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DIVERSION OF FORCE

By

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I intend to complete a body of work using the concept of diversion of force as a departure point.

A paper which will include the organic and inorganic scientific references which have affected my thinking and visual imagery will accompany and support the studio work. Other sources which have aided my exploration of the subject will also appear in the written presentation.
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INTRODUCTION

Whether it is observed for the marvelous effects that it can create in our daily lives, dissected to ascertain the process that cause its actions, or represented visually in an attempt to freeze and preserve one aspect of its transient manifestations, light remains an integral part of all life. Light is an energy which causes motion and change and is an entity which causes that sensation which stimulates us to constantly challenge and alter our perceptions. It is a force that effects every facet of existence.

Since light is such an all-pervasive aspect of life as we know it, the fact that it has captured for centuries the interest and imagination of scholars, scientists, and artists is of little wonder. Efforts to represent, analyze, and explain light have filled canvases, pedestals, and volumes. And yet, while modern science and technology have been able to hypothesize, theorize, and in some instances prove the existence of some attributes of light, only theories remain which attempt to define the true nature of light despite centuries of research and a multitude of discarded answers. So the investigation continues. Light as an element of art has also undergone scrutiny and transition and continues still to be a vital factor in visual expression.

Everyone who is captivated by the effects of light may perceive it in different ways. My personal view of light is that light is a force, invisible yet powerful. However, unlike most forces which respond to opposition with destruction, light is enhanced when it encounters a barrier, for only then can it be detected by human visual apparatus.
Only when it is diverted from its original path does light reveal its existence and perform its wonders.

When I first became aware of my interest in light I became anxious to discover exactly what light was, how it worked, and the role it played in my chosen area of concentration, art. For these reasons this paper is presented in two parts. The first part is a brief survey of the history of light in those areas of human investigation labeled art and science. Because there is such a plethora of information available from both disciplines, to ignore those rich resources would have been an act of willful culpability. The second part of this document is a record of a personal celebration of the existence of light and its effects and introduces examples of the visual works which were inspired and influenced by some of the information contained in Part I of this paper. Other related sources are also cited.
Part I

LIGHT AND SCIENCE

To describe as scientists the first persons who attempted to explain the nature of light is, perhaps, misleading. The early Greeks who formulated explanations of light did not use methods that conformed to contemporary concepts of scientific inquiry but relied solely on their intellectual capacities to discern reasons for the natural order of their world. They performed no experiments to substantiate their pronouncements and felt no compulsion to limit themselves to conjecture in a single specific area. Also, in attempting to explain light, they did not divorce light from the function of vision.¹

The earliest documentation of study into the nature of light begins with Empedocles of Agrigentum (c. 500 - 430 B.C.) who believed that light was emitted by the eye and vision produced when particles emitted by objects encountered the eye-produced rays. From this point, written history abounds with explanations of light.²

Plato, Socrates, Aristotle, and Euclid all formulated theories which attempted to explain the nature of light. The most important


theories of the Graeco-Roman age came from Euclid who created the concept of the rectilinear ray which had no physical substance and, as a concept, has served as the basis of geometrical optics.  

Through the ages, light remained a puzzle for inquiring minds and the most renowned thinkers of the ages attempted to explain exactly how light was made, emitted, transmitted and received. In the attempt to understand one facet of existence, people formulated theories of light as waves, light as particles, color as a result of light, color independent of light, the eye as prime source of illumination, light as an externally present quality, and so on. Work of contemporary pertinence did not appear until the seventeenth century when the diffraction and reflections experiments done by Grimaldi and Newton's discovery of the spectral breakup of white light occurred; all theories which not only described how light reacts but also how that reaction aids sight.

Grimaldi's contributions to the study of light were many. Through experimentation he proved that light had velocity of a finite nature, was propagated and traveled by means of rectilinear rays which were endowed with an undulation of high frequency, and which could stimulate the sensation of color, and could be reflected following the laws of Euclid. In his book, De Lumine, Grimaldi showed how light could be refracted and diffracted (Figures 1-6) and could heat bodies or pass through them without heat.  

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3Ibid., p. 23.

