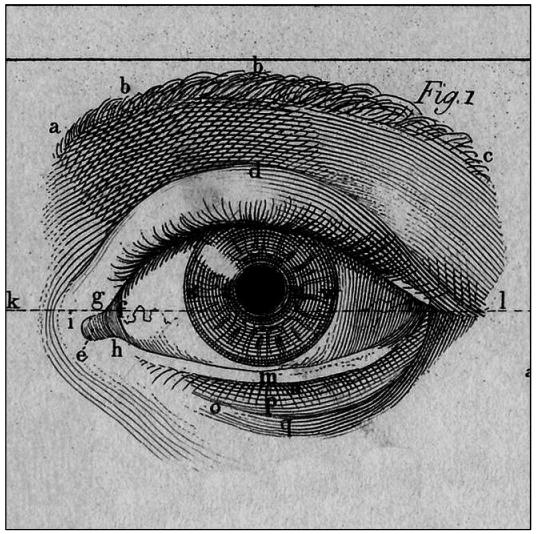
How Eyesight differs from Perspective

Comments about Eyesight by a Perspective Theorist



James David Barnes
2019

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M.C. Escher – 1957 – "Regular Division of the Plane: III"

- **Perspective is an exact simulation of human eyesight.**
- **Perspective is not an exact simulation of human eyesight.**

The goal of this book is to explain why both of these statements are true – and why both should be accepted as good and necessary ideas.

Paradoxical as they might superficially sound, both principles underpin future progress in Science and Fine Art.

The apparent contradiction seems to be a problem of finding a short expression – a failure of our contemporary language-- a lack of concise thought.

Attempts to mash the ideas into a compromise (such as: "*Perspective is a general approximation of eyesight, but not a complete model*") tend to complicate users' understanding without ever providing the '*complete model*' implied (and without ever proving that there ever will be a "complete model"). We lack precise terminology because we lack precise knowledge.

In the following pages I will try to enunciate unanswered questions about eyesight and Perspective, in the hope that the future may someday find a better mode of expressing the principles of human eyesight.

Perspective is like a giant highway interchange, with various streams of thought passing through in various directions.

Many different programs of research and practice employ *Perspective*, or are developing new applications of *Perspective*. It is difficult, if not impossible, to survey the entire literature.

I have recently spent several years reading about eyesight in *Perceptual Psychology*. I do not want this book to try to be a critique of that literature, whose various theories I neither grasp firmly, nor am able to recite precisely. I have read almost none of the literature of medical *Ophthalmology* (the Physiology of the Eye) nor of *Neurology* (the functioning of the brain). There is a great deal of research underway, and still more ahead.

But I have read a lot about *Perspective*, and grasp enough *Geometry*, to hope that this book may give insight into the problems – to leave a record of how they appear (at least to me) at this time.

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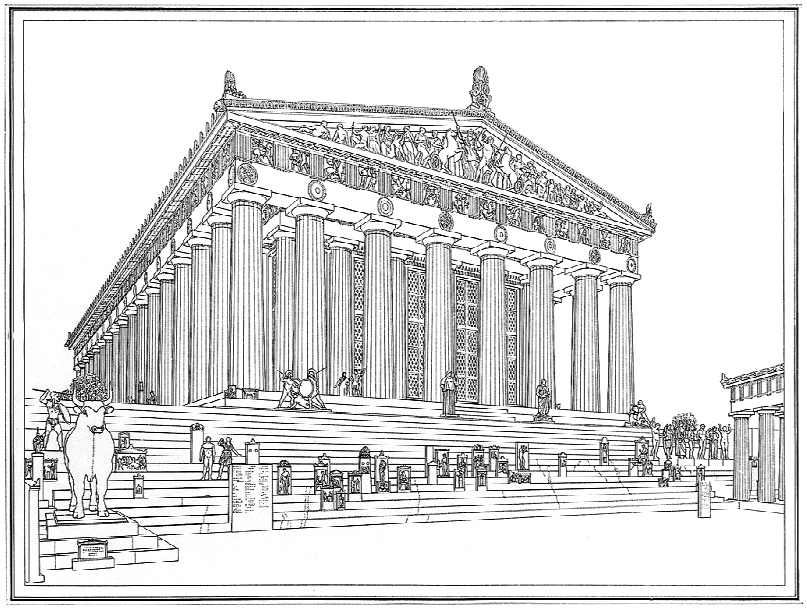
Definition of "*Perspective*"

(a point, some lines, and a plane)



Restored perspective drawing of the Parthenon by G.P. Stevens

In our everyday language "*Perspective*" is a word having several different meanings. One reads about "*a perspective on current politics*", or attends a lecture about Beethoven's symphonies considered "*from the perspective of 21st Century music.*" In these senses, *perspective* is a metaphor -- the idea of things being proportioned, and arranged for consideration from a unique 'point of view'. Such poetic metaphors allude to the much older optical science of *Perspective*. In this book our definition will include none of these metaphorical uses of the word *perspective*; we are interested only in the optics.

