrations to add a traditional touch. I’ve had some opportunities to share digital techniques with GNSI members in demos and talks, and hope to share more in the future, making digital tools more accessible to science artists.

Like many in this field, I am often asked if I see myself more as an artist or a scientist, and I believe I fall pretty close to the middle of the spectrum (if a “spectrum” exists). Science is what we observe, or what we can deduce. Art is the way I process what I see, what I know, and how I understand the world. It is how I communicate concepts and break down data and relationships between actors in nature. I actually think I’m a bit addicted to the process of illustration, and that were I to suddenly find myself independently wealthy, I’d keep working full weeks just to keep receiving new visual puzzles to solve.

I recently moved with my husband and young daughter to Kathmandu, Nepal where I continue to work in freelance science illustration and animation. We plan to be here two years, which is a long stay in a location for me, and I hope to take advantage of my relative settlement to pursue some sculpture and painting projects along with my (mostly digital) client projects. I am looking forward to the exciting natural world explorations my new location provides, with all sorts of landscape and ecosystems packed into one tiny country, there will be a lot to appreciate.



Giant Prickly walking stick poster completed during graduate school in collaboration with the National Aquarium.

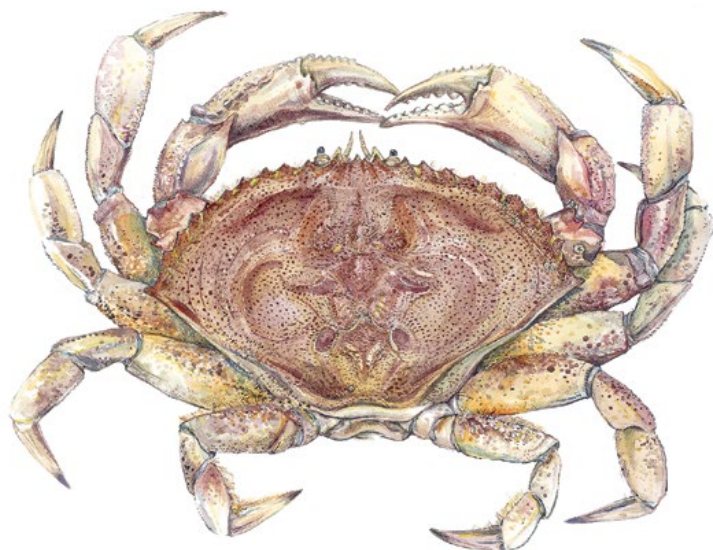


Check out my work at www.mesaschumacher.com and find me on twitter and instagram @mesabree.

ILLUSTRATING NATURE:

Presenting the 2018 graduating class of the California State University Monterey Bay (CSUMB) Science Illustration Program

— Jann Griffiths



Laurie Mahan Sawyer
Dungeness Crab (*Cancer magister*); watercolor

2018 CSUMB Science Illustration Program Students:

Allison Arnold
Brett Bell
Megan Bishop
Alli Fitzmorris
Jessica French
Jann Griffiths
Sylvia M. Heredia
May Jernigan
Danielle Jolette
Yun-Kae Kiang
Valeria Pellicer
Charlotte A. Ricker
Laurie Mahan Sawyer
Liana Vitousek
Chen Zha

We are the California University Monterey Bay (CSUMB) Science Illustration students graduating in June of this year. There are 15 of us, from all across the United States—from the Pacific Coast (Washington and California) to Michigan to Missouri to Texas, as well as from all around the world (Mexico, Taiwan, China, and British Columbia.) We are a diverse group, ranging in age from our early twenties to our late fifties. As well as art, our backgrounds include biological sciences, architecture, philosophy, and business. The one thing we have in common is the desire to draw what we learn, what we know, and what we see: the intricacies of science and the beauty of the natural world.

We all feel extremely fortunate to have been accepted into CSUMB's prestigious and rigorous program as an important step in fulfilling our career aspirations and dreams. The curriculum consists of twelve demanding courses over a nine-month period, culminating in an exhibit at the Pacific Grove Natural History Museum, and a ten-week internship at organizations such as National Geographic, Scientific American, the Chicago Field Museum, the Smithsonian, the Cornell Lab of Ornithology, as well as smaller non-profits and educational institutions.