4Ibid., pp. 124-158
Fig. 3. Reflection from the two faces of a transparent slab, from De Lumine

Fig. 4. Diagram showing the reflection of light, according to Grimaldi, from De Lumine

Fig. 5. Diagram illustrating one of the 17th century theories of refraction, from De Lumine

Fig. 6. Diagram illustrating another 17th century theory of refraction, from De Lumine
Fig. 1. Fermat's Principle and the law of refraction

Fig. 2. The first experiment on diffraction, from *De Lumiére*
Newton's major contributions towards light study included further refinements on the reflection and diffraction studies done by Grimaldi and experiments concerning the spectral separation of light components through prisms which led to the evolution of contemporary spectroscopy. (Figure 7). Although the theories and experimentation of Isaac Newton were to be revered for decades, the major fallacy in his work was his adherence to the corpuscular theory of light which stated that light was composed of material particles having a different mass according to color. This theory was to be conclusively disproved by the work of Augustin Fresnel.\(^5\)

The reputation of Newton was so unassailably established that the work of Fresnel met much opposition. However, by studying shadows (Figures 8 & 9) Fresnel was able to support the position of the wave theory against that of the corpuscular theory. Light did not travel as a physical quality but was composed of an insubstantial ether, that elusive and rarefied ether which filled the universe and permeated even the pores of material bodies.\(^6\)

Currently, the way in which light is produced is believed to be understood. Based on the work of Grimaldi, Newton, and the many others who had studied light, experiments done by Max Planck, Albert Einstein, and Ernst Rutherford led to Neils Bohr's quantum theory which led to quantum mechanics. By applying the theories of quantum mechanics in relation to atoms and matter, scientists are now able to conceive

\(^5\)Ibid., p. 174.

\(^6\)Ibid., p. 255.
Fig. 7. Diagrams showing the "rings", from *Opticks*
Fig. 8. Diagram explaining geometrically the formation of diffraction fringes in the shadow cast by a thread, in which A B represents the thread and S the luminous source, from Oeuvres complètes d'Augustin Fresnel.

Fig. 9. Diagram used by Fresnel to explain the diffraction fringes at the edge of the shadow of an obstacle, from Oeuvres complètes d'Augustin Fresnel.
of light as energy which has the characteristics of waves and particles. Light is believed to be emitted when a ray of light encounters matter interacting with that obstruction in such a manner that an electron absorbs energy and is kicked into a higher orbit. In approximately a hundred-millionth of a second, the electron jumps back to its original orbit, giving off a photon of light as it does. The electron is now pictured as a wave traveling around a nucleus rather than as a particle.\(^7\)

Contemporary explanations concerning phenomena such as reflections, refraction, diffusion, and interference are all based on the work of seventeenth and eighteenth century scientists and vary little in their visual presentation from those decades old diagrams. (Figures 10 - 12).\(^8\)

However, the question of what is light still goes unanswered. Science can explain how light works and is produced but there the knowledge ends. The ancient Greek philosophers were correct in their failure to divorce vision from light for without a receptor, light does not exist. There is an inseparable linkage between light wave, object, eye, and mind. If any description can be given to light it is that agent whereby we see.

Nothing exists which flows between psyche and eye to which the name 'light' can be given. To the word 'light', therefore,

\(^7\)Morris, Light, pp. 92-110.

Fig. 10. Fermat's principle in reflection.

Fig. 11. Plane wavefronts reflected by a plane mirror

Fig. 12. Angular light distribution in specular reflection (extreme left) and diffuse reflection (extreme right). The surface on the left is perfectly smooth. The surfaces are of increasing roughness.
only one meaning remains, namely 'absence of darkness' the very same meaning attributed to it by philosophers two thousand years ago. That 'there is light' simply means that the psyche is not idle but reproduces phantoms, even if only in a dream.9

LIGHT AND ART

Obviously, visual art could not exist without light but, beyond that apparent function the way in which light is used in art has, like theories of light in science, undergone transition and been a vital factor for centuries. The main difference in the investigation of the two disciplines is that artists were frequently more interested with the analysis of effect than the causative factors or mechanics of light.