Our definition:

***Perspective* is a geometrical method for deriving an exact simulation of human eyesight.**

In this optical sense we nowadays tend to use *Perspective* to describe a method of drawing, rather than the complete science of Optics or the full medical study of eyesight (ophthalmology); nevertheless, *Perspective* still serves as our mathematical model of basic vision, our scientific definition of a "standard observer". It predicts and describes the order of views.

Perspective is a simple scientific theory; and relatively easy to understand.

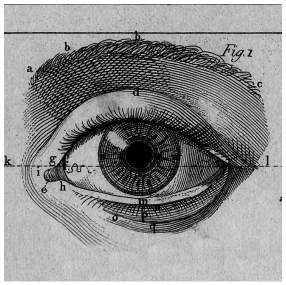
Perspective employs a single **point** in space (the "Eye" of the observer) and an array of **lines** (" sight lines") between the Eye and every object being viewed. To produce a visual image we insert a **plane** (a "picture plane") into the path of the sight lines, between the Eye and the objects being viewed.

That is all there is to it. You now know all about Perspective -- in one sense. Digging deeper we may find subtle shades of meaning to each term – which I would now like to try to explain. As we try to impose stricter definitions onto each term, we start to generate alternative meanings, and thereby create variations to Perspective. Perspective grows from a single method into a family of methods. Many of its variations are already well known to readers – "moving pictures" or "wide angle photos" – while other variations are relatively rarely seen, such as "stereoscopic views". I'm now going to try to sketch the entire *Perspective* family tree, branching out from its basic method. **The most commonly-used method will be our definition of *Perspective*, while the more complicated, or rarely used, versions will be given separate names.**

a Point

… a single arbitrary POINT in space … which we will call "the Eye"

Also, the *Eye* is sometimes called the "*Point of View*", the "*Vantage Point*", the "*Observer*", the "*Pinhole*" of a camera obscura, the "*Aperture*" of a photographic camera, the "*Oculus"*, or the "*View Point*".



That a human eye, both eyes working together, or an entire human body, could be reduced to a single geometric point is a fairly bold assumption.

We might consider human eyesight as having three modes:

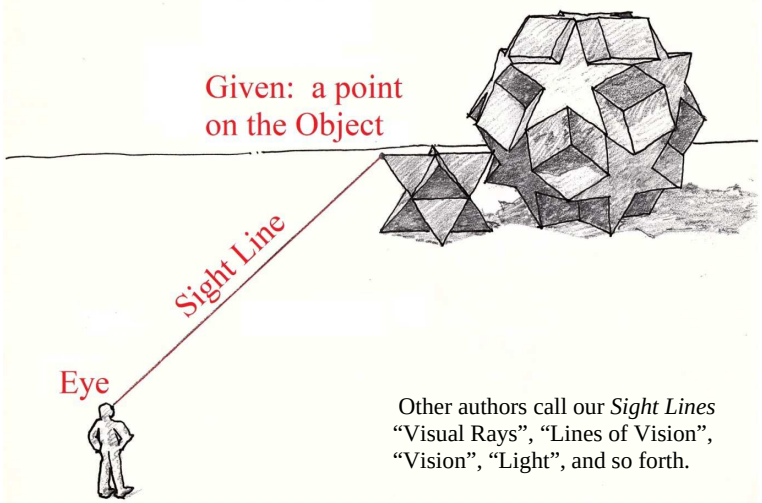
1. a **fixed gaze** in a single direction (the center of the field of view being called the "*direction of gaze*", or the "*central ray of vision*");
2. **rotating eyeballs**, the direction of gaze moving around while the head remains stationary; and
3. **the whole head rotating,** looking about in various directions.

In our theory of Perspective, such motions of the eyes or head make no difference. The Eye of Perspective is actually more like a theoretical peephole, a fixed point in space through which the observer may look in any direction using any of these three modes of sight.