Our coursework, taught by Ann Caudle, Jenny Keller, Amadeo Bachar, Jane Kim, and Andrea Dingeldein, provides opportunities for us to work in different

media including watercolor, gouache, acrylic, pen and ink, and colored pencil, as well as the ever-increasing need for digital illustration skills, including animation. Throughout all our courses, whether they focus on specific areas such as botany or zoology, we are given the freedom to explore our own areas of interests and preferred media. We are also trained in the business of being professional illustrators, both by our instructors and outside guest speakers. Topics include everything from portfolio presentation and small business management to copyright law.

The CSUMB program also emphasizes conceptual illustration, teaching us how to depict concepts and ideas in addition to concrete objects. Class opportunities have included creating drawings from magazine article titles and excerpts, as well as being paired with scientists to illustrate their research.

We are all extremely excited to be entering the professional world of science illustration and using the talents, skills, and knowledge gained this year to contribute to the understanding of both scientific and conservation efforts in the world in which we live. The images in this article are introductory examples of our work.

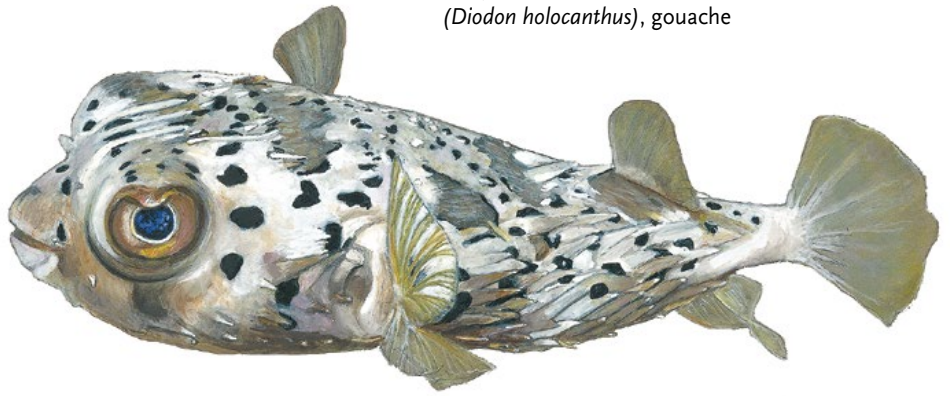


Brett Bell
Leaf Study (*Acer macrophyllum*);
watercolor, colored pencil, and gouache