In early Egyptian architecture, light was used to enhance structures and to illuminate relief detail. It was also channeled to dramatically highlight religious events.10

When the Romans used light as a pictorial element of wall paintings it was used for illusionary effects and was a no more systematic approach to the behavior of light than was the handling of perspective. Any three dimensional qualities were achieved by foreshortening, actual relief, and linear articulation. The absence of


a consistent view of the visible world is the main difference among Roman painting and that of the Renaissance or of modern time.\textsuperscript{11}

In the centuries which separate the Roman era from the Renaissance, light appears in painting as more than a condition of atmosphere. In Christian art it is frequently used symbolically to represent the presence of divine grace or holiness. Fabric drapery and richness is represented by highlighting. However, when the technique of chiaroscuro, or the modeling of forms by the use of light and shadow, became one of the major visual tools of Renaissance painters, the use was considered revolutionary because forms no longer seemed to stand side by side but to partake of a new pictorial unity.\textsuperscript{12}

The existence of color theories, the advent of photography, and perhaps the scientific researches into the nature of light and color done by Chevreul, Helmholtz, Maxwell, and Rood contributed to the visual vocabulary of the group of painters known as the Impressionists.\textsuperscript{13}

The Impressionists are so important in any discussion of light in art for, unlike the Renaissance painters whose light is the light of the studio and who sought to define by light and shadow, the Impressionists' light is the light of nature used to represent what


\textsuperscript{12}Ibid., p. 349.

is actually believed to be seen; not what is known.\textsuperscript{14} Unlike the light of Turner which is the light of cosmic forces and a romantic symbol, the light of the Impressionists is an optical phenomenon; part of a visual reality.\textsuperscript{15}

The Impressionists sought to act purely as receptors of stimuli; they profess not to analyze form but only to paint the light reflected from matter and conveyed to the surface of the retina. They sought to reproduce the effect of that light rather than the known form of the object causing reflection.\textsuperscript{16}

In the period following Impressionism, the artist whose work is most germane to this discussion is Georges Seurat. Because Seurat attempted to base his painting on scientific principles to such a pronounced degree, he is considered to be the most systematic painter who ever lived.\textsuperscript{17} And, of all the painters who attempted to use a scientific base, he is considered the only one of major importance whose art suggests the laboratory as much as it does the studio.

By eliminating from his palette earth colors and black, Seurat followed the dictates of modern physics concerning the composition of light. Through scientific division of color and optical mixture,

\begin{flushright}
\textsuperscript{14}Morris, \textit{Light}, p. 53.
\textsuperscript{15}Canady, \textit{Mainstreams of Modern Art}, pp. 222-223.
\textsuperscript{16}Ibid., pp. 95, 222-225.
\textsuperscript{17}Ibid., p. 314.
\end{flushright}
Seurat was able to materialize the sensation of luminous color he received from nature.\textsuperscript{18}

No discussion, however brief, of light in art would be adequate without the acknowledgement of photography. Based on the camera obscura principle described by a tenth century Arab scholar and later in Da Vinci's notebooks, photography came into existence in the early eighteen hundreds when a method of permanently fixing an image was finally found. By 1850 photography had become basically the same process known today.\textsuperscript{19}

Photography not only freed the painter of the need to work in a representational mode but became, in time, an art form. By varying exposure times, reworking images, superimposing images, and numerous other techniques which now embrace film and videotape, artists continue to manipulate light saturation as well as image. Light in this form of artistic endeavor has assumed a different function and direction which has not yet been exhausted.

More contemporary works using light are in the areas of both painting and sculpture. Various technological developments enabled artists to use actual light emitting and producing elements in their work.

During the first quarter of the twentieth century the artist whose interest in light was the most sustained was Moholy-Nagy. In a


\textsuperscript{19}Morris, Light, pp. 72-91.
manifesto coauthored by Alfred Kemeny in 1922, On the Dynamic-Constructive System of Force, Moholy-Nagy predicted that light would bring forth an entirely new kind of art. 