For short, we simply call this point **the Eye**.

Lines

… one unique line exists between each point on an Object and the Eye … which we will call a "*Sight Line*".



Other authors call our *Sight Lines* "Visual Rays", "Lines of Vision", "Vision", "Light", and so forth.

Sight Lines are usually taken to be physical light (the path of light photons); but Perspective does not necessarily require photons. *Sight Lines* might also be surrogates for light -- electron particles, sound waves, magnetic flux—any particle or field variation. *Sight lines* may also be purely imaginary and completely fictional.

We usually assume that *Sight Lines* are perfectly straight lines. This seems so self-evident that it is used as a foundational assumption in Physics: light traveling through empty space is our standard gauge of straightness. But in non-standard versions of Perspective *Sight Lines* are not necessarily straight; and passing through extreme gravity, atmospheric refraction, or transparent lenses, *Sight Lines* might be curved.

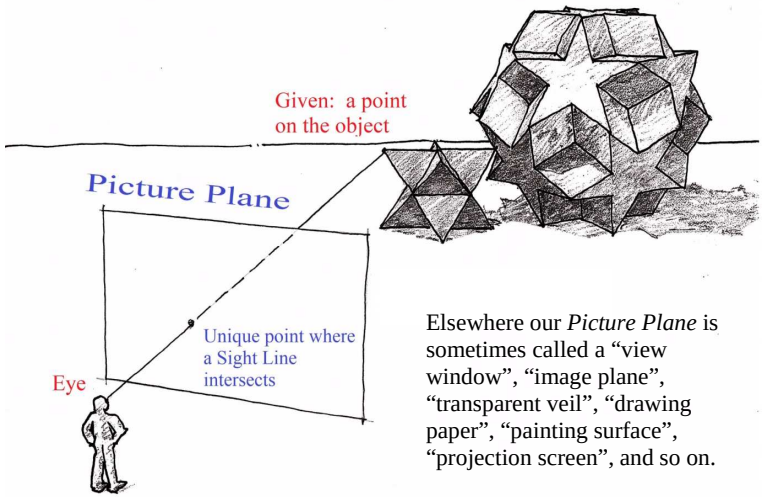
We usually organize the Eye and various *Sight Lines* into a system of angles using Euclidean Geometry; but Perspective works in all geometries -- including any Non-Euclidean spaces.

We usually let opaque objects nearer to the Eye block out *Sight Lines* from objects farther away (having the same angle with respect to the Eye); but sometimes we create Perspectives with "cut-away views", or transparencies revealing views, of otherwise covered objects.

As geometric vectors, *Sight Lines* may either travel in to, or out from, the Eye.

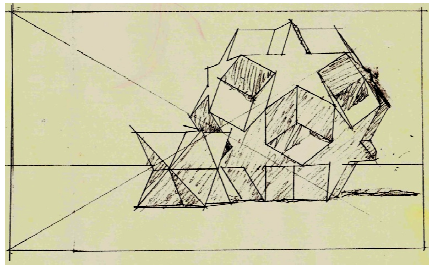
a Plane

… a flat PLANE is set in the path of the Sights Lines …which we will call the "Picture Plane"