Yun-Kae Kiang
Pelagic Snail; acrylic



Jann Griffiths
Longspined Porcupinefish;
(*Diodon holocanthus*), gouache



May Jernigan
Blue Atoll Echeveria; watercolor

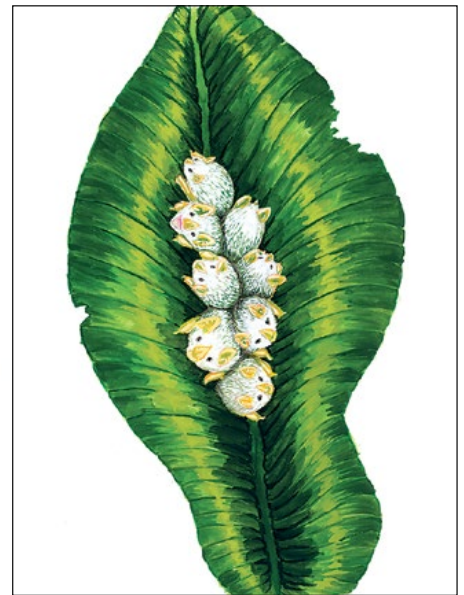


Danielle Jolette
Marsh Wren, (*Cistothorus palustris*); acrylic

Charlotte A. Ricker
Sea Otter (*Enhydra lutris*); ink on scratchboard



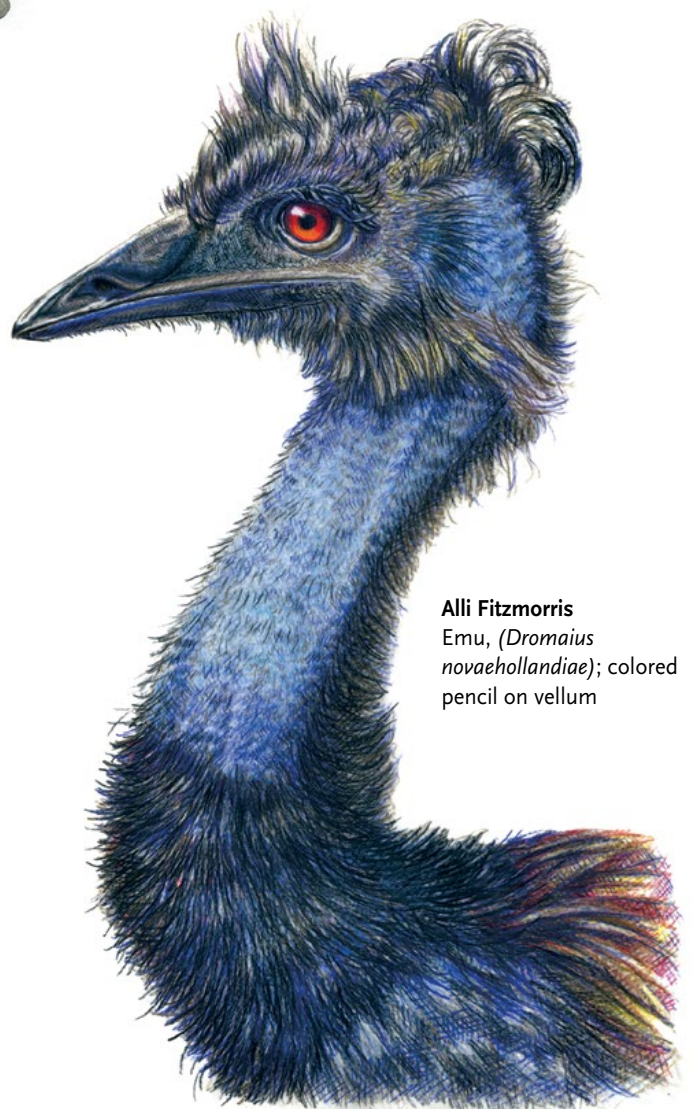
Liana Vitousek
Northeastern Naturalist; gouache



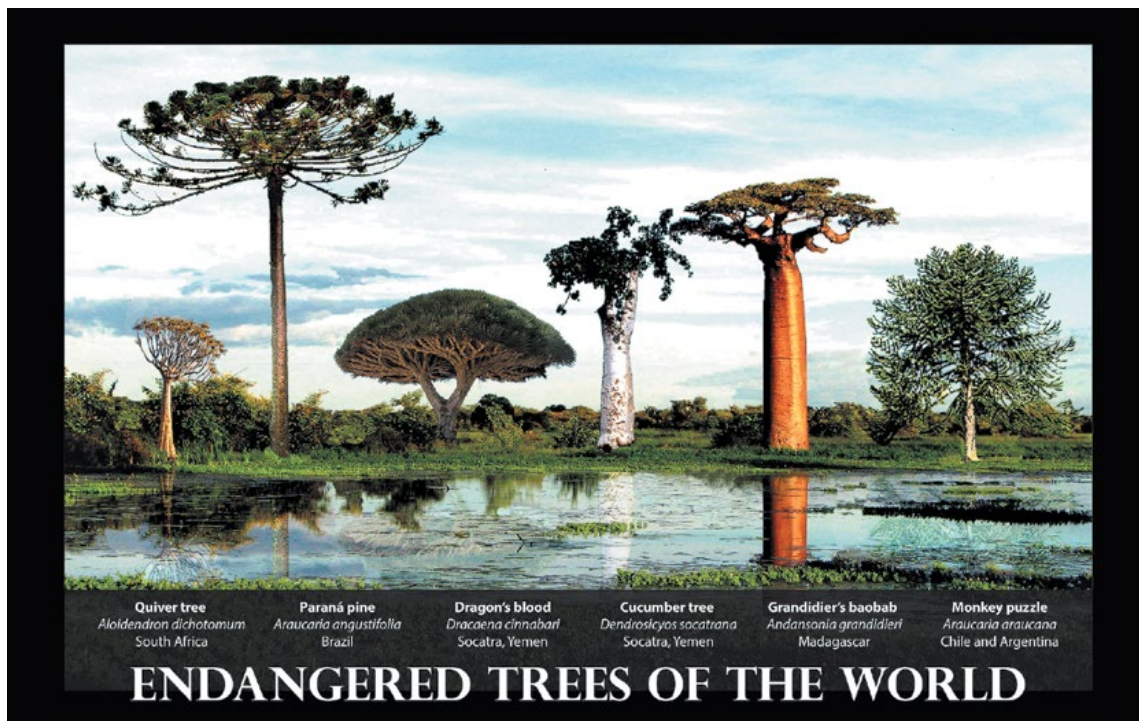
Valeria Pellicer
Honduran Tent Bats; gouache