With the aid of technical assistance, Moholy incorporated electric light in his sculpture known as the Light-Space Mondulator. A moving construction of reflective surfaces ringed with colored lights, it bounced back light reflections to the viewer and cast three constantly changing shadows on the surrounding walls. 20

In the early 1960's the use of electric light and light effects in works of both small and monumental scale became dramatically evident. A group calling themselves ZERO, to emphasize their rejection of tradition and their desire to make a new beginning, to start from nothing, was formed in Dusseldorf. One of the principal members of the group, Otto Bein, began to project light "paintings" on the wall, ceiling and floor areas by placing pre-cut stencils over a light source. Another member of ZERO, Gunther Uecker, built programmed light environments. 21

Concurrently with ZERO, the Groupe de Recherche d'Art Visuel (GRAV) founded in Paris refined techniques of movement and introduced light as an independent medium seeking to simultaneously enlarge and control their use of light. 22

21 Ibid., pp. 56-57.
22 Ibid., pp. 57-59.
Continuing from the sixties into the seventies and eighties, artists are still working with light. Holograms, X-rays, lasers, as well as neon tubes and other light instruments are still being used and have become established components of the artist's arsenal.

Even as scientific exploration into the nature of light is not ended, the ways in which art uses light are not fully exhausted.

From using natural light as in the case of Egyptian architecture to representing the illusionary effects as in the case of Roman painting as well as the Op Art of the '60's, artists have progressed to using literal light. For centuries light has been a vital consideration for visual image makers and all indications suggest that it will continue to be a prime consideration for future artists.

INTERFACE

Because of the accessibility of a wealth of information concerning the manner in which science and art have approached the subject of light, an in-depth study has not been pursued here. The main purposes of this overview of light's history have been simply to (1) emphasize the span of time during which light has been a subject for study, (2) establish that neither science nor art has yet fully explored the subject, and (3) acknowledge that both disciplines have provided a firm foundation on which further exploration can be based.

The specific references included were chosen because they were instrumental in elucidating a certain concept or are pertinent
to the second portion of this paper.

By discussing the role of light in art and science independently, the impression may have been given that art and science are autonomous. Since only one example of a direct interaction between the two had been cited—the painting of Seurat—it is necessary to dispel that impression by quoting, at length, from The New Landscape, by Gyorgy Kepes:

In the thought of the seventeenth century are the seeds of the widely held belief that art and science are polar opposites, mutually exclusive in aims, methods and results. The view that quantitative, measurable attributes of things are real and that direct sensory experience is unreal and untrustworthy leads quite logically to a value judgment favorable to science and unfavorable to art. The one becomes approved for its rationality and precision, the other distrusted as subjective, untestable and prelogical. This distinction, which Galileo drew, was an intellectual necessity for the development of the exact sciences. But the separation of art and science in our minds is no longer useful and will not bear close scrutiny. History shows that these two creative human activities are interdependent, no matter which of the two the times emphasize more strongly. Each achieves stronger growth when nourished by the other. Notably, the renewal of the scientific inquiry that flowered in the achievements of the past five centuries was led by great painters, sculptors, and architects of the Renaissance. The work of Masaccio, Alberti, Pollaiuolo, Leonardo and Durer was as much systematic inquiry into the structure of the natural world as it was artistic creation. Their concrete and communicable vision of natural order proved as fateful for the development of science as for the development
of art; it can be called art or science with equal validity. At certain times in history, more attention was focused on art than on science; today those relative positions are reversed. At no time has one existed independently of the other. In our day, the artist and the scientist are almost never the same person—a circumstance which obscures but does not alter the connection between art and science. Art and science are ordering activities of the human mind. Through sifting and organizing the order relationships impressed on us by our senses, they distill our significant experience and bring us insight into the order relations of nature.23

It is my belief in the validity of the previous statement which encouraged me to trace the evolution of the theories of light from a scientific viewpoint and the use of light in the realm of art. The natural result of this exploration was a desire to again bring together the two disciplines using information from both. The second part of this paper is concerned with that synthesis.