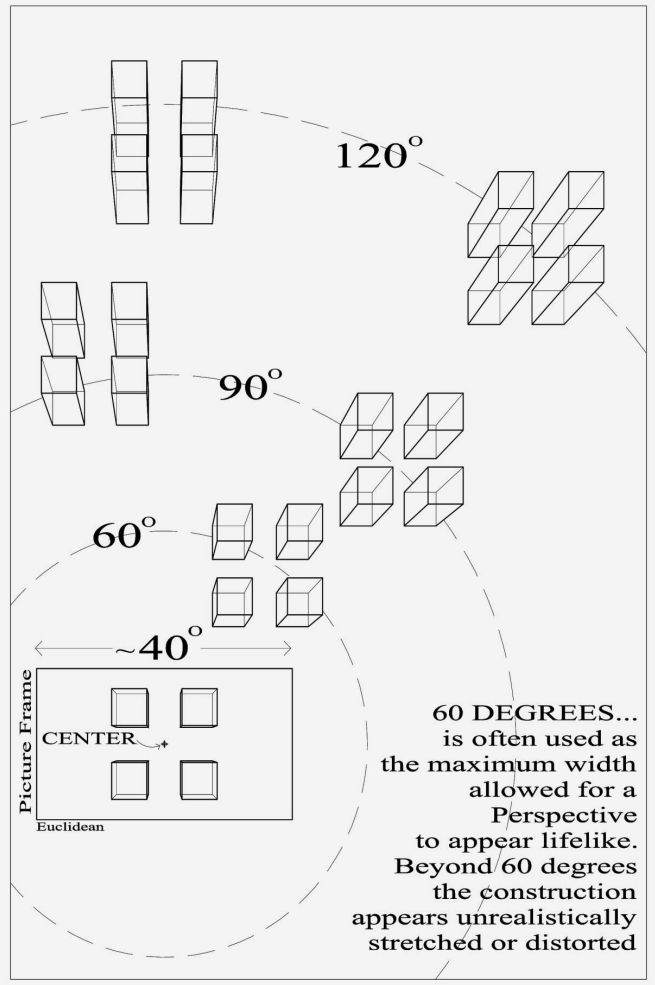
Elsewhere our *Picture Plane* is sometimes called a "view window", "image plane", "transparent veil", "drawing paper", "painting surface", "projection screen", and so on.

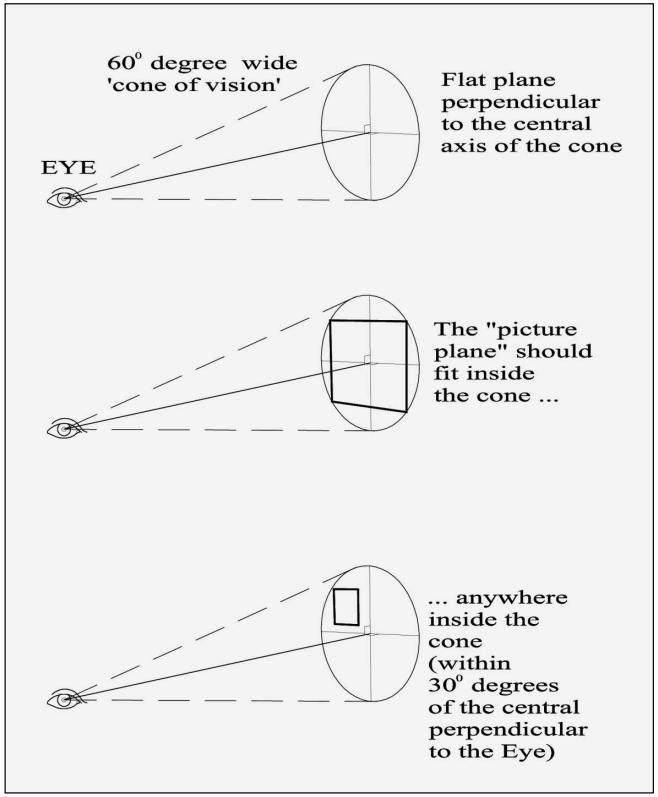
Where Sight Lines intersect the flat *Picture Plane* they create unique points which may be used in various ways to draw a picture (fabricate a visual image). The side of the *Picture Plane* facing toward the Eye is almost always the visual image used.



A *Picture Plane* may be established in innumerable ways -- at varying distances from the Eye, with variously shaped edges to its perimeter frame, its center shifted from side-to-side. Its surface may even be tilted – but only with a certain restricted limit …

… the limit of adjustments to a flat Picture Plane





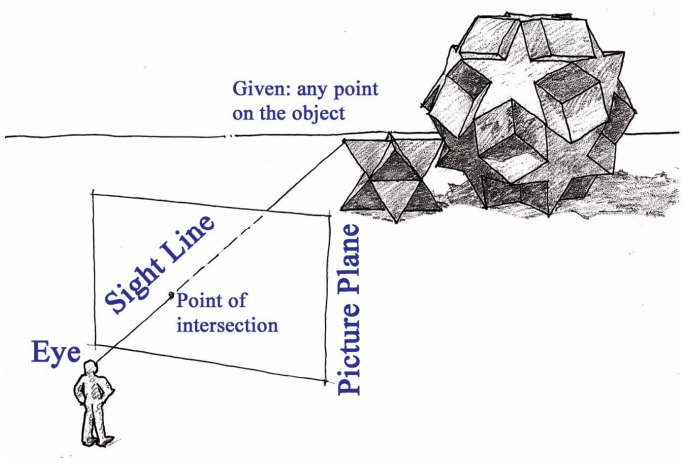
This rule of a 60 degree *cone of vision* limiting the veracity of a Perspective image is a somewhat arbitrarily chosen number -- a mere 'rule of thumb'. Ultimately artists needs to judge extreme cases with their own eyes.