Megan Bishop
Western Grebe glow-thru; digital



Alli Fitzmorris
Emu, (*Dromaius novaehollandiae*); colored pencil on vellum

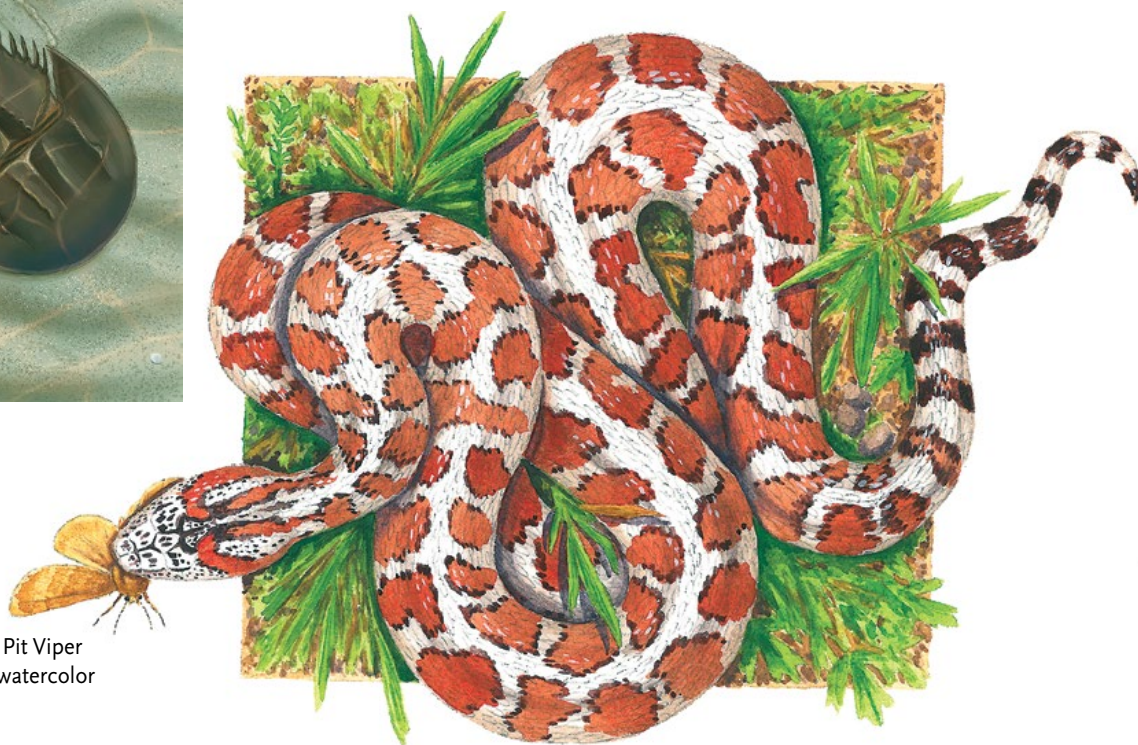


Sylvia M. Heredia
Endangered Trees of the
World; digital

Allison Arnold
Pacific Mackerel Skull
(*Scomber japonicus*);
ink on vellum



Jessica French
Atlantic Horseshoe Crab,
(*Limulus Polyphemus*); digital



Chen Zha
A New Moth-Preying Pit Viper
Species from China; watercolor

Chapter Happenings:

A LOOK AT GNSI CHAPTER ACTIVITY, PART II

Our local Chapters are the heart of the GNSI!