A distinct possibility exists that there is so much to be absorbed during the course of one lifespan that the mind recoils in horror from the onslaught of stimuli. There is a fairly good possibility that in order to stay sane, or approach that state of being that is considered by one's peers to represent sanity, that a person chooses not to become involved with life at large (usually spelled LIFE) and instead concentrates on some facet or few facets that appeal or appall. Or at least that is what I feel; not that life is so grand and wonderous but that life is so incredibly overwhelming that one needs to periodically focus on a central theme to find a tether. But this is not what I know, for there are few bits of information that I would be able to state as unassailable fact. I can only relate those concerns which are of personal interest and which I have chosen to believe, consciously (and perhaps even fallaciously) but not consciously fallaciously.

Having rejected organized religion, the American Dream, and having no sacred bonds, vows or philosophies except a rather outmoded sense of morality which prohibits me from committing any of society's heinous crimes, I had to actually make a conscious effort to examine my world and determine what made it at times so fascinating. Thus I arrived at the subject of this thesis which is Diversion of Force with
light as the force.

Scientifically, light is not a force for to a scientist force means something such as gravity or pressure. But I am not a scientist and can take the liberty of envisioning light as a force. To me light makes all things possible. Without it the universe as we know it would not even have things go bump in the night. Light is that power which enables us to form all our visual perceptions even when those perceptions are really personal illusions. Light creates the most marvelous free spectacles of existence. Ignoring the fact that without light biological life would not exist (for even the blind are sustained by a natural cycle made possible by light), and disregarding our inherent physical dependence upon it, light is still a fascinating subject for anyone who is as interested in how something works as they are in the fact that it does work.

It is marginally possible for me to mentally create a world where rainbows and spectacular sunsets do not exist because they are not part of a daily repetitive pattern, but instead something rare and poignantly beautiful, elusive and ethereal. It is also possible for me to observe a fleshy, waxy form and call it a lily; to see faceted gems and give them only a cursory glance; to notice a body of water and casually catalogue it as a lake, pond, or ocean for these are frequently mundane things. What causes me to be taken aback and compelled to re-examine these frequently mundane things is the incidence of light. And, like thousands of other beings who have populated this planet, I marvel at the transformation light has wrought.
There are many forms and objects that need only diffuse lighting to reveal an inherent integrity which is pleasing to the "average eye" and which elicit what could be termed a universal positive response. However, even these objects seem to transcend their own being when light becomes an obvious or dramatic factor. And as great as is my interest in observing these new qualities that light seems to impart to forms and masses, my desires to know how it happens and what specific actions cause this transformation are of equal importance.

I cannot deny that it was once my desire to capture and preserve the special shows that light presents; the sunrises, crepuscular skies, luminious floral forms, and dappled aqueous surfaces. My attempts seemed to me to be pallid. Through my research concerning the role of light in works done by artists through the centuries I realized that their concerns, for most part, differed from mine. I had been trying to imitate without understanding. Past artists chose to represent the manifestations of light or to use literal light while my interest lay in understanding and representing the functions of light that made all the manifestations possible.

The test of time has shown the validity of the concern of my predecessors but my position is also valid. I offer a record of personal concern and by so doing hope to communicate my awe and delight. As Lewis Mumford writes, what is art but an attempt to visually communicate an individual viewpoint:

Art, in the only sense in which one can separate art from technics, is primarily
the domain of the person; the purpose of art, apart from various incidental technical functions that may be associated with it, is to widen the province of personality, so that feelings, emotions, attitudes and values, in the special individualized form in which they happen in one particular person, in one particular culture, can be transmitted with all their force and meaning to other persons or to other cultures . . . Art arises out of man's need to create for himself, beyond any requirement for mere animal survival a meaningful and valuable world; his need to dwell on, to intensify and to project in more permanent forms those precious parts of his experience that would otherwise slip too quickly out of his grasp, or sink too deeply into his unconscious to be retrieved. 24

If the desire is to visually represent the way in which light works, then that information is readily available. We live in technical and specialized times. The rudiments of the behavior of light are taught in most secondary schools so that many people have done basic experiments with prisms, breaking light into spectral bands, and reflected light experiments. But, an in-depth knowledge can be acquired through reading in the physical sciences, freeing one of the necessity of becoming a scientist in order to understand natural phenomenon.