Often the perpendicular from the Eye to the flat Picture Plane is considered as being concurrent with the observers' *direction of gaze* (their eyesight's center of view). Though generally Perspective seems to work best for them to be aligned together, these are two unrelated geometric ideas. Sometimes it is better for them to be separated in our considerations.

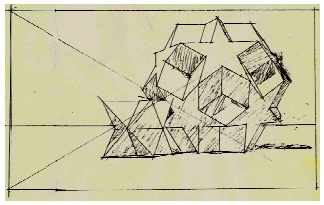
The image produced by a simple basic camera is equivalent to the image on a picture plane in Perspective

For a *Camera Obscura*, or a *Pinhole Photographic Camera*, the geometry of Point , Lines, and Plane are exactly the same, though the names of the components may differ. The Picture Plane is flipped over to the opposite side of the point Aperture.

So, while the Perspective format was like this:

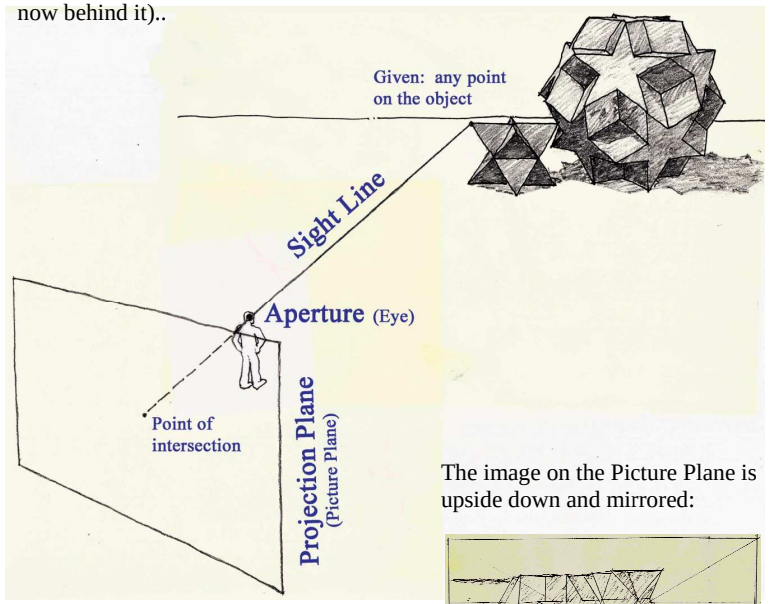


… with a resulting picture image appearing like this:

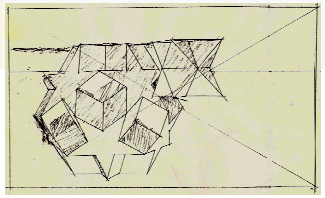


… the Camera format will be like this:

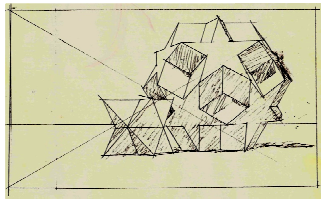
if the setup matches (is equal and symmetrical-- with the same sized Picture Plane, set at the same angle, at the same distance from the Aperture but now behind it)..



The image on the Picture Plane is upside down and mirrored:



When we "develop" the camera image (reverse it), it will be exactly the same as the Perspective image.



The basic theoretical camera's picture image is identical (fully equivalent) to the Perspective picture image; therefore **we may speak of their resulting views interchangeably** —as a single idea.

Variations:

The manner in which Perspective pictures might be rendered has endless variety.

The image may be only simple outlines, or fields of color without well defined edges.

The image may have no specific type of illumination, or may be illuminated by direct sunlight, moonlight, or any sort of artificial illumination (either direct or diffused).

Perspective images may be colorless or may be colored in any conceivable manner.

Atmospheric effect, secondary reflectance, and surface detail may be rendered in numerous different styles.

Edges and details may be rendered in sharply delineated focus, or blurred into a soft haze.

There is a long history of different geometric methods for deriving a precise Perspective geometry on the Picture Plane – there is no one single "correct" drawing procedure.