While many members are unable to attend our annual conferences, their membership in local chapters gives them similar opportunities to connect with other science artists, exhibit their work, explore new techniques and discover valuable assets right in their own locales.

Here is another taste of what a few of our dynamic Chapters and Groups have been doing:



Great Lakes Chapter members' selfie, at the Ryerson Woods art exhibit, and some of our art from a day at the Chicago Botanic Garden.



GNSI Great Lakes

We represent members of Guild of Natural Science Illustrators living in southern Wisconsin, northern Indiana and northern Illinois (SW Michigan folks welcomed too!). Most of our meetings are held in the Chicago area. Great Lakes gatherings include lectures, workshops, exhibits and field trips. We share information, learn new techniques and network about our experiences in freelancing, exhibiting and staff positions.

We represent a variety of experience levels from full-time scientific illustrators and educators to museum employees, scientists, and researchers.

Recent exhibition sites include the Brushwood Center at Ryerson Woods and Fernwood Nature Center. Members can often be found sketching at the Morton Arboretum, Chicago Botanic Garden, Shedd Aquarium, and monthly at the Field Museum of Natural History.

Contact Carrie Carlson for more information:
humla@cscarlson.com
www.facebook.com/gnsigreatlakes



Would you like to join a chapter or start a new one?

The GNSI currently recognizes 12 Chapters and 2 Groups:

- California
- Carolinas
- Finger Lakes
- Great Lakes
- Great Plains
- Greater New York
- Greater Washington DC
- Illinois Prairie
- Maine Group
- New England
- Northwest
- Oregon
- Portugal
- Texas Group

You do not have to be a GNSI member to join a Group or Chapter, but of course we encourage you to join us. If you wish to attend a Chapter/Group meeting or event, contact an officer or member for specific dates, times and locations. Links to Chapter/Group contacts are available on the GNSI website: gnsi.org/groups

For information on Groups and chapters and how to set up or join, contact GNSI Membership Secretary Daisy Chung.



GNSI Great Plains

The Great Plains chapter of GNSI had an active 2017 and we're planning an exciting 2018! We are also excited to have welcomed a few new members.

We were involved in two outreach activities this year. The first was Wild Adventures at Pioneers Park Nature Center, Lincoln, Nebraska, where we demonstrated and assisted kids and adults in drawing nature. We also participated in Bug Fest, an educational outreach of the University of Nebraska–Lincoln Entomology Department, with members demonstrating scientific illustration to the general public. We had a tour of Nebraska's Morrison Microscopy Core Research Facility which has state of the art imaging systems including light/fluorescence microscopes, confocal laser scanning microscopes and electron microscopes. We visited Fontenelle Forest's Raptor Refuge in Bellevue, NE, with an informational presentation by Raptor Recovery staff with time for sketching and a hike. Member Sally Cox gave two woodblock printing workshops to members in her studio. 2018 started with a field trip to Lauritzen Gardens in Omaha for the Metamorphosis exhibit of reclaimed plastics into works of art and for sketching.

Upcoming events include a canoe trip at Fontanelle Forest, an animal sketching workshop with Gail Guth, and a member exhibit at Lauritzen Gardens in November and December.

Great Plains chapter members come from Nebraska, Kansas, Iowa, Minnesota, Missouri and anywhere else for whoever wants to travel and spend time with like-minded artist/scientists.

Contact Lana Johnson for more information:
ljohnson1@unl.edu
www.gnsi-gp.org



Left: Bug Fest, University of Nebraska–Lincoln Entomology Department
L-R: Lana Koepke Johnson, Camille Werther, Donna Henrickson, Anne Holz, Rick Simonson

Above, top: Erin Skornia sketching at Fontanelle Forest, Bellevue, Nebraska

Above: Tour of Raptor Recovery at Fontanelle Forest, Bellevue, Nebraska; L-R: Donna Henrickson, Sally Cox, Tim Kettler, Camille Werther, Erin Skornia, Melissa Heberer, Michelle HansenDaberkow, Sara Taliaferro, Melody Albert, Lana Koepke Johnson, Dana Clements, Rick Simonson

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