The idea of artists turning to science for explanations of nature and the universe is neither extraordinary or new. In his Les Phenomenes de la Vision, published in 1880, David Sutter wrote:

Science relieves one of all uncertainties, permits one to move about in complete

freedom and in a greatly extended area; therefore, to believe that one necessarily excludes the other is to doubly wrong both art and science. Does science not enable us to give a reason for all things, to know the limits of each genre, the character of each passion, of each situation of the soul, and to express it with the color and degree of power which suit it? 

From my own research concerning light I know that Sutter was more eloquent than accurate. Science does not have all the answers and cannot still explain the true nature of light. It can however, explain the way in which light works to create exciting effects and by performing this function provides a method to better approach the world. It may not relieve one of all uncertainties but does greatly extend the scope of the individual. In addition, the diagrams used by scientists to illustrate a concept (such as the ones in Figures 1-12) are often of such arresting clarity that they tease the mind to expand upon the simple drawings, projecting them into a third or even fourth dimension, adding fantasy and animation to line. While the results of such flights of fancy are based on logical, scientific conjecture of "fact", the results are no longer tied to the page but exist in another realm.

It seems fitting to state here that while the departure point for the work chronicled in this paper is diversion of force or the ways in which a light ray responds when diverted from its path, the intent has been to merge what I have learned of light through scientific sources with what I perceive or have learned of light from observation and

25Homer, Seurat, p. 46.
artistic sources. I have attempted to answer the questions my visual world elicits and in finding some of those answers, concretely represent a personal resolution. My expression of this understanding is more visual than verbal and influenced by those schools of thought which include romanticism, realism and cynicism.

When I first approached this body of work, my knowledge of light's actions did not extend much beyond the basic fundamentals of reflection and refraction, thus my first pieces in this series are concerned with these relatively simple concepts.

All life is an illusion. What the eye and mind concoct is the result of reflection and both eye and mind are occasionally confused by the discrepancies produced when light is refracted, (the prime example being when light passing from air to water changes velocity and makes the objects submerged in water appear to be slightly offset or displaced).

To visually communicate the illusionary and deceptive properties of light I sought a material that would be more amenable to the purpose than the metals and gemstones which have been for centuries, the traditional jewelry substances. While jewels and metals are ideal for displaying total reflection and refraction they still seemed inadequate when the desire was to show degrees of transparency, internal luminosity, and to suggest the illusionary qualities of light.

Glass would have been an acceptable medium but was discarded as a possibility because of the existence of plastics; specifically, acrylics and acetates.
Plastics have been used prominently in jewelry since the 1960's so they are not a new, only relatively new, medium for artistic expression. When the intent is to address the machinations of light when it encounters an obstacle, plastics are the ideal choice. They can refract, diffuse, and channel light in a multitude of ways. The diagrams in Figure 13, from Plastic As Design Form by Thelma Newman, begin to explain not only how plastic and light interact but how specific effects can be achieved and have been of great aid to me during the course of my own exploration. Not surprisingly, diagrams concerning light and plastic resemble closely the classic diagrams included in Part I of this paper used to explain, in general, how light works.

LIGHT INFLUENCED WORKS

The first piece in this series (shown in Figures 14 & 15) is concerned with reflection and absorption of light. The lightly frosted superior planes are tilted to partially interrupt and reflect light at different angles. The small pins which glow with an almost gemlike quality were used primarily as a fixture system and as a design element, but they are fire polished and therefore channel light in the manner of fiber optics, thus reinforcing the subject of the piece. Beyond the top reflecting plane lie four additional layers. The purpose of the first layer is to introduce the element of color and to absorb most of the remaining directed light. Because that layer receives rays of depleted energy, the reflected color is of a lower intensity then the same color viewed from the side of the piece, where it receives direct light (Figure 15). The succeeding layers are present to further emphasize
Not only do carved lines glow with piped light, but curved and straight acrylic edges transmit light in angular directions.

92% of light entering an unscratched sheet of acrylic will be transmitted by internal reflection to the opposite edge. If light inside the piece of acrylic strikes the surface at an angle greater than 42.2 degrees, it is bent so that it cannot escape into the air but must be reflected back to the other side of the plastic piece. The light will bounce back and forth until it reaches the far end, and will glow.