The possible range of scale for Perspective imagery is limitless-- from telescopic views of the farthest stars to microscopic views of the tiniest particle. (Adding the Heisenberg Uncertainty Principle we would amend that to: "…views of the next-to-tiniest particle.")

If we add an element of time to our Perspective construction then we start creating:

- "Time exposure" pictures, or "double exposures" images.
- Motion Picture methods (*Movies*) create a family of Perspective imagery wherein a series of discreet Perspective pictures seem to merge into a continuously moving image..
- at substantial fractions of the speed of light we may create *Relativisitic Perspectives*, where it becomes essential to define the precise timeframes of the various Perspective components.
- *Glide Projections* are a separate family of Perspective constructions where the position of the Eye or Picture Plane varies for different areas of the picture plane.

Quantum Perspectives are another separate family of Perspective constructions with a variety of different conventions, whereby molecular or atomic sized structures are pictured.

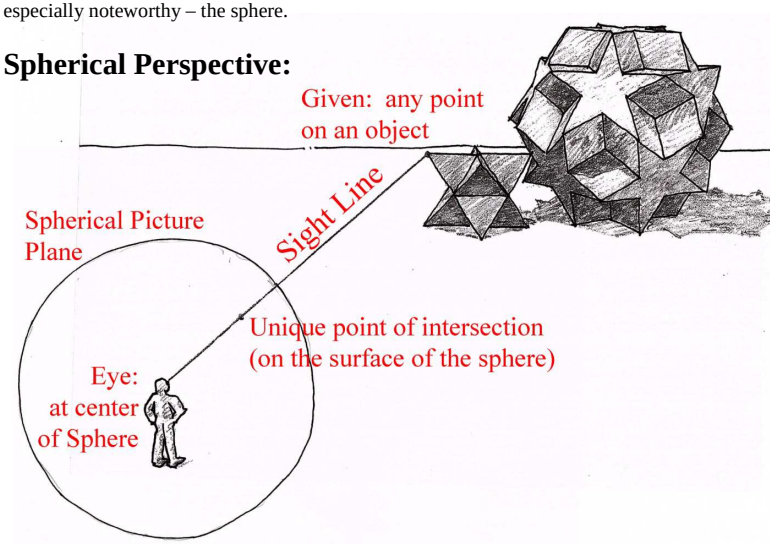
Stereoscopic pictures (3D movies) use two eyes to create binocular images.

Holograms process a series of Perspective views to create a three dimensional image.

Using non-photon instruments there are limitless possibilities for Perspective views made by Sonograms, Magnetic Resonance Imagery (MRI), Electron Microscopes, etc.

Though Perspective images are usually projected onto a flat Picture Plane, the image surface does not necessarily have to be flat – it might have any form. One alternative geometry is especially noteworthy – the sphere.

Spherical Perspective:



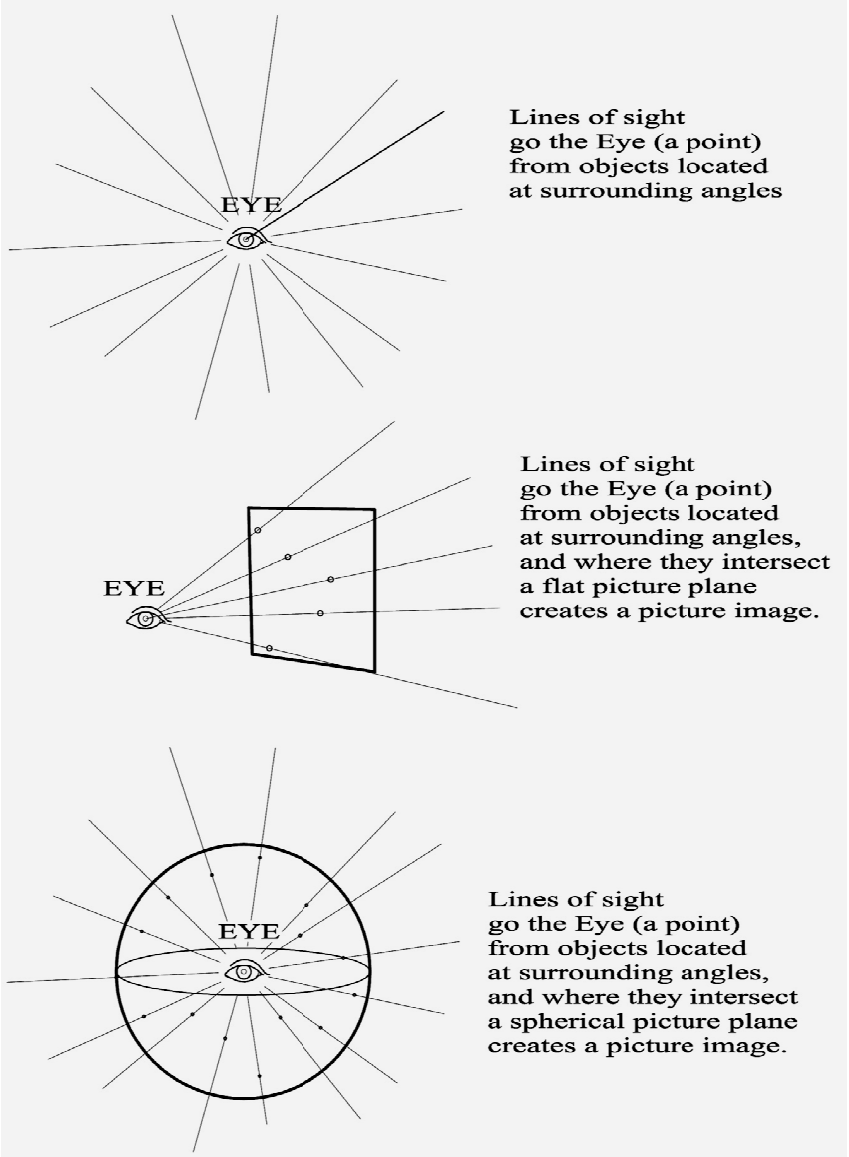
In Spherical Perspective (or a Spherical Camera) we set the Eye (or Aperture) at the center of a regular sphere (of any radius). Where a Sight Line intersects the surface of the sphere is the unique location for the corrsponding point of the image for any given object being seen.

The Spherical Camera avoids any limit to the width of view being considered.

Spherical Perspective provides a faster and simpler calculation model for mathematicians.

But to transfer the image of a Spherical Perspective onto a flat surface requires additional work. There are innumeral possible geometric methods for flattening. The image on the surface of the sphere might be flattened by any of the procedures which cartograhers use to draw flat maps illustrating the surface of the Earth. The usual flat Picture Plane method of our usual Perspective method is what cartographers call an *Azimuthal Gnomonic Projection*. For usual conditions, of all the possible flattening procedures it alone renders every straight line of any object array as straight lines on the flat picture surface -- which turns out to be a most significant feature (for reasons which have long been somewhat controversial and are not presently understood.)

"Curvilinear Perspective" is another name -- I prefer "Spherical Perspective".



1. Vision can be described by a point (the Eye) and lines (Sight Lines) arranged at various angles. This alone provides us with a simplest theory of *vision*.

2. In order to describe eyesight as a picture, or as a two-dimensional image, we need to insert a surface on which the picture may reside. The simplest and most enduringly popular version is to insert a flat picture plane – a transparent window – into the path of our Sight Lines, on which the visual image is said to reside. Such images are deemed valid within a 60 degree wide cone of vision. **Under usual conditions, this is our Perspective format, our standard definition of the term *Perspective*.**

3. We may substitute a regular spherical surface with the Eye at its center. We call this system, and all its derivative flattened picture images, *Spherical Perspective*.

I have long wondered which of these models should be deemed *basic science*, and which should be categorized as secondary *technology*. In practice there seems to be no animal vision without a retinal picture plane, but nowhere do retinas grow as perfectly flat planes or regularly spheres. The most prevalently used model is the Perspective picture window view (the basic photograph); but I accept all three as valid models for the eyesight of a scientific observer.

In the past I have tried to equate Perspective pictures with retinal eyesight – terminology which is useful but ultimately confounding -- I've stopped trying to use it. It is helpful in the beginning of our understanding of eyesight to think of the eyeball as a camera obscura, but as our understanding of eyesight increases that model breaks down – as the remainder of this book will try to explain.

But in all these considerations there are always economies of technology and economies to the viability of our theoretical modeling. It is the thesis of this book that despite an increasingly complex understanding of human eyesight, that Perspective will endure as the most used theory of vision – because it is the simplest and easiest to employ and because it provides most of the answers to our questions about the order views.

Having now defined Perspective, let us consider how it differs from eyesight.