The Art of the Critique: Techniques-based tools for critical thinking

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The critique is an integral part of every medical illustration curriculum and is designed to point out technical deficiencies and strengths, to establish ways of improving the illustration, and to help instill in the student the value of critical thinking. These techniques, many of which experienced illustrators instinctively implement and take for granted, may be completely new and underutilized by the beginner. A concise list of techniques, for use in both the planning and rendering phases of creating a medical illustration, provides an efficient set of tools for the novice medical illustrator to improve his/her artwork.

Introduction

Medical illustrators use artistic license as a tool for simplification and effective communication. Throughout history there have been a plethora of media available, ranging from traditional practices such as pen & ink, watercolor and sculpture, to modern tools such as digital painting programs, animation, and 3-D computer graphics software. Regardless of the tools or media used by the illustrator, basic principles of visualization and effective communication underlie all platforms. In any media, effective images are the result of careful consideration of the fundamental physical behavior of light on form (Jessup and Mascaro 1989).

This article provides an overview of many basic techniques and conventions used by experienced biomedical illustrators. It is designed to provide students, novices, and illustrators in a teaching environment a quick and effective shortlist to help critique a medical illustration. In addition to analyzing a piece, being mindful of, and effectively implementing these techniques throughout the project development can avoid pitfalls and help improve the final rendering.

The critique is an integral part of every biomedical illustration curriculum; it is designed to point out technical deficiencies or strengths, to establish ways of improving the illustration, and to help instill in the student the value of critical thinking. A critique has two components for analysis: content and technique. Although we agree that content is very important and is the foundation on which any successful communication is based, in this paper, we are mainly concerned with technique. Apart from content, careful analysis of why things work or do not work can invariably be attributed to one or more of the techniques discussed below. From our experience (Art as Applied to Medicine 1970-2010), in many cases, dramatic improvements can be achieved by simply implementing or improving on one or a combination of these. Since the novice illustrator is often faced with a huge spectrum of varying artistic styles and creative freedom, having a thorough knowledge of these practical techniques can provide an effective set of tools to help guide the beginner to focus and improve on their work through self-evaluation. To this end, the authors provide a concise checklist of the most practical and effective techniques.

Methods and Techniques

Experienced medical illustrators instinctively implement many communication conventions and techniques, and take for granted what may be new to and underutilized by the student or novice medical illustrator. Most of these conventions and techniques are encountered in medical illustration graduate programs through various projects and assignments. However, to our knowledge, they have not been collected as a group and concisely outlined as a usable armamentarium list. Table 1 identifies two basic phases in the development of the most common and important principles, techniques, and conventions. Although there is much overlap, the list is divided into a more general "Planning" phase and a more technical "Execution" or rendering phase. Some techniques can be applied in both phases. We will briefly describe each technique, providing figure examples when warranted.

Planning Phase

Simplification and Idealization

Medical illustration, by its very essence, requires some degree of simplification and idealization of the subject. It is the role of the illustrator to visually educate the reader regarding a complex biomedical procedure, structure, or process in an aesthetic and efficient manner. Showing a meticulous rendering of the threedimensional structure of a protein, may not be as effective for the reader as showing a simplified, schematic lock & key

Table 1. Practical Techniques List	
Planning Phase	Execution Phase
•Simplification and idealization	•Light and shadow
•Composition and design	Upper-left light source
Avoid visual monotony	Highlight considerations
Audience	Simplified core shadow
Styles	Cast shadows
•Contrast	•Arrows
•Time	•Color conventions
Collapsing and expanding	Wet media (Transparent watercolor,
•Transparency	acrylics, gouache)
•Size, scale, and orientation	Digital platforms
 Basic sections and views 	 Basic techniques for linework
Orientation adjectives	Three basic techniques for Pen
Sectional planes	& Ink rendering: crosshatch,
Views	eyelash, stipple
•Perspective	Snodgrass
Architectural	•Cut vessels and tubes (conventions)
Artistic	•Instrumentation
	•Text and labeling

mechanism to teach the interaction in a molecule/receptor complex (Figure 1). Idealizing a subject may entail creating an "average" or simplified view, while being mindful of existing conventions or visual archetypes. "living" Illustrating anatomy is preferable to illustrating cadaveric anatomy. Showing the idealized or average state often gives visual clarity, unless, of course, the illustration is a specific case study. One can modify, enhance, or diminish any aspect of the subject to render it more "realistic", instead of merely transcribing a photo or still life. Omitting anomalies and unnecessary intricate detail also helps to achieve visual clarity (Crosby and Cody 1991).

Composition and Design

Good composition and design are almost always relevant considerations in providing a balanced, aesthetic





Figure 2. This complex layout exemplifies an organized visual flow of didactic information designed with several hierarchical levels of scientific information. The major focal points: earth, man, cell, and DNA/chromosome are all visually tied with DNA helix strands, 'ribbon people' cut-outs, and overlapping elements. Each focal stop presents progressively deeper and sophisticated data. The piece can also function as four individual, discreet layouts, owing to its intended 4-page fold-out design. (First published in: Simpson, BW. 2007. The Genetic Journey: Following DNA from Cell to Society. Johns Hopkins School of Public Health Magazine. Spring.) © JHU-Jennifer E. Fairman



Figure 1. Idealized nerve terminal bouton is shown with simplified molecule-receptor complexes to represent the vast array of interrelated biochemical cascades. 2004. (First published in: Meyer RA, Ringkamp M, Campbell JN, Raja SN "Peripheral Mechanisms of Cutaneous Nociception," In Textbook of Pain, Fifth edition, S. McMahon, M. Koltzenburg (Eds.), Elsevier.) © JHU-Ian Suk



Figure 3. A. Small and dark nucleus pulposus provides sharp contrast with lighter surrounding tissue and complimentary purple color also provides a visual focal point demonstrating disc herniation. © Ian Suk B. Bold lines and dark-value areas help demarcate skin incisions and craniotomies, respectively. (Published in: Colby GP, Coon AL, Tamargo RJ. 2010. Surgical Management of Aneurysmal Subarachnoid Hemorrhage. Neurosurg Clin N Am 21. Philadelphia: Elsevier, 11(2):247-261 © JHU-Ian Suk

Some common graphic effects that can have tremendous impact on overall composition arise from using lines and rectangles in an image. Intersecting lines and shapes can form vertices that may create unintentional focal points, a common pitfall for the novice, while judicious use of lines/dashed lines is critical in representing incisions, transparent objects (Figures 3B, 4 (top)), and label leader lines. Similarly, "boxed" (with line or full-bleed cropping) elements to highlight an orientation inset or zoom are effective ways of establishing visual order and emphasis.

In thinking "outside the box", "breaking borders" adds visual weight or interest and a sense of dynamic motion. However, one must be wary of the possibility that the object breaking the border may actually be cropped by the printer or production editor.

Avoid Visual Monotony

Same-sized structures repeated many times in a step-bystep sequence can be visually monotonous. Similarly, perfect patterns may give the illustration a mechanical look. For example, fat lobules or cut muscle fascicles with perfectly even shapes and orientations create a monotonous wallpaper effect. Having an odd number of structures alleviates visual monotony and gives a more "natural" appearance than even numbers. Having random clusters of shapes within a uniform background also enhances naturalism.

One can avoid visual monotony in large expanses of uniform tissues by adding arbitrary artifacts (color, inconsistent blemishes, folds), in order to increase organic realism and dimension. For example, large sheets of fascia or ligament may have small dents and striated areas and show cool, bluish or violet sheens.

Audience

Knowing precisely the reader or audience will determine many other technical aspects in the Planning stage, the most notable being the use of simplification and idealization where the level of complexity depicted is ideally suited for the target audience.

Styles

There are as many "styles" of rendering (across many media) as there are medical illustrators. Individuality aside, one may argue that there are certain "trends" that, for better or worse, escape the attention of the student medical illustrator, since everything is new and novel for them. A good historical perspective allows the novice illustrator to have a more global view of art forms and stay abreast of emerging styles and media.

Technology often dictates and establishes trends and styles. An example is the dark blue dye used in Diazo 35mm film slides that were used mostly for text and line-art graphics in scientific presentations in the late 20th century. It was a popular method used by the scientific community before use of full-color slides (E-6) and digital Microsoft[®] Powerpoint[®] (2004). This traditional film method has spilled over into the digital realm and we still have prevalent dark blue background text slides in Microsoft[®] Powerpoint[®] (Collins 2004).

Another example is the obsolescence of traditional ophthalmologic watercolor illustrations. With the advent of sophisticated wide-angle optics and electronic flash in photography (Bennett 2006), the once well-established



Figure 4. Top. The critical aspects of vestibular nerve surgery are depicted by collapsing time and omission of unimportant detail. (First published in: Dandy WE. 1945. Surgery of the Brain, Lewis' Practice of Surgery; Vol 12. Hagerstown: W. F. Prior. 196 (Fig. 80). Printed with permission from Brödel Archives, Johns Hopkins Dept. of Art as Applied to Medicine) Bottom. Unparalleled soft tissue details are clearly outlined through the course of pregnancy. Size scale is defily manipulated to show comparative embryological development. (First published in Padget DH. 1948. The development of the cranial arteries in the human embryo. Contrib Embryol 32:205-261, Plate 1.)

specialty in retinal paintings such as those by Annette S. Burgess at Johns Hopkins Hospital (Wilmer 1934) has become obsolete. The demise of one technique often gives birth to a completely new technique or media. Advancements in ophthalmological surgery have required novel illustrations in keratotomy, laser corneal surgery, and intraocular lens procedures, amongst others. As in any other

profession, medical illustration is subject to constant change, reinvention, and evolution.

Contrast

Although equally pertinent in the Execution Stage, as a subset of light and shadow, the authors feel that overall contrast established at the Planning Stage can be a most effective tool from the outset. Contrast is simply the juxtaposition of differences in: value (light against dark), hue (complimentary colors), scale, clarity of focus, or rendering styles (such as the use of bold, hard-edged outlines), that helps to define and emphasize the main subject.

Time

The task of collapsing and expanding time is an essential aspect of describing a surgery or other process. Surgical procedures generally involve many steps within an extended span of time. It is the role of the medical illustrator to emphasize/de-emphasize certain steps in keeping with what is appropriate for the given audience. It is often possible to depict several steps in a single image (collapsing time), while keeping the "surgical moment" as the focus. Even a step-by-step project entails a great deal of visual editing to clarify information. Kretzer et al. (2004) report the genius of Dorcas Hager Padget to selectively impart scientific understanding in her neurosurgical and embryological illustrations (Figure 4 (bottom)).

A common pitfall for the novice illustrator is to illustrate everything, consequently losing focus and leaving the viewer to decipher the important aspects of the procedure. McConathy (1989) emphasizes the critical aspect of having a clear focus in a sequential surgical illustration series through simplified renderings.



Figure 5. Variety of scaling techniques are used to represent gross anatomy, microscopic anatomy, and sequential, time-based biochemical cascades. (Published in: Huang J. et al. 2006. Vascular inflammation in stroke and focal cerebral ischemia. Surgical Neurology 66:232-245.) © JHU-Ian Suk

Time-based phenomena also occur in biochemical cascades and reactions where time is expanded or slowed down, and real-time interactions may be actually milliseconds in duration. Here, the emphasis is on sequence and the respective roles of the individual molecules (Figure 5).

Transparency

Transparency is the technique of showing one structure behind another, for example, showing bone through transparent skin. It is a highly effective tool to elucidate many layers of three-dimensional anatomy and also can help compress time in a lengthy procedural event (Figure 4 (top)).

To convey transparency, a background object disappears around foreground edges (e) and also around foreground highlight (h) areas (Figure 6A). This principle is the same across many media. Gerald Hodge (1974, 1984, 1989)



Figure 6. A. Pen & Ink Transparency demonstration by Gerald Hodge. An effective method of enhancing realism in organic tissue is to stagger the highlights (h) to suggest unevenness and inconsistencies of the tissue surface. The same effect can be achieved with a core shadow (e). (From Hodge G.P. 1974. Practice Sheet for use with India ink and fine flexible pens. University of Michigan.) B. Note the fading of skull lines to suggest transparency (arrows). Dentition roots are stippled to denote a secondary level of transparency. Dental anatomy of the cat and dog. 2005. © Tim Phelps.

demonstrates very effectively this transparency technique as well as combining different techniques of pen & ink rendering in a single image.

Size, Scale, and Orientation

Size

The working size should always be considered before starting an illustration. Generally, working larger at the sketch stage ensures a clear and sharp final piece, especially if there is a slight reduction in size in the final reproduction. Since enlarging a raster image often creates blur, working larger in the beginning also provides a small safety buffer if there is a need to enlarge the final image. For traditional two-dimensional artwork, working size typically ranges from 120%-150% of final size.

Scale

Scale within a piece can often be established with a knownsized element, such as a red blood cell, surgical instrument, or even a surgeon's fingertip. If no visual clues are readily available, it is appropriate to add a scale bar, for example, 1mm.

Orientation

Including an orientation inset is an effective way of quickly guiding the viewer to a focal area and/or a particular view in three-dimensional space.



Figure 7. Illustrated Summary of Basic Sections and Views. 2003.© Jennifer E. Fairman

Basic Sections and Views

Various terms to describe anatomical orientation and sections can be confusing for the novice illustrator. Below is a general overview of some common words that share much overlap in the scientific, artistic, and clinical arenas (Figure 7).

Orientation adjectives:

Cranial, cephalic, superior - Upwards, towards head Caudal, inferior - Downwards, towards tail Anterior, ventral – Front, towards belly Posterior, dorsal – Rear, towards back Lateral - Towards side Medial - Towards midline Proximal - Towards center, or towards origin, deep Distal, peripheral - Outwards, or away from origin, superficial

Sectional planes:

- Sagittal vertical plane dividing the body into right and left parts
- **Coronal** vertical plane dividing the body into front and back parts
- Axial transverse or horizontal plane, dividing the body into superior and inferior parts

Views:

A-P (Anterior-posterior or frontal view)

- Patient is facing the viewer patient's right appears on the left of the image (Figure 8).
- Lateral (side) view Clinically, the patient is looking to the left of image BUT artistically, subject is often illustrated looking right (Figure 9).
- **Cross-section** Viewer is looking up (cranially, from the patient's feet) at the axial section (Figure 10).

Oblique section/view (Figure 11).

- **Zoom View** a portion of image is enlarged dramatically to clarify detail. The enlarged image and inset box are often connected with subtle expansion leaders or shading (Figure 12).
- **Exploded View** a linear or non-linear arrangement of three-dimensional depiction of structures to emphasize relative order of location from proximal to distal and relative positions of intrinsic structures in three-dimensional space (Figure 13).
- **Combination View** combination of sectional views and other transparent or three-dimensional views (Figure 14).



Figure 8. A-P (Anterior-posterior) x-ray of abdomen.



Clinical

Artistic





Figure 10. Axial MRI section at the upper thoracic level.



Figure 11. Oblique, three-dimensional view of the brain with coronal and sagittal sections. © Ian Suk



Figure 12. A small portion of the image is zoomed in to highlight detail.



Figure 13. This exploded view shows linear, truncated sections along fallopian tube. 1928. Max Brödel. (Published in: Cullen T. S. Uterine Hemorrhage and its Treatment. Journal of the Missouri State Medical Association October, 1928. Printed with permission from John Hopkins Art as Applied to Medicine: Brödel Archives)



Figure 14. Combination view. Sections are combined with intact skull with transparent skin to explain surgical anatomy. 1915. Max Brödel. (Published in: Heuer G. J. 1920. Surgical Experiences with an Intracranial Approach to Chiasmal Lesions. Archives of Surgery 1(2). Printed with permission from John Hopkins Art as Applied to Medicine: Brödel Archives)

Perspective

Walters and Bromham (1970) outline the mechanics of the three main types of point or architectural perspective. The latter three types are more artistic and subjective:

- 1 point perspective
- 2 point perspective
- 3 point perspective
- Curvilinear/panoramic perspective (Cole 2000, Flocon 1987) – extremely wide angle including fish-eye, patchwork of images and continuous pan; much optical distortion
- Aerial perspective closer objects are in sharper focus (often with thicker outlines) and color is more intense.
- Focal perspective ¬ area outside of focal area is blurred or vignetted (Figure 15).

Execution Phase

Light and Shadow

Upper-left light source

Upper left lighting source is a convention in medical illustration. This is a combination of 1) upper lighting, which we interpret instinctively based on overhead sunlight and interior lighting and 2) light from the left, to avoid casting



Figure 15. A. 1-Point Perspective. B. 2-Point Perspective. C. 3-Point Perspective. D. Curvilinear Perspective. (VP-Vanishing Point) 2010. © Ian Suk

a shadow on images depicting a right-handed operator or instrumentation (Figure 16).

In medical and scientific illustration, the convention is to assume upper left light source such that the shadow and cast shadow will fall towards lower right of the object (Figures 16, 17, 18). A consistent direction of light source enhances realism. Depicting different light sources must be done with caution and specific purpose. A direct frontal light, such as that created by an electronic flash, tends to flatten objects create unnatural cast shadows.

Upper left lighting is a useful convention, particularly for surgical illustration, because the majority of the population, including surgeons, is right-handed, thus allowing a clearer illumination of the focus area. A light source from the right would cast an unwanted shadow, from the hand or instrument, directly into the area of interest. Upper-left lighting allows clearer illumination of the focus area. If there is a pair of hands, it should be right and left, from one active participant. Showing two left or two right hands can often be confusing, without deliberate purpose.



Figure 16. Right-handed operator is the popular convention. Upper left light source illuminates anatomy surrounding correct placement of intubation mask and subsequently, the cast shadow from hand or hand itself does not impede view of critical areas. © Ian Suk

Highlight Considerations

When rendering a highlight on a tissue surface, one must consider the three attributes that affect its appearance: **intensity of light source; tissue texture; and ambient light**. A common mistake is to render the specular highlight *too evenly*, causing it to lose its organic feel. The tissue then looks too mechanical, like a plastic object, instead of an organic vessel, intestine, or stomach. An effective method to enhance the realism in organic tissue is to stagger the highlights to suggest unevenness and inconsistencies of the tissue surface (Figures 6(A), 27 (Right)). The same unevenness can also be implemented in a band of core shadow.

Simplified Core Shadow

In a focally lit environment with simple, direct, singlesource lighting, the combined simplified "band" of shadow area on the object is termed Core Shadow. Although it is in reality a continuous subtle range of light to dark tones, identifying this graphic "band" across objects is an efficient way of quickly delineating form (Figure 17).

Cast Shadows

Cast shadows are often used by the illustrator to draw attention to a key element. For example, the most important surgical instrument tip can cast a darker, sharper shadow on the underlying tissue, becoming more diffuse as it moves away from the source (Figures 18, 19). This creates a subtle "arrow" pointing to that area of interest. Cast shadows also greatly enhance contrast and dimensionality by revealing form on projected contours. In laparoscopic or minimally invasive surgery, the illustrator can manipulate the frontal light source to create dramatic, instructive cast shadows (Figure 19).

Arrows

Arrows are important graphic elements of an image that can:

- highlight an object
- show direction/motion/twist/transformation/ development/time lapse
- greatly enhance spatial relationships (in the case of three-dimensional arrows)

A sloppy arrow (rendered ineffectively or with inappropriate size, shape, or color) can greatly diminish the aesthetics of an otherwise, well-executed, elegant illustration (Figure 20).

Color Conventions

Mascaro (1984) suggests that colors in anatomical and surgical illustration are merely "symbolic colors...which have been adopted for reasons of information and clarity" and only bear rudimentary semblance to reality. Some common color assignments to various tissues are: red for arteries, blue for veins, yellow for nerve and fat, light green for lymphatics, brick red for muscle, whitish-yellow for fascia, off-white or beige for bone, and dark green for bile.



Figure 17. The core shadow is graphically simplified into a black band. Many art textbooks use the terms penumbra and umbra to define this core shadow. © Ian Suk



Figure 18. Cast shadow from the neuroendoscope helps direct the eye to the focal point and heightens dimensional form of both endoscope and the surrounding tissue. © Ian Suk



Figure 19. Dramatic cast shadows of instruments reveal a lower-left light source and help emphasize the focal point. © Corinne Sandone



Figure 20. Directional arrow highlights the surgical approach and viewpoint of the surgeon through craniotomy. It sets the stage for a subsequent close-up illustration (not shown) of the vestibulocochlear area. 2005. © Ian Suk



Figure 21. A variety of conventional colors are used to represent numerous tissue types in oblique view. (Published in: Hsieh PC, Li KW, Sciubba DM, Suk I, Wolinsky JP, Gokaslan ZL. 2009. Posterior-Only Approach for Total En Bloc Spondylectomy for Malignant Primary Spinal Neoplasms: Anatomic Considerations and Operative Nuances. Neurosurgery, Dec:65 (6):173-181.) © JHU-Ian Suk

It is ultimately the decision of the medical illustrator to use ANY color to help clarify or emphasize an aspect of the illustration (Figure 21).

Wet Media (transparent watercolor, acrylics, gouache)

In rendering with traditional water-based media, the basic minimum palette comprises: six primary colors (a warm and cool hue of the three primaries) and three secondary colors. In addition, basic white/black colors include: titanium white, and lamp or ivory black (Figure 22).



Figure 22. Basic watercolor palette includes a warm and cool version of each primary color. Names are examples from Windsor & NewtonTM Artist's Watercolour tubes. Note the derived secondary colors: orange, green, and purple. © Corinne Sandone

The main traditional application techniques are: wash, wet-on-wet, glazing, and dry brush.

The use of a large brush for initial tones or wash effectively achieves tonal values quickly. Initial undertone painting is an effective way of establishing value and enhancing dimensionality. The first local color wash can be fairly dark, since transparent watercolor dries about 15% lighter. Successive layers can be applied while the paint is wet or completely dry. With very little paint on a brush applied to a undertone enables incremental, controlled application of pigment.

Digital Platform

The traditional palette also applies to digital media. The technical challenges of proficiency in using software programs notwithstanding, fundamentals of color theory also apply. Currently, most transparent and opaque effects produced by traditional watercolor, gouache, and oil impasto effects can be simulated on digital platforms. In many ways, the digital version is quite forgiving and allows the novice to use, mix, and pick colors with greater accuracy and predictability than traditional media–owing to the latter's inconsistent pigment concentrations amongst different colors and different brands.

Basic Rendering Techniques in Linework

Three Basic Techniques for Pen & Ink Rendering:

For many years pen & ink (and all forms of black and white digital linework) has been the standard for delivering economical, fast, and simple visual communication in print publications. There have been many styles of pen & ink and digital linework, ranging from complex, fully rendered figures with detailed eyelashing and stippling, to simple schematic contour drawings, using thick and thin, weighted contour outlines to suggest form. Although Pitz (1984) gives examples of an array of styles, his grayscale exercises on achieving tone emphasize practicing uniform lines and crisp tapers. In rendering, the primary ways of creating grayscale values in line art include crosshatching, eyelashing, and stippling. Combining several methods must be done with care, as this can make the figure appear erratic and discordant.

- Crosshatching Method using the combination of two or more sets of crossing lines to build up texture using angled and rectilinear intersecting lines (Figure 23).
- **2)** Eyelashing Tapering the width of lines to suggest core shadow tones (Figure 24).
 - When rendering tubes, curvature of the lines follow imaginary ellipses in perspective (Hodge and Hodges 1989).
 - Snodgrass: "Snodgrassing" is a term used to describe "placing extra ink at the junction" (Hodge and Hodges 1989) of converging angular lines and functions as a visual punctuation of cast shadow and dimensionality (Figure 25). The term was coined after the American entomologist Robert E. Snodgrass (1875-1962).
- **3)** Stippling combination of ink dots of varying sizes and varying spaces in between dots (Figure 26)
 - the same principle is used in producing halftone in print, where lighter areas are depicted with proportionately smaller-sized dots.

Cut vessels and tubes (conventions)

Depicting theoretical cut vessels and tubular structures reveals a great deal of information on their trajectory and dimensionality. Arteries tend to be more tortuous, have slightly thicker walls, and usually have rounder cross-sections, as compared to veins. Veins are often depicted showing a bit of collapse or hourglass shape in the cross-section (Figure 27).



Figure 23. Both angled (a) and rectilinear (r) crosshatching are used effectively to render tone of mucosal lining of bronchioles. © JHU-Tim Phelp's

Instrumentation

Accurate depiction of mechanical devices cannot be overemphasized. It is equally important however, to "integrate" the visual weight, style, and level of detail commensurate with the emphasis of the illustration. Exceptions include having deliberate emphasis on an instrument for its novelty of use or for marketing purposes (Figure 28).

An example of an incongruous illustration is showing a surgical procedure with a scalpel rendered in perfect mechanical detail, amidst surrounding tissues and background rendered in a



Figure 24. Carefully eyelashed lines are used to simulate core shadow of the swim bladder of a seahorse. A variety of line techniques are used to differentiate various anatomical structures. © JHU-Tim Phelps



Figure 25. Effective use of Snodgrassing (arrows) visually punctuates the cast shadow and helps define which structures are in front of another. © Corinne Sandone



Figure 26. Stipple is used to render subtle patterns of leaves and cicada wings. © *Tim Phelps*

loose, gestural style. Unless the scalpel itself is the focal point or being used in an instrument advertisement, it should play a secondary role to tissue cutting or surrounding anatomy.

Text and Labeling

When handling body text, one must be mindful that it is an important design element and its shape, whether columnar blocks or justified text wraps, has inherent esthetic value and visual flow dynamics.

As a general rule, the fewer fonts used, the better. When reduced in size, serif fonts are easier to read in printed body text but legibility is often diminished on a monitor or transmissive media. A common beginner's pitfall in labeling is using fonts that are too small or too large. Careful consideration of font size, design, and legibility of text is an effective tool in enhancing the pedagogy and communication of an image.



Figure 27. Left. Example of cut artery, spine, and spinal cord. Right. Veins are often depicted with slightly collapsed walls and usually are less tortuous than arteries. Also note staggered treatment of highlights. © Ian Suk



Figure 28. Prominent depiction of instrumentation was required to convey a novel way to mechanically correct spinal deformity. Deliberate use of warm grey and bronze hues helps integrate the metallic devices with background organic tissues. (Published in: Hsu W, Saidi HA, Suk I, Gokaslan ZL, Wolinsky JP. 2010. A New Technique for Intraoperative Reduction of Occipitocervical Instability. Operative Neurosurgery, June:66 (2):319-324.) © JHU-Ian Suk

When labeling, one should avoid crossing leader lines. The width of leaders lines should include consideration of final image size reduction. If using a ball at the end of a leader, the diameter should not exceed 2-3 times the leader width. In applying multiple branches to a leader line, sequential order should be (from the straight leader): Top to bottom and Left to right (Figure 29).

Conclusions

Powerful computers and 3-D rendering and animation software, the internet, and instant hand-held communication

devices continue to evolve and transform the way medical/scientific education is created and disseminated (Corl et al. 2000). Despite the ever-changing environment, basic techniques and tools of visualization remain applicable and useful in self-evaluation and critical thinking for the novice biomedical illustrator.

The continuing need to visualize the "unseen" will always predicate the need for biomedical illustration – regardless of media change. Even in the dynamic world of 3D animation, fundamental principles of composition and design, contrast, idealization, color, etc. all play a role in



Figure 29. "Examples show use of lines, endpoint balls/dots, and sequential labeling when there are a series of structures. Order is conventionally from left to right and top to bottom."

education and communicating the unseen. Another example of visualizing the unseen occurs in the growing popularity of minimally invasive surgery. While it is certainly an attractive option from a clinical/patient perspective, compared with traditional surgery, it reduces the amount of visible anatomy for the illustrator and its narrow field of vision poses anatomical landmark challenges for both the clinician and illustrator. However, all these myopic views through various "scopes" and "tubes" may in fact, not diminish, but actually generate a tremendous need for clear, didactic visualization from biomedical illustrators, and consequently require a firm understanding of the techniques described here, thus fulfilling the adage:

"Medical Illustrators draw what cannot be seen, Watch what hasn't been done, And tell thousands about it without saying a word." (AMI 2007).

It is this doctrine, towards which all use of medical illustration techniques strive. Despite constant evolution in content, media, styles, and technology, the techniques remain widely applicable since they fundamentally deal with communication through effective use of basic light on form, composition and design, and sound color theory. To fully explain and show the implementation of each technique is a task far beyond the scope of this paper. The authors have highlighted some of the most common ones encountered in practice over four decades of academic teaching. This concise outline attempts to encompass a wide spectrum of the most useful techniques and conventions to refer to when critiquing a biomedical illustration piece, and gives the novice biomedical illustrator a practical, convenient checklist of basic tools for critical thinking.

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References

AMI - Association of Medical Illustrators. 2007. http://www. ami.org/ECOMAMI/timssnet/common/tnt_frontpage.cfm [Accessed on 28, February 2007]

Art as Applied to Medicine Department (AAM), 1830 E. Monument St. Ste 7000, Johns Hopkins University. 1970-2010. Curriculum critiques in applied art courses. [Faculty-wide participation several times a year from 1970 to present]

Bennett T. J. 2006. Ophthalmic Imaging – an Overview and Current State of the Art: Part I. *JBC* 32(2):16-26.

Colby GP, Coon AL, Tamargo RJ. 2010. Surgical Management of Aneurysmal Subarachnoid Hemorrhage. *Neurosurg Clin N Am* 21. Philadelphia: Elsevier, 11(2):247-261. [Figure 3B]

Cole A. 2000. Perspective. New York: Dorling Kindersley, 47.

Collins J. 2004. Education Techniques for Lifelong Learning – Making a Powerpoint Presentation. *Radiographics* 24:1177-1183.

Corl F. M., M. R. Garland, E. K. Fishman. 2000. Computers in Radiology – Role of Computer Technology in Medical Illustration. AJR *Am J Roentgenol* 175:1519-1524.

Crosby R. W. and J. Cody. 1991. Description of Techniques [Max Brödel's own words]. In: *Max Brödel, The Man Who Put Art Into Medicine*. New York: Springer-Verlag, 324.

Cullen T. S. 1928. Uterine Hemorrhage and its Treatment. Journal of the Missouri State Medical Association, October. [Figure 13]

Flocon A. and Barre A. 1987. *Curvilinear Perspective: From Visual Space to the Constructed Image*. Berkely and Los Angeles, University of California Press.

Heuer G. J. 1920. Surgical Experiences with an Intracranial Approach to Chiasmal Lesions. *Archives of Surgery* 1(2). [Figure 14]

Hodge G. P. 1974. Practice Sheet for use with India ink and fine flexible pens. University of Michigan. [Student handouts for Pen & Ink course, Figure 6A]

Hodge G. P. 1984. Using pen and ink. *Biomedical Communication*. Aug;12(4):20-2.

Hodge G. P. and E. R. Hodges. 1989. Line and Ink. In: *The Guild Handbook of Scientific Illustration*. New York: Van Nostrand Reinhold, 95-119.

Hsieh PC, Li KW, Sciubba DM, Suk I, Wolinsky JP, Gokaslan ZL. 2009. Posterior-Only Approach for Total En Bloc Spondylectomy for Malignant Primary Spinal Neoplasms: Anatomic Considerations and Operative Nuances. *Neurosurgery*, Dec:65 (6):173-181. [Figure 21]

Hsu W, Saidi HA, Suk I, Gokaslan ZL, Wolinsky JP. 2010. A New Technique for Intraoperative Reduction of Occipitocervical Instability. *Operative Neurosurgery*, June, 66 (2):319-324. [Figure 28] Huang J., U. M. Upadhyay, R. J. Tamargo. 2006. Vascular inflammation in stroke and focal cerebral ischemia. *Surgical Neurology* 66:232-245. [Figure 5]

Jessup M. E. and D. Mascaro. 1989. Light on Form. In: *The Guild Handbook of Scientific Illustration*. New York: Van Nostrand Reinhold, 71-91.

Kretzer, R. M., R. W. Crosby, D.A. Rini, R. J. Tamargo. 2004. Dorcas Hager Padget: neuroembryologist and neurosurgical illustrator trained at Johns Hopkins. *Journal of Neurosurgery* 100:719-730. [Figure 4]

Mascaro D. 1984. The use of color in anatomical and surgical illustration. *Journal of Biocommunication*. Nov:11(4):4-16.

McConathy, D. 1989. Canonical Form as a Model for Surgical Illustration. *Journal of Biocommunication*. 16(2):20-27.

Meyer RA, Ringkamp M, Campbell JN, Raja SN. 2004. Peripheral Mechanisms of Cutaneous Nociception. In: *Textbook of Pain, Fifth edition*, S. McMahon, M. Koltzenburg (Eds.), Elsevier. [Figure 1]

Microsoft[®] Office[®] 2004 Macintosh Standard. 2004. Microsoft[®] Powerpoint[®] for Mac Version 11.2.3. Redmond, WA: Microsoft Corporation.

Pitz H. C. 1984. *Ink Drawing Techniques*. New York, Watson-Guptill Publications, 47.

Simpson, BW. 2007. The Genetic Journey: Following DNA from Cell to Society. *Johns Hopkins School of Public Health Magazine*. Spring. [Figure 2]

Walters N. V. and J. Bromham. 1970. *Principles of Perspective*. New York: Whitney Library of Design.

Wilmer W. H. 1934. *Atlas Fundus Oculi*. New York: The Macmillan Company.

Windsor & Newton. Windsor & Newton Artist's Watercolours. Harrow, Middlesex: Windsor & Newton.

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