Digital Illustration of Insects

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Whether objects of disdain or desire, insects have long been the subjects of human artistic expression. Insects appeared in prehistoric petroglyphs and pictographs, Renaissance religious art, and contemporary graphic illustration, among many, many other works of art from around the world and throughout history (Hogue 1987). The beauty, complexity, and diversity of insects, along with their profound impact on human culture, make them compelling subjects for art and illustration.

The morphological complexity of insects, expressed most profoundly in the complexity of the exoskeleton, is of primary importance in insect taxonomy. In some groups, the complex nature of the male genitalia is used to separate the species, but in other groups and at other taxonomic levels, characters of the wing venation, appendages, body sclerites, cuticular structures, and color, to name only a few of hundreds of characters, are used to separate and identify the various forms.

These characters are often so complex that they cannot be sufficiently or fully described in words, and illustrations or photographs necessarily accompany formal taxonomic descriptions and identification keys. When rendered with skill and attention to detail, these illustrations can transcend their purely utilitarian purposes and become works of art, if art is defined as the product of human creative endeavor that evokes emotion and admiration. Many contemporary illustrators of insects have inspired my appreciation for the beauty and complexity of insects, and I have tried to emulate their techniques in my own taxonomic efforts. These artists include, among many others, Anker Odum, Ralph Idema, George L. Venable, Richard E. White, Walter Linsenmaier, Bernard Durin, J. Marie Metz, and Arwin V. Provansha.

Benefits of Illustration

Beyond drawing morphological structures for use in taxonomic descriptions and keys, illustration offers many benefits. The process of observing an insect while illustrating it allows the entomologist to study the position and internal structure of appendages and other body parts. This is the primary means of inferring the homology of these structures, especially when examined within a comparative framework, and represents the science underlying the art of insect illustration. This close observation, where every line, curve, edge, and connection are followed and rendered in a sketch, is one of the great benefits of traditional illustration. Other benefits include the ability to selectively illustrate only taxonomically important parts. Illustration also overcomes the depth of field problem of macro photography (digital "z-stacking" software and scanning electron microscopy notwithstanding). The way light falls on the specimen and the contrast between light and shadow are completely controllable in illustration. Lifelike postures can be depicted with illustrations, and perfect specimens can be reconstructed from a series of preserved specimens where no single specimen is fully intact. Finally, illustration is inexpensive; in the hands of a skilled artist, a crow-quill pen and a bottle of India ink can produce remarkable results.

Challenges of Illustrating Insects

Insects offer numerous challenges for the illustrator. The relatively inexpensive cost of materials is offset by the need to magnify the subject. Most insects are very small, and microscopes are expensive. Some insects must be observed under compound microscopes in addition to the more commonly used stereomicroscope (with the additional cost of drawing tubes, photographic attachments, etc.). Insects within the different groups are often mounted or curated in different ways (e.g., on pins, in vials of alcohol, on microscope slides), and their parts may have to be dissected and prepared in such a way to be visible, especially internal or overlapping, nontransparent structures.

Although we tend to think of insects as common and ubiquitous, many are known from only a few museum specimens and must be handled with great care. The complexity of the insect exoskeleton is a challenge, as is the complexity of its surface features (pits, ridges, hairs, scales, etc.). Capturing the color of insects is a significant challenge, even if they are black, but very shiny, and especially if they are metallic or iridescent. Compound eyes are particularly difficult to capture on paper, especially if there is a need to reproduce the individual eye facets—imagine the iridescent eyes of a tabanid fly or the metallic green eyes of some dragonflies! In all cases, accurate rendering is of utmost importance as the shape and position of even individual setae can be taxonomically important.

Digital Illustration Applications

Many techniques are available to the illustrator, each with its advantages and appropriate use (Hodges 2003). These have traditionally included black and white (pen and ink, scratchboard, Coquille board), continuous tone (ink wash, carbon dust, graphite pencil), and color illustration techniques (watercolor, gouache, and acrylics; colored pencil; mixed media). With the advent of the "digital revolution," the use of computers and software applications to produce digital illustrations has been added to the artist's toolbox. Two types of software applications, bitmap or raster applications and vector or object-oriented applications, can be used to produce digital illustrations.

In bitmap applications, a virtual grid (*bitmap*) of pixels (*pic*ture *el*ements) is used to represent an image. Pixels are the smallest individual components of a digital image. On a computer monitor, each pixel appears as a small square with a fixed size, location, and color or grayscale value; and it can be edited individually. Bitmapped images are resolution dependent: the resolution of the image produced is dependent on the display device (computer monitor, printer) and the inherent resolution of the bitmap image. An image displayed or printed above its defined resolution becomes "pixelated."

Bitmapped images come from capture devices (digital cameras, scanners), screen capture applications (SnagIt, Grab, Screenshot Plus), and image-editing programs such as Adobe Photoshop, Canvas, Corel Painter, and GIMP. These applications are ideal for editing continuous-tone digital images such as digital photographs, where the ability to edit individual pixels can result in precise to subtle changes in color and tone (e.g., taking the "red eye" out of targeted areas of a digital photograph or changing the brightness or contrast across the entire image).

In vector applications, mathematical expressions or vectors define "objects," such as lines, curves, and shapes. Vector applications produce drawings or illustrations with crisp edges, uniformly smooth lines, and smooth changes in tone or color. Vector applications are resolution independent: They have no defined resolution and can be scaled smaller or larger without any loss of clarity; their "resolution" depends only on the resolution of the monitor or printer. Vector applications are represented by drawing programs such as Adobe Illustrator, CorelDRAW, Inkscape, and Canvas, and by computer-aided design (CAD) programs. Vector drawings can be "rasterized" and then edited in image-editing applications; but once rasterized, they lose their vector editing qualities.

Bitmapped images cannot be "vectorized." Although bitmapped images can be placed and scaled within vector illustration files, they cannot be edited. The file sizes of the two applications are also different; vector files tend to be small (tens of kilobytes), while bitmap files tend to be large (tens of megabytes). Both applications can be used to produce digital illustrations of insects "from scratch." In the hands of a skilled digital artist, these are almost indistinguishable from illustrations produced with traditional media.

Many drawing and image-editing applications are available commercially (e.g., Adobe Photoshop and Illustrator), through "open source" applications, or as "free-ware"(e.g., GIMP, Inkscape).

I was introduced to digital illustration about 6 years ago and started out using Adobe Illustrator and Adobe Photoshop. I continue to use these applications in my work, and I continue to learn new features and "tricks" every time I use them. The examples of techniques given here are from these Adobe applications. Illustrator and Photoshop are popular applications, and there are many user guides and manuals on the market (e.g., Alspach 2007, Blatner et al. 2007, Fuller and Fuller 2007), as well as the built-in help files in the applications themselves.

Digital Drawing using Adobe Illustrator

The process of digital illustration with Adobe Illustrator begins with a pencil sketch of the subject (Fig. 1a). In entomology, this is usually done from a specimen observed under a microscope outfitted with a drawing tube or ocular grid. Achieving an accurate, detailed pencil sketch is the most important step in the process! Once achieved, the pencil sketch is scanned via Adobe Photoshop's TWAIN interface or from a scanner's built-in scanning software.

The process then moves to Adobe Illustrator, where the scanned image is placed as a template layer and scaled to the appropriate size. The drawing begins by using Illustrator's drawing tools, primarily the Pen tool, to digitally "ink" the template layer. The Pen tool creates paths to which strokes of different line weights and color (usually black) are applied. By varying the stroke weight or by using the Outline Stroke feature, weighted lines can be produced so that the illustration takes on shape and depth. The final illustration takes on the look of a traditional pen-and-ink illustration (Fig. 1b). Illustrator's Pen tool is one of its most powerful fea-
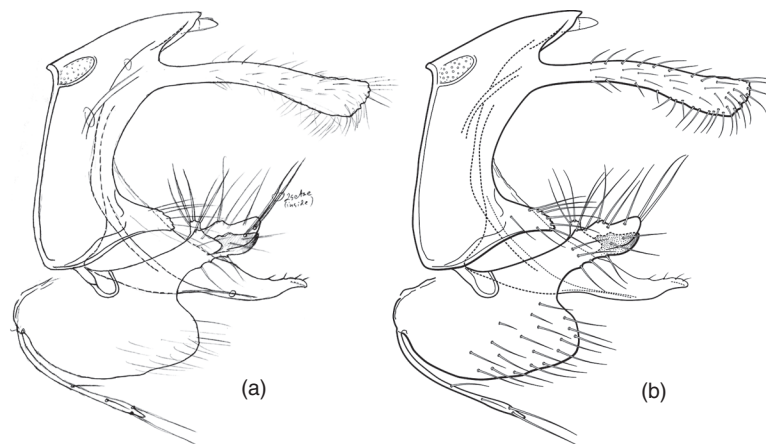

(a) (b)

Fig. 1. Simple black-and-white weighted line illustration drawn with Adobe Illustrator. (a) Pencil sketch of caddisfly male genitalia, which forms the base template of the illustration. (b) The finished illustration, created with a custom-designed setal brush.

tures. The ability to select individual components of a path (by direct selection of anchor points and adjusting direction lines) allows for precise changes in the shape of paths. Targeting paths to different layers adds editing flexibility to the illustration. In addition to the Pen tool, Illustrator's Pencil, Line, and Brush tools also create paths. By varying the length and stroke of paths, these tools can be used to create digital stipples or crosshatches (Figs. 2). Custom brushes can also be created, for example to produce setae or scales, even with setal sockets, that are drawn as single paths (Fig. 1b).

In addition to drawing lines, Illustrator can also create shapes. These shapes can be filled with solid color or with a grayscale or color linear or radial gradient, where the tonal value or color smoothly changes from one part of the shape to another (Fig. 2). More complex gradients can be applied to shapes by using the Gradient Mesh feature. With this technique, a closed shape is created, filled with black, and a gradient mesh grid of user-selected numbers of rows and columns is applied. Anchor points at grid line intersections can be individually selected and a grayscale value (0–100% across 256 tonal values) can be applied. Additional grid lines can be added or subtracted using the Gradient Mesh tool, and anchor points can be moved to affect how the gradient is distributed between anchor points. Additional shapes, with gradients applied, are targeted to layers, and the layers are stacked to achieve the desired orientation (e.g., the overlapping tergal plates on an insect's abdomen). A gradient mesh applied to simple shapes, with the shapes organized in layers, can produce remarkable results, either in grayscale alone, or with the added dimension of color (Figs. 3 and 4).
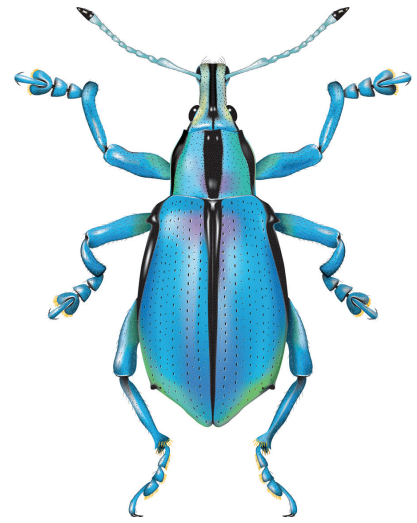

Fig. 2. Digital stipple, crosshatch, and linear gradient illustrations of caddisfly cases drawn with Adobe Illustrator.
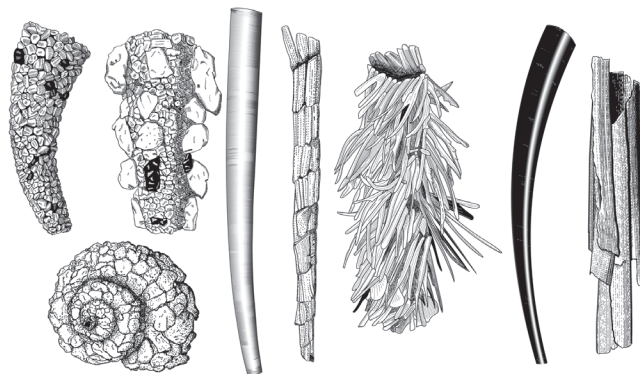

Fig. 3. Complex grayscale gradient mesh illustration of a parasitic wasp (*Sulcarius biannulatus*, Ichneumonidae) rendered with Adobe Illustrator. Inset: The gradient mesh.


Fig. 4. Complex color gradient mesh illustration of a weevil (*Eupholus loriae*, Curculionidae) rendered with Adobe Illustrator.

Digital Painting using Adobe Photoshop

This process can also begin with a scanned, carefully rendered pencil sketch, but because the objective is to produce a detailed color illustration, a high-quality digital photograph is a preferred starting point. Before moving to Photoshop, the photograph is placed in Adobe Illustrator as a template. Illustrator's Pen tool is used to create simple closed paths to outline the shape of the specimen and its parts, much like the shapes in a paint-by-number kit. No fills, colors, or differential line strokes must be applied. It is at this point, too, that the appendages can be arranged to offer a life-like posture with the proper perspective (Fig. 5a).

Once the outline is achieved, the file should be saved in its native Illustrator file format (extension ".ai"). The paths drawn in Illustrator are selected, copied, and pasted into a new Photoshop document. In Photoshop, the paths appear together in the "Path" palette, where each one can be selected, loaded as a selection, and the selection is targeted to a layer. With the selection still active, it is filled with a color that reflects the base color of the specimen (Fig. 5b). Targeting individual selections to layers and stacking these layers into the appropriate order adds tremendous editing flexibility to the process. Once all the selections are filled with color, Photoshop's powerful, versatile Brush tool is used to add highlights to light-struck areas, and shadows to edges hidden from light. The convention in scientific illustration is to have the origin of light coming from the upper left-hand corner, from about 45° off the surface. With the base pixels in a layer selected, a large diameter, soft-edged brush set at a low opacity is used to add white highlights, and a similar brush set to black is used to create edges in shadow (Fig. 5c). By varying the diameter, hardness, tip shape, color, and opacity of a brush, more and more detail can be built upon the basic shapes in each layer (Fig 5d). If this detail is itself targeted to separate layers, the ability to edit the
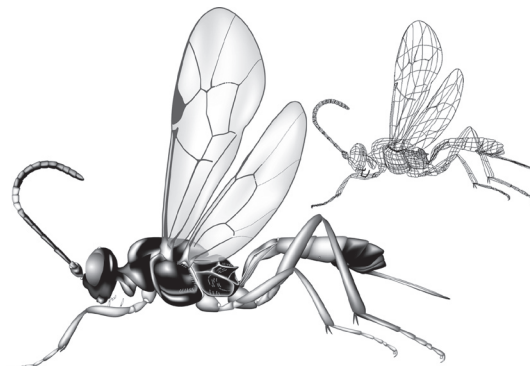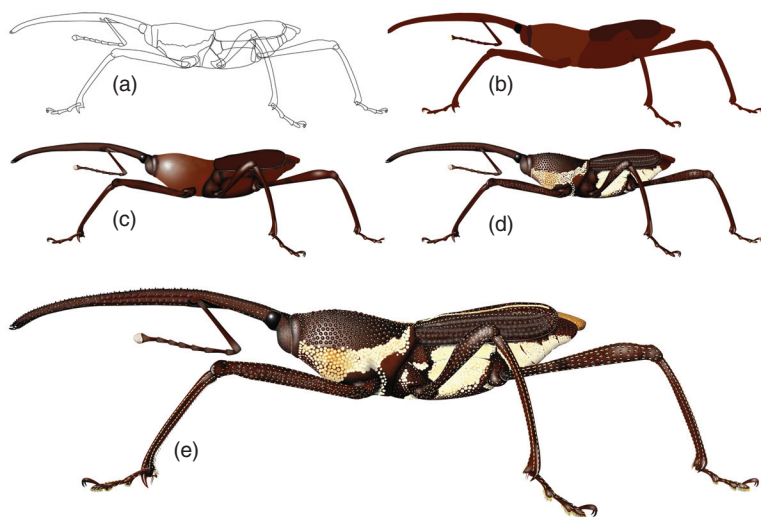
Fig. 5. Adobe Photoshop digital "painting" of a weevil (*Autonopis* sp., Dryophthoridae): steps in the process. (a) Paths rendered in Illustrator and copied into Photoshop. (b) Paths targeted as selections and filled with solid color. (c) Highlights and shadows added to the base fills. (d) Details added with the brush tool. (e) Additional fine detail added with the brush tool to complete the illustration.

illustration is greatly enhanced. Photoshop illustrations can contain hundreds of layers (the weevil painting in Fig. 5 contained more than 165 layers, and several more were merged during its creation). In addition to the versatility offered by layers, Photoshop comes with a large library of preset brushes that emulate traditional media brushes. If these are not sufficient, custom brushes can be designed and saved to a brush library. Finally, the ability to edit to the level of individual pixels means that fine details can be captured to give strikingly realistic results (Fig. 5e).

Benefits of Digital Illustrations

Currently available image-editing and drawing applications offer the user a diverse array of tools, including preset and custom brushes and pens, gradients, fills, filters, color libraries, layers and layer effects, layer blending modes, text tools, opacity and transparency functions, file formats, etc., etc. These tools and features allow for almost limitless experimentation and artistic expression. Moreover, "mistakes" can be easily undone, and new techniques can be tried without fear of ruining the illustration. The "Undo" command in Illustrator and the "History" function in Photoshop allow the user to back up through time to undo numerous sequential actions. The Pen tool in Illustrator overcomes the "steadiness-of-hand" problem experienced by beginners who often have trouble drawing smooth, uniformly curved lines with traditional pen and ink. Resolution is independent in vector applications such that illustrations can be reproduced at any size, but even with bitmapped applications, initial resolutions can be set such that printed or displayed output can be remarkably detailed. Finally, once in a digital format, illustrations can be saved in numerous graphic file formats for printing, posting on a Web site, or using in multimedia CD-ROMs, such as interactive keys.

Digital illustration provides an almost unlimited opportunity for those with a passion for insect diversity to express the complexity and beauty of insects in a medium that can be shared instantly via the Internet or, more traditionally, in print.

Students and others with little artistic experience or skill can use the techniques to produce work of professional quality. New digital tools, features, and enhancements are continually being added to existing applications or to new software. The world of 3D digital illustration (my next personal challenge!) and animation also beckon; these can have great utility in teaching, for example in insect morphology.

References Cited

Alspach, T. 2007. Illustrator CS3 Bible. Wiley, Indianapolis.

Blatner, D, C. Chavez, and B. Fraser. 2007. Real world Adobe Photoshop CS3: Industrial strength production techniques. Peachpit Press, Berkeley, CA.

Fuller, L. U., and R. C. Fuller. 2007. Photoshop CS3 Bible. Wiley. Indianapolis.

Hodges, E. R. S. (Ed.). 2003. Guild handbook of scientific illustration. John Wiley & Sons. New York.

Hogue, C. L. 1987. Cultural entomology. Annu. Rev. Entomol. 32: 181–199.

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