1. Regular or specular reflection is in a mirror reflection. A ray of light hits the material and is reflected off.
2. Diffuse reflection is when reflected light is scattered in all directions.
3. Spread reflection is usually on a matte surface.
4. Mixed reflection occurs when part of the light is diffused and some is regularly reflected, as off a shiny pointed surface.
5. Scattered reflection happens when tiny portions of the surface act like mirrors and cause a multiplicity of separate reflected rays, as in rippled plastic or wrinkled metal foil.

Fig. 13. Interaction of light with plastic from Plastic as Design Form by Thelma Neuman.
Fig. 14. Brooch of acrylic and acetate. 1 X 3".
Fig. 15. Side view of the brooch shown in Fig. 14.
Fig. 16. Reflection. Brooch of acrylic and acetate. 3¼ X 3".
the fact that the light that encounters the front of the piece is diverted from its path to such an extent that only the second layer which absorbs most of the remaining energy is visible from the frontal view. The observer has only to change vantage points to receive direct reflections. The intent was to present an illusion which challenged the perceptions wherein the facade hints at but does not disclose the totality. Light is used to shield as well as illuminate. By using the principles of reflection, I was able to reveal as well as obscure.

Another early piece based primarily on reflection is shown in Figure 16. This piece employs two angled planes which allude to the rectilinear propagation of light and to a law of reflection which states that the angle of incidence is equal to the angle of reflection (Fermat's Principle, Figure 10). The almost transparent planes suggests the invisibility of a ray of light which becomes visible upon encountering an obstruction and is reflected back to create a visible image. The back triangle serves to delineate the area of the light interplay. The curving pink acetate was included not only to emphasize the transparent, translucent, moving into opaque interplay, but also as a lyrical element dictated by a personal aesthetic concern. As mentioned previously, I had no intention of doing models in the way that a scientist would construct a visual representation of a molecule. All the works in this series are inspired by the knowledge of scientific principles, but the visual image is of prime importance. For this reason many elements which exist in the pieces would seem inappropriate to anyone who might approach the work with the expectation of seeing readily accessible illustrations.
The booch shown in Figure 17 is also concerned with reflection, but this time the angled planes are of such a density that no light appears to penetrate to the portion of the plane behind it. It is as if the light does not originate from a primary source but has experienced a lessening of energy by having already been bounced off other surfaces. The small pins here assume a greater importance and serve as a reminder that light, especially natural sunlight is seldom unidirectional for the pins glow within the valley of reflected light, in a sense basking in that light.

As my research progressed and I discovered more about the role light plays in enabling us to perceive images, my pieces showed that knowledge. Understanding, however, did not diminish my interest because light is a magical quality. As Gyorgy Kepes says:

When science makes minor mysteries disappear greater mysteries stand confessed. For one object of delight whose emotional value science has inevitably lessened—as Newton damaged the rainbow for Keats—science gives back double. To the grand primary impressions of the world of power, the immensities, the pervading order, and the universal flux, with which the man of feelings has been nurtured from the old, modern science has added thrilling impressions of manifoldness, intricacy, uniformity, inter-relatedness, and evolution. Science widens and clears the emotional window. There are great vistas to which science alone can lead, and they make for elevation of mind. The opposition between science and feeling is largely a misunderstanding.26

Fig. 17. Brooch of acrylic. 2½ X 3".
Fig. 18. Three acrylic brooches on wall mount. Each brooch is approximately 7/8 x 3".
Unlike contrived magic tricks performed by prestidigitators to beguile and entertain, the light that science attempts to define is a natural kind of mystery. Powerful rays traveling at incredible speeds through the void of space, encountering few solid masses, reach earth's atmosphere, begin to come in contact with matter and are sent bounding and careening. Light rays come winging their way to a planetary surface where instead of wrecking havoc (although heat as a result of light is not always benevolent) this energy is diverted and in that divergence are transformed to form a vital link between form and perception. They need neither stage nor props and perform daily. If the process of study discloses some of the properties of light, it does little to rob those actions of their enchantment.

The pieces represented in Figure 18 suggest that enchantment. The forms which allude to those of prisms are of a translucent material so that instead of breaking light into spectral bands, light is diffused and because of this redirection interior voids are sharply defined as edