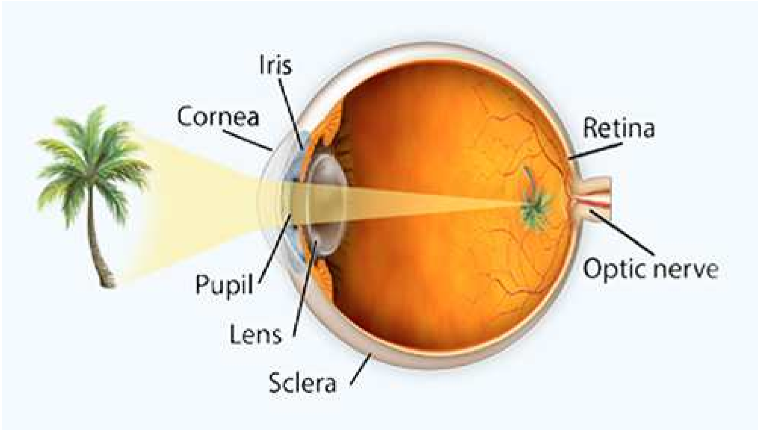
1a. Flipping the Image Upside-down



Without the slightest conscious effort we "*reverse*" the image projected onto the retina of our eye.

This book starts with the simplest and proceeds toward the more complicated, in its list of ways that eyes differ from Perspective.

Separate aspects of eyesight are better understood by other experts; this book attempts to provide an overview of the whole problem.

The brain is an unsolved mystery –this book is a list of unanswered questions. No one can explain how a brain inverts a visual image.

How Eyesight Differs from Perspective: Part 1

1b. Focus

In Perspective, where the Eye (or Aperture) is a dimensionless point, focus is not an issue.

In human eyesight, image focus is always an issue.

In the photographic versions of Perspective, image focus is always an issue**--** even in the sizing of the tiny pinhole for a simple “pinhole camera”.

The technical subjects of optical focus and aperture size will not be discussed in this book.

Artists can simulate detail focus in a Perspective picture in ways impossible for a human eye, or a standard camera, to focus at a single instant of time.

Separate from optical focus, the human eye has a capacity to focus attention on specific details.

The magnification of vision by mental concentration will be discussed separately, later in this book (section **2a: Zoom**).

1c. Binocular views

Perspectives typically are composed using a single “point of view”, one observing “Eye” defined as a single geometrical point in space.

Of course most humans see with two eyes, not one; and the eyes of human are larger and more complicated than a single point.

The OPTICS of Euclid (circa 300 B.C.E.)
includes 3 propositions about binocular vision.

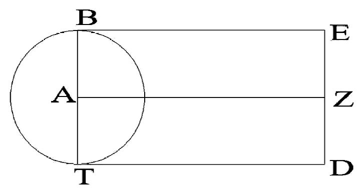


Figure 25.

When a sphere is seen by both eyes, if the diameter of the sphere is equal to the straight line marking the distance of the eyes from each other, the whole hemisphere will be seen.

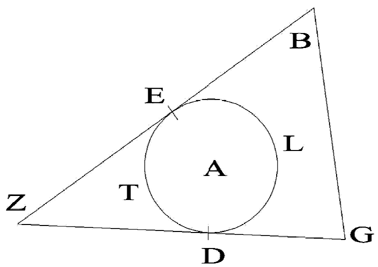


Figure 26.

If the distance between the eyes is greater than the diameter of the sphere, more than the hemisphere will be seen.

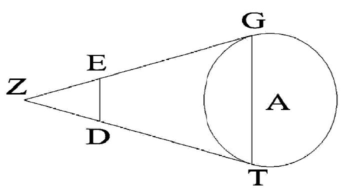


Figure 27.

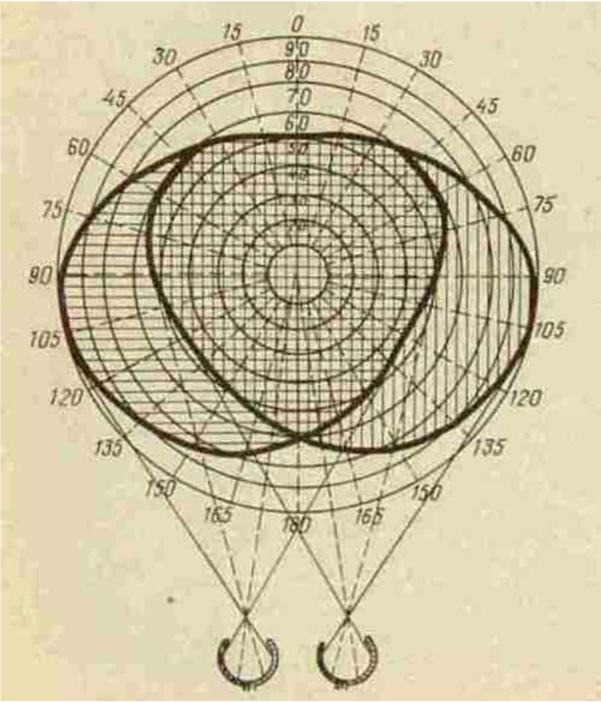
If the distance between the eyes is less than the diameter of the sphere, less than a hemisphere will be seen.

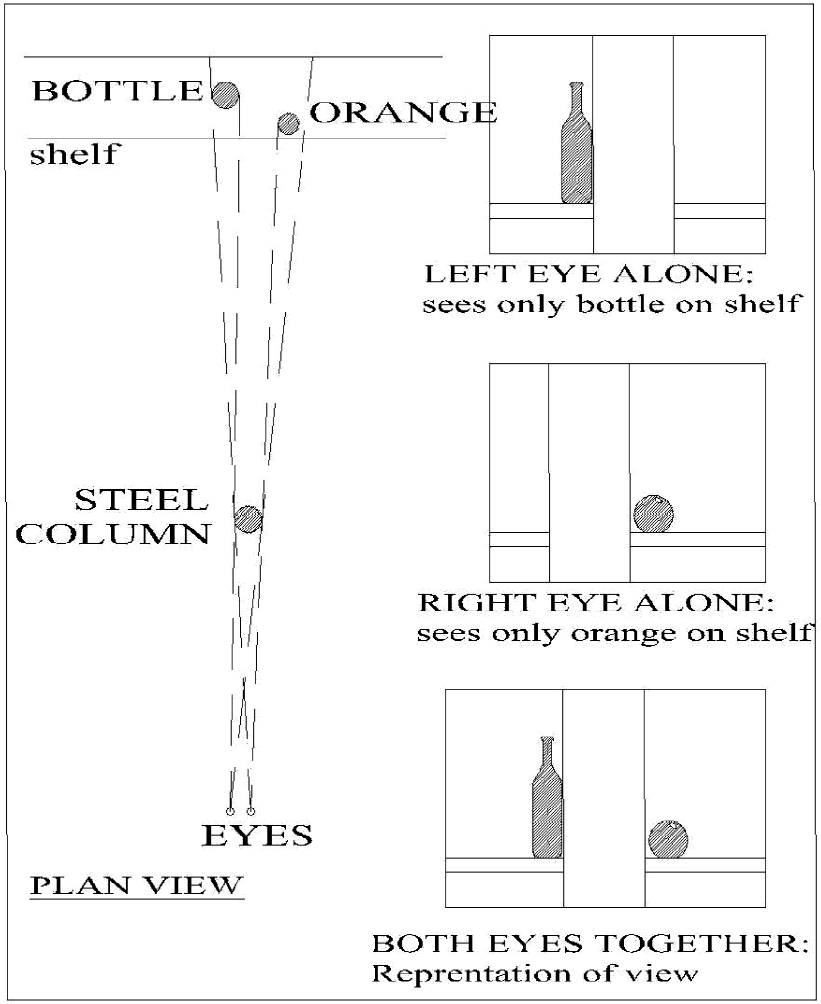
(Quoted without Proofs from 1945 translation by Harry Edwin Burton)

Stereoscopic Perspectives are a sub-group of Perspective illustrations in general.

Binocular vision is listed here as one of the ways eyesight differs from Perspective because stereoscopic views are relatively rarely seen.

To be technically accurate, we should say that a Stereoscopic Perspective (or a stereoscopic photograph) differs from binocular human eyesight, just as Perspective differs from eyesight in general, as throughout this work.

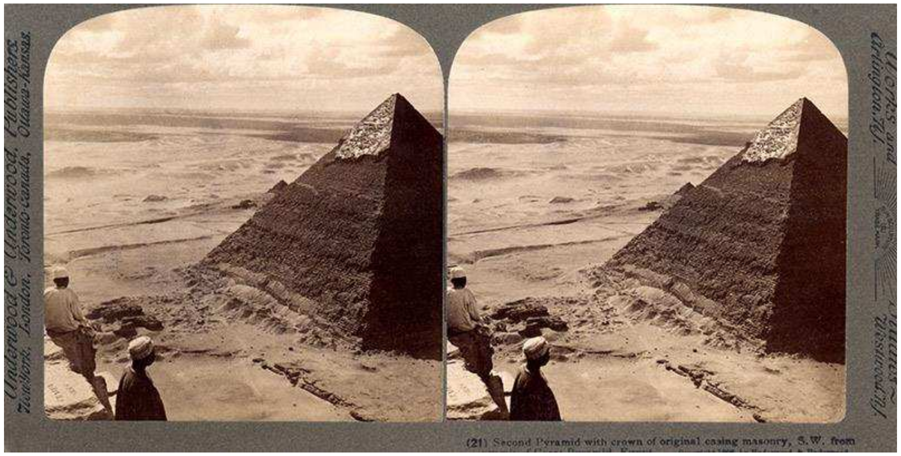




With binocular vision we see a little bit around things, and we see a little bit more of the side surfaces of nearby objects.

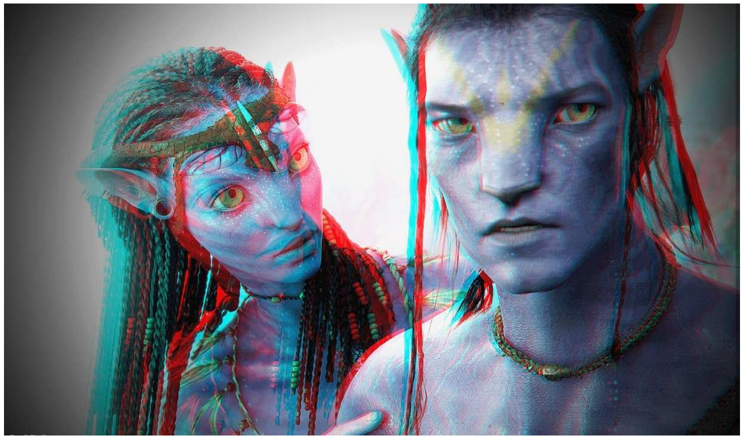
There is no way to squeeze all these "extra angles" into a single exact Perspective image. Binocular vision is different from any possible sort of single-surface picture plane view.

Binocular vision is two separate images somehow combined by the brain together into one (usually). We currently don't know how the brain does it, and does it so well (usually).

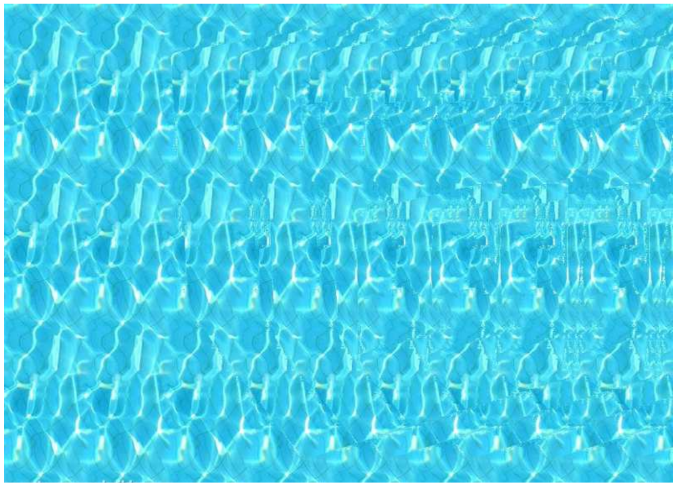


Stereoscopic photographs (and drawings) started being made many years ago. There are many different types of stereoscopic cameras and stereoscopic viewers.

Stereo-photos seem to have been even more popular at the end of the 19th century than they are today.



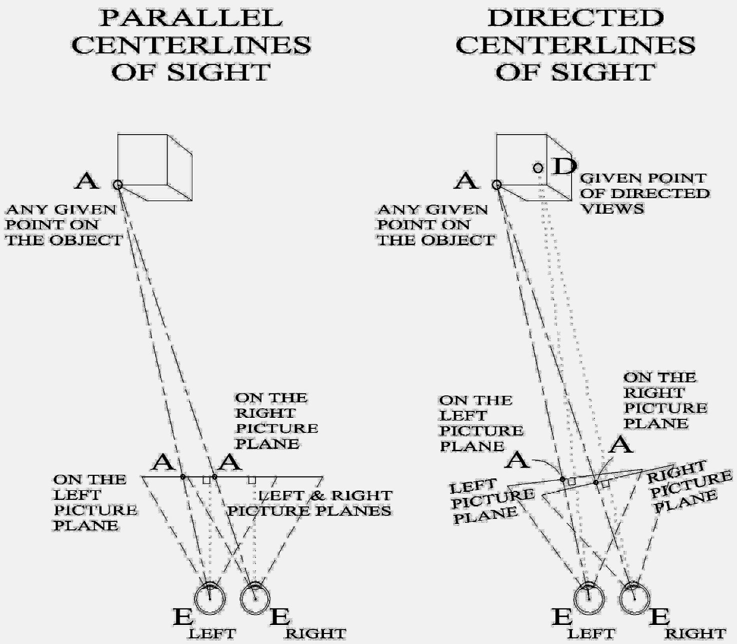
Stereoscopic movies started being made shortly after motion picture cameras were invented. Today there are many different types of stereoscopic movie cameras and stereoscopic movie-viewing ‘glasses’.



“*Magic Eye*” pictures can induce 3-dimensional images after a prolonged period of binocular gaze. *(Enlarge and stare into center.)*

Holograms are a whole new family of 3-dimensional images produced by various methods and various types of equipment.

Holograms were first invented in the 1960s, but are rarely seen today.



There are various geometric arrangements for drawing Stereoscopic Perspectives. Various centerpoints of may be used for rotations.

Furthermore, separate spherical picture-planes might be constructed for each Eye, using various flattening geometries of Curvilinear mappings.

Stereoscopic Perspectives are a family of methods, employing various rotations, and distances, of picture-planes, etc.

I must confess that I have never spent much time studying the mathematical methods of simulated stereoscopic vision, nor do I understand the problems and possibilities of Hologram imagery. Stereoscopic pictures are indeed 3-dimensional views and I always enjoy studying them; yet (to my eye at least) none of them is completely successful. The photos have a way of failing to portray the “roundness” of nearby objects, tending instead to flatten objects -- a series of overlapping flat planes. For some reason the *“Magic Eye”* images come across (to me at least) with more “roundness”.

Stereoscopic photographs have been around far longer than motion pictures, but their popularity seems to be decreasing, rather than expanding. Similarly, holograms have been produced for more than fifty years, but have failed to replace standard, or stereoscopic, Perspective views.

In conclusion, considering Binocular Vision, we may see that Perspective illustration is not a completely realistic simulation of human eyesight-- it is not even the most advanced simulation now available; still, it remains our dominate model. Technical economies make other methods more expensive and cumbersome, and their added features are apparently not worth the extra effort. In the end it is the mental imagination inside the brain that carries an image across the bridge to believability. Extra effects are unnecessary – internal imagination completes our vision.

1d. Motion
(and the "*persistence of vision*")

Perspective, in its basic format, neglects *Time*.

In normal human eyesight, everything is in motion, and even slight dislocation will alter views.

The invention of motion picture cameras introduced Perspective images that move. A series of stationary Perspectives, seen in rapid succession, simulates moving eyesight. You might easily imagine your eyes as a *movie*-camera.

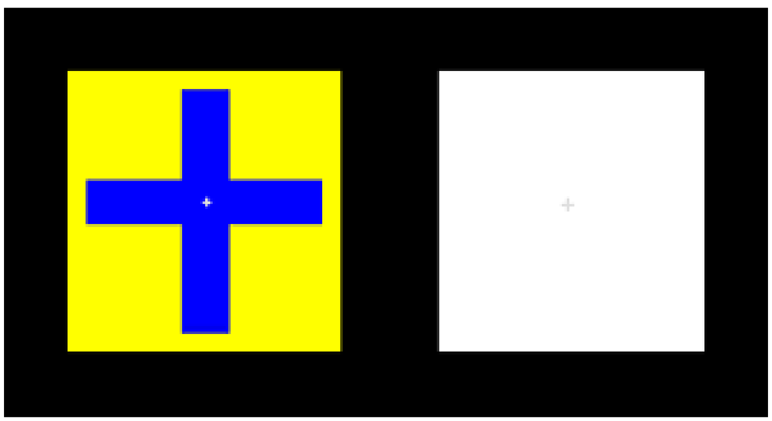
But as with static Perspective, *movies* differ from eyesight. Firstly, eyesight is somehow coordinated with physical sensations of motion. Fast changing human views seen racing through a house easily become a jumpy and incomprehensible confusion when seen as a similar *movie*.

A whole book could dwell on this topic alone. I am not experienced in making *movies*, so (with an abrupt hiccup) I now skip on, leaving expansion of this vast topic to others.

There is a natural "speed limit" to the biological mechanisms of human eyesight, often summarized in the expression '*persistence of vision*".

When the separate images of a *movie* film strip are seen in fast succession, they merge into a seemingly continuous moving picture. An entertaining magician can perform fast movements of hands which are invisible to normal eyesight – "*the hand is quicker than the eye*". When our human eyes periodically *blink* shut, we hardly notice the interruption to our view.

The bio-chemical reactions of eyesight may also be temporarily sustained after staring – producing short-lived "after images".



Look at the **+** *in the middle of the blue figure above for 15-30 seconds.*
Then look at the tiny **+** *in the center of the* ***white square*** *on the right.*

Perspective theory predicts none of the time effects of eyesight.

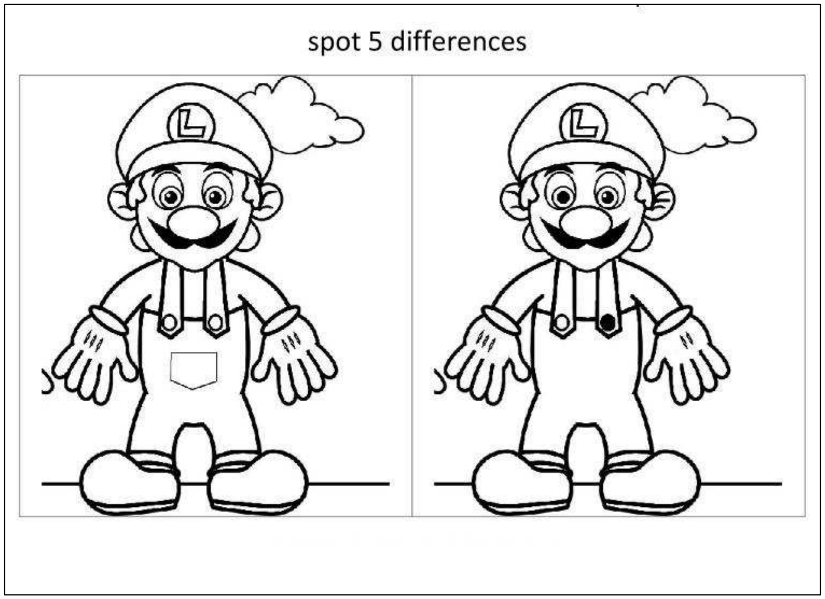
Perspectives (photographs) can be engineered to show effects of time not visible to human eyes.

Action too fast for a human eye to see can be frozen in a Perspective picture (such as this high-speed photography).

Views from various different moments in time can be compiled together into a single Perspective image.

1e. Reduction of Detail

(Detail is selectively filtered by eyesight and by Perspective)

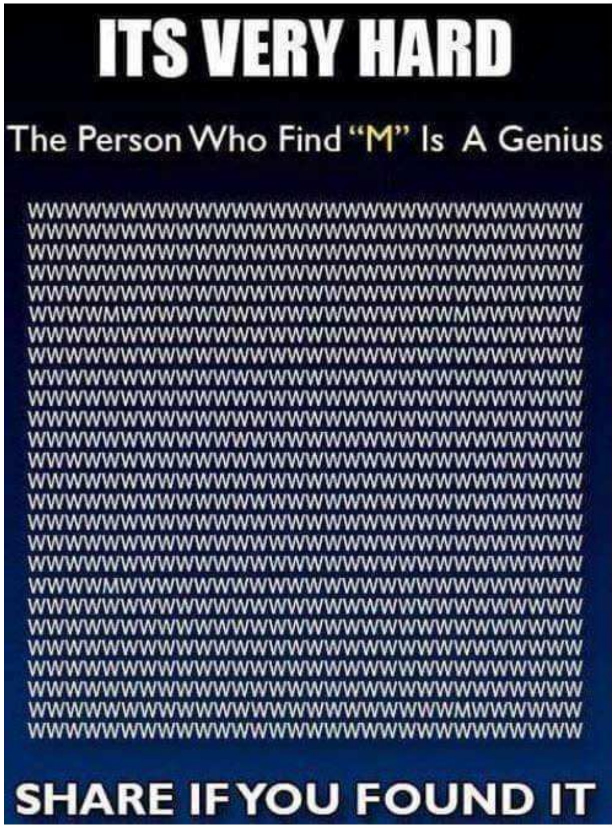


Eyesight fails to see details that are plainly within view.
There is nothing in Perspective theory to predict this.

The range of detail in Perspective images is often less acute than human vision; but, inversely, specific detail aspects of a Perspective image may be enhanced to supersede the capacities of normal human eyesight.

Everyone has had the experience of failing to see an object sitting in open view, but obscured by surrounding clutter. Your shoes disappear in your cluttered bedroom; your hammer becomes invisible on top of your workbench.

Two thousand years ago the ancient Greek philosophers accounted for this basic feature of human eyesight by theorizing that a finite number of 'light rays' emanated outward from a person's eyes. Until the sweeping light rays touched the object ("felt it"), it was not seen. We have abandoned this theory -- now we can no longer explain why details are not being seen.



We might think we see everything in our eye's field of view, but we really cannot.

Find six differences between the two pictures of Sam, Katie and Spike at the beach

From these "Spot the Difference" picture games, I can accept two generalized principles:

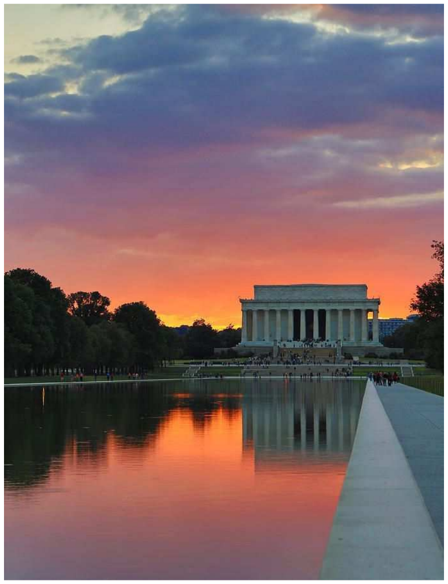
1. **Human eyesight occurs simultaneously on different mental "levels"** – at the same moment our retinas see a detail at one level, our brains do not see the detail at another level.

2. **Eyesight is a series of different mental activities at different times**, instead of one single mode of mental activity. Eyesight changes. Eyesight can learn, and eyesight can forget.

There is second version to this *Reduction* idea. Quite different, it goes like this:

There is a reduction of detail within any Perspective picture. Instead of the temporary mental reduction of recognition, this is a physical reduction within the image.

This reduction is not a part of the theory of Perspective, but it becomes a practical necessity because of the technologies of rendering a Perspective picture.

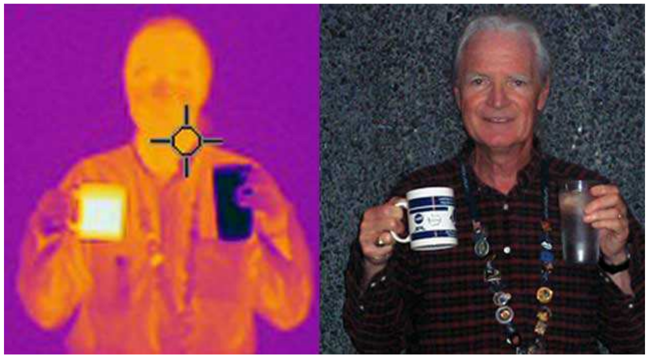


A photograph of a sunset may be pretty, but it fails to capture the rich range of color that our eyes experience when seeing the real thing. Our eyes have greater sensitive to color, and are able to adjust for more subtle nuances of light, than the technologies most of our photographs are able to mimic.

Perspective pictures typically reduce the number of sight lines.

On the other hand, we can adapt Perspective illustrations to specialize in details that the biology of our eyes cannot see – such as X-ray pictures, or heat sensitive images of Infra-Red radiation. A Perspective can also illustrate sight lines other than photons of light.

Perspective imagery: X-ray vision



Perspective imagery: Infra-Red picture of heat

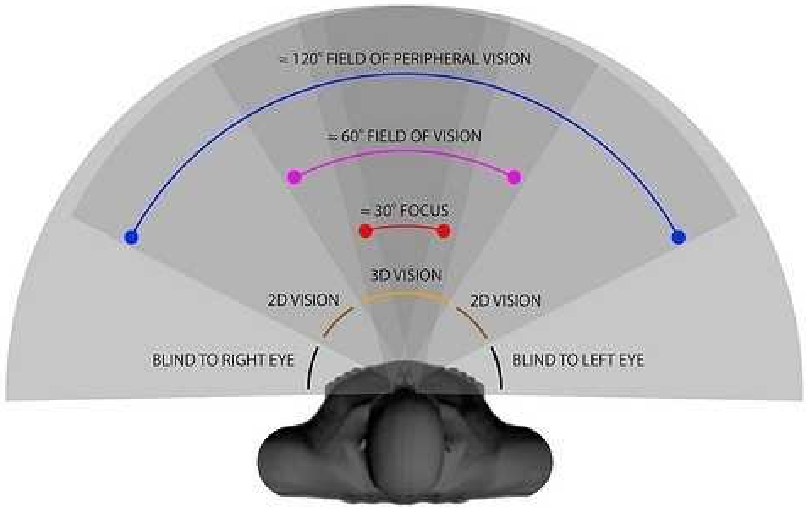
By specializing the detail of our Perspective illustration we are able to create pictures of things our eyes alone could never see. Such specialized details might be physically real, abstractly theoretical data, or purely imaginary.

1f. Wide-Angle Views
(Do straight lines always appear straight?)

Rickstraw Downes – photo by Morgan Taylor -- 2018

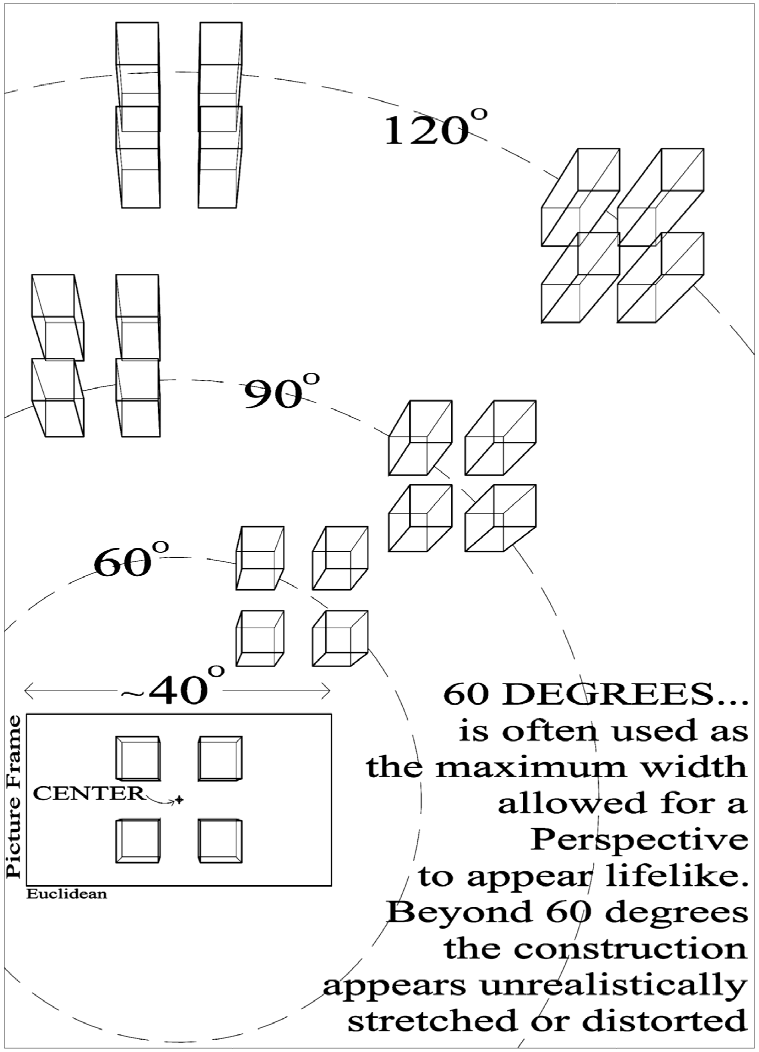
Perspective illustrations only appear visually realistic in views spanning less than 60° (approximately).

Normal human eyesight, on the other hand, spans a far greater width. A fixed human gaze encompasses approximately 180 degrees (without eyeballs moving or head rotating).

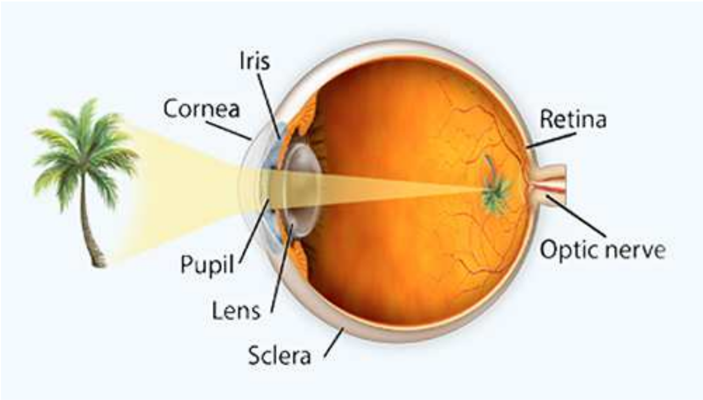


A human eye's light receptive cells are more numerous (more densely packed together) at the center of view; and our vision gets fuzzier and less distinct toward the outer limits.

Holding a straight-ahead fixed gaze, stretch your arms out, and wiggle a finger on each side (motion is more easily detected at the far limits). Your angle of view will span 180 degrees or slightly more (depending on lighting conditions and your individual eyesight).



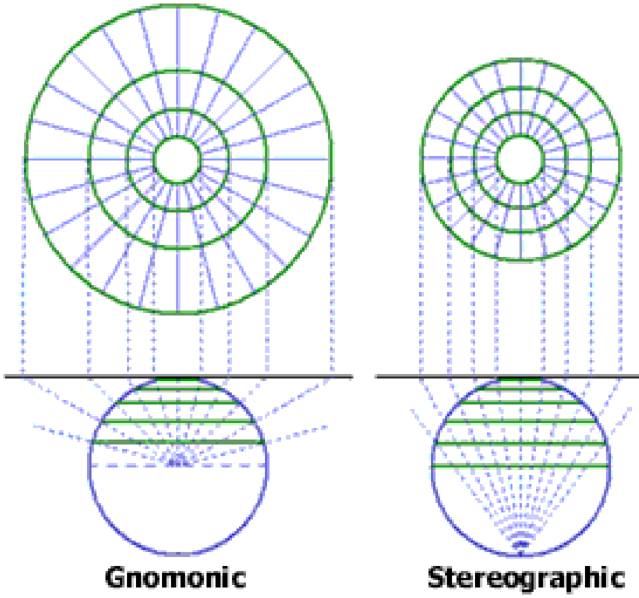
The usual explanation for this Perspective limitation goes like this:



Our retinas are approximately a sphere in shape. Trying to flatten the curving retinal images is like trying to flatten a map of the surface of a spherical Earth.

Perspective uses the same geometry as the globe mapping system called "*gnomonic projection*".

Just as *Gnomonic Projection* produces greater and greater map distortions as the encompassing angle widens, *Perspective* also produces greater and greater visual distortions as the angle of view departs farther from perpendicular center.



It might seem that a *Stereographic Projection* mapping geometry might be a closer match to the geometry of a human eye and might provide a more realistic illustration -- but it does not.

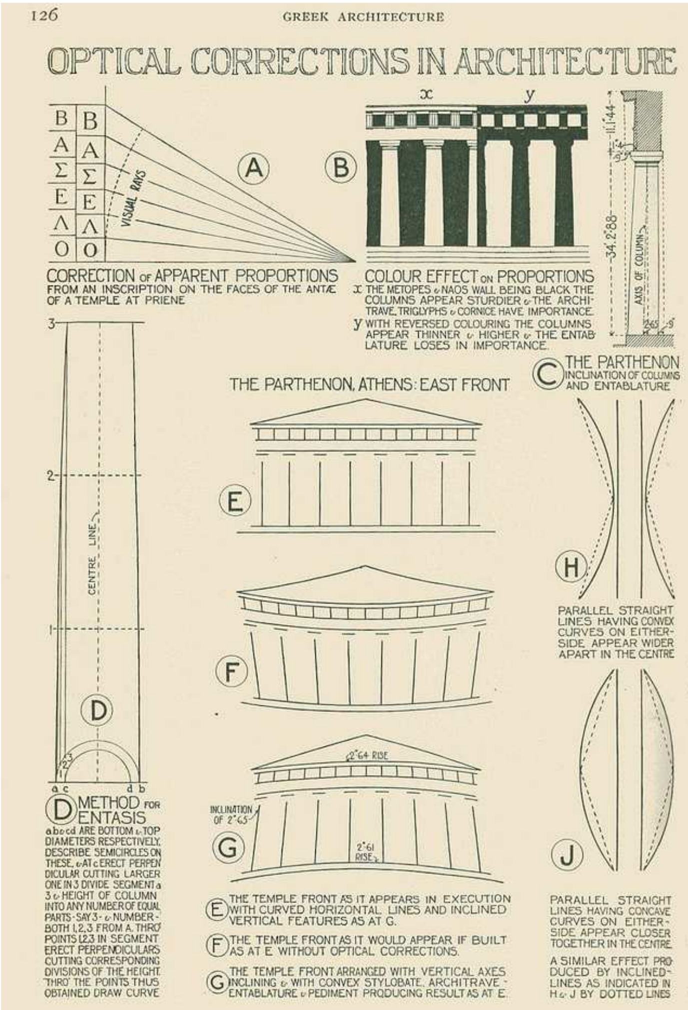
In photography, there are all sorts of different “wide angle” lenses with views wider than 60 degrees, including 360 degree images …

… but with every wide angle photographic lenses, some straight lines will invariably appear as curves …

… or the picture image bcomes visually distorted, as it does when Perspective views exceed approximately 60 degrees.

As with drawing flat maps of a spherical Earth, there are innumerable possible geometrical methods for drawing flat pictures of wide angles views.

As of this writing, there is no general consensus of opinion as to which method is best, or most realistic. A lot of the discussion revolves around whether straight lines appear as curves to the human eye; and, if so, exactly what are the shapes of the curves. It is an ancient problem **--** perhaps there is no single correct answer.



page from Sir Bannister Fletcher's — "A History of Architecture"

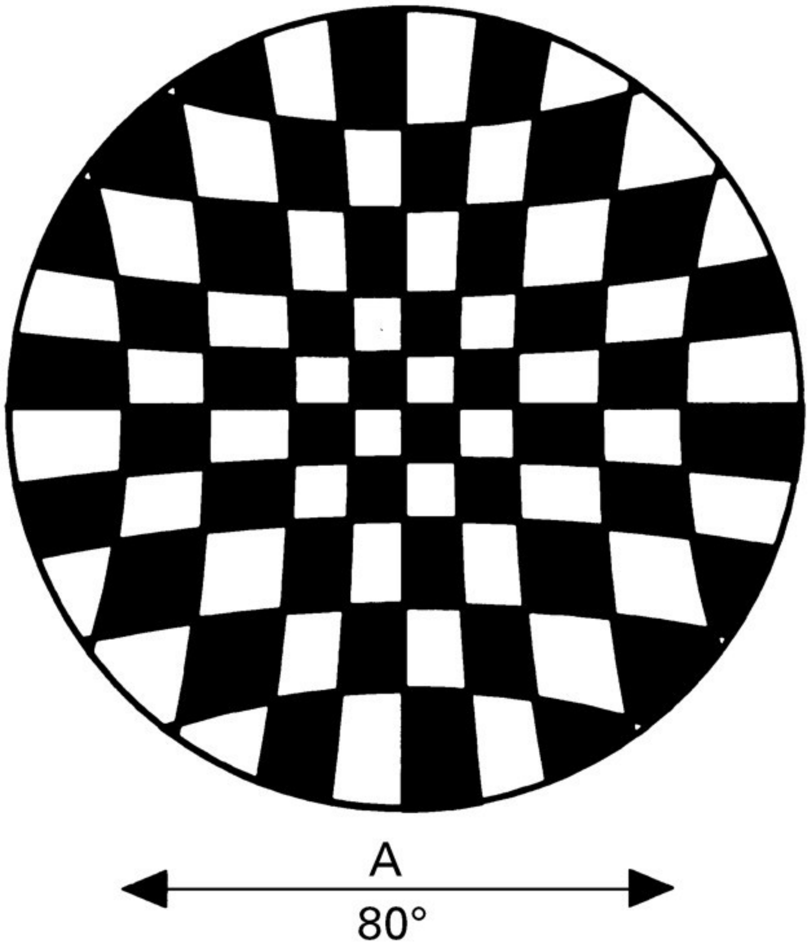
Discussion about straight lines appearing as subtle curves (and curved lines appearing absolutely straight) goes back (at least) to the time of the design of the classic Parthenon in Athens (~447-431 BCE). It is interesting to note that Perspective geometry was invented by the ancient Greeks at approximately that same time, in that same city of Athens.

About a century later, during the Hellenistic age, geometer Euclid, in his book on *Optics,* carefully avoids stating that straight lines will appear to the eye as straight.

The literature about this ancient discussion has been almost entirely lost. Such scant evidence remains today that it is hard to reach any conclusion about the original understanding or intent of the ancient Greeks. I would caution future students to be wary of already existing confusion between *optical corrections* and *optical refinements.* Use your own eyes.

Dr. Kim Veltman has followed the long discussion about *Curvilinear Perspective* (straight lines appearing as curves). He has compiled a large bibliography of literature about the long and winding history of this interesting topic.

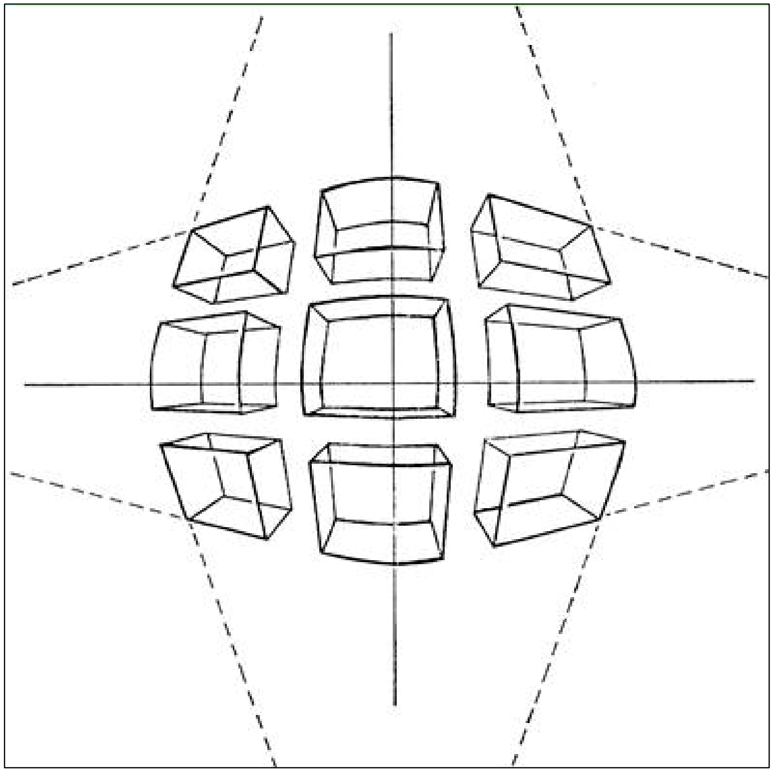
Helmholtz's checkerboard



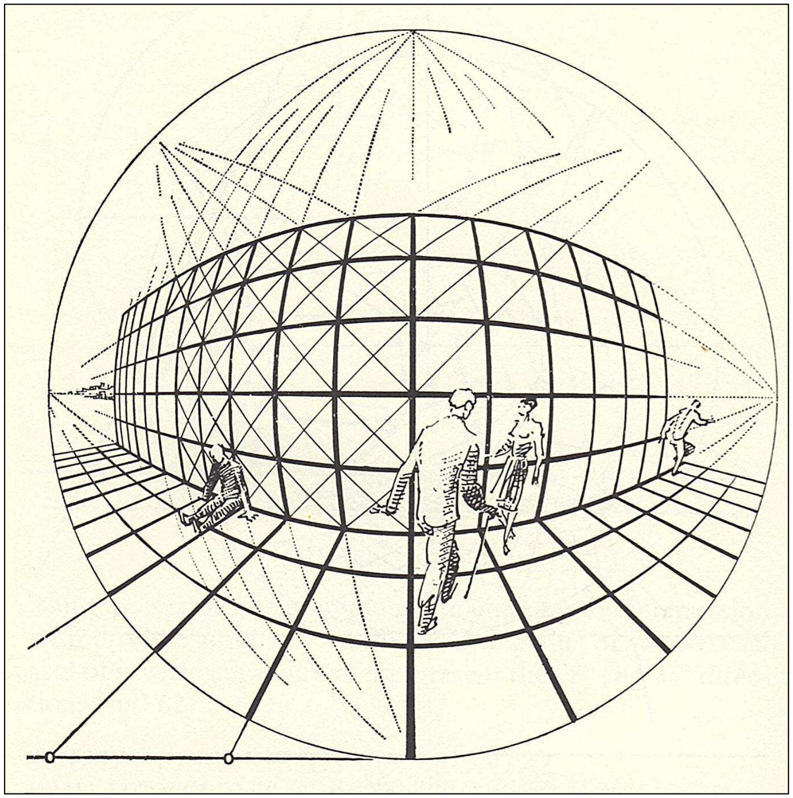
Set one open eye close to the center of checkerboard, such that approximately 80 degrees in your field of view spans the distance included in arrow "A".

During the 19th century the great German scientist Hermann von Helmholtz published a series of studies about eyesight including this checkerboard experiment. At very close range (with the checkerboard almost filling their entire field of view) typical observers will report seeing the curving checkerboard take on a strictly straight-line rectilinear appearance.

During the late 20th century artist Robert Hansen proposed that straight lines appear as hyperbolic curves.



Robert Hansen: "This Curving World: Hyperbolic Linear Perspective"; Journal of Aesthetics and Art Criticism, 32/2 (1973)



André Barre and Albert Flocon; "La Perspective Curviligne" (1968),
translated as "Curvilinear Perspective: From Visual Space to the Constructed Image" (1987).

A few years later Hansen helped translate *Curvilinear Perspective*, the best book yet written (in my opinion) about rendering views of wide-angle fields, by French art academicians Flocon and Barre.

What do you see with your own eyes?

There is the simple experiment of standing in front a long flat wall, to study the geometric appearance of the straight edges along its top and bottom, stretching out on each side.

In these attempts to describe wide angle eyesight as a flat picture image, the precise position of the *centerline of view* (the *direction of gaze*) becomes significant.

I would propose that there are (at least) three different methods of looking at the long straight edges of the flat wall:

a. I fix my *direction of gaze* at eye level, and consider how the straight edges appear in my peripheral view.

   Often I see the straight edges curving in the periphery of my view, but those curves are rather indistinct. At other times I cannot see any noticeable curvature.

b. I rotate my eyeballs, while holding my head still.

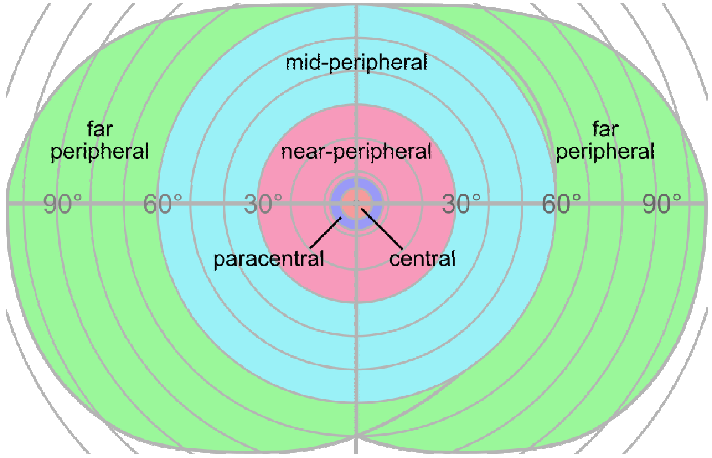
   And therein resides a possible contradiction: As I move the center of the gaze up and down, the geometry of the image does not appear to be flexing – or it changes only slightly, in a fuzzy manner, at the periphery of my view. This would seem to contradict the theoretical diagrams of Hansen, Leonardo, and Flocon and Barre. Their curves should visibly flex as the observers' gaze was being rotated.

c. Finally I rotate my head freely (keeping my shoulders stationary).

   For me the image changes and the straight lines at the top of the bottom of the long flat wall "seesaw" up and down.

It is my suspicion (m hypothesis) that my eyesight has more than one geometry, especially in its outer periphery.

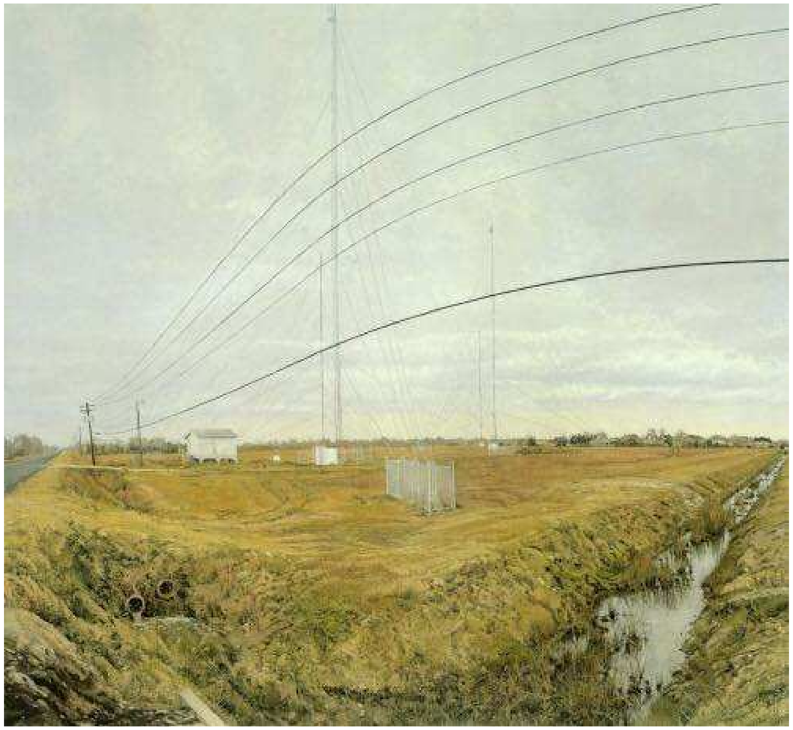
When I look at the Helmhotz *checkerboard* I can readily see straight lines appear where there are curves. But standing close to a flat wall, looking up at its straight top and bottom, I can both see the hyperbolic curves of Hansen's curvilinear perspective while, a moment later, I can feel my mind thinking (re-constructing) "straight line/ flat wall". My peripheral sight seems indefinite.



It seems to me that there is a strong human preference for pictures in which straight edges are portrayed as straight lines; and the unresolved question:"*Do straight lines appear straight?*" somehow contains a key ingredient to understanding the success of the Perspective illustration principle.

Separate chapters will discuss: distortion inside the 60^o cone of vision, and possibilities for creating realistic wide angle views in art.

Conclusion: The Perspective geometric method is only valid as a realistic simulation of human eyesight within an approximately 60 degree wide cone of vision (the pink area of this diagram). A normal field of view extends far beyond that 60 degree limit, but we have no single precise universally-accepted method of predicting, or simulating, its optical appearance.



Rickstraw Downes – photo via Morgan Taylor -- 2018

Aside: Starting in the mid-20th century there were a series of academic papers in the field of *Perceptual Psychology* (A.A. Blank- 1961; J.M. Foley- 1964; T. Indow; 1967; R. French- 1987; P. Suppes; 1977; etc.) which attempt to explain wide-angle eyesight in terms of Non-Euclidean Geometry. In my opinion this approach is without any valid understanding of Non-Euclidean Geometry -- it is a dead-end in the exploration of the understanding of wide angle human vision. A fuller explanation of this confusion is given after the conclusion of this volume, in the "***Appendix 1: A Confusion of Similarities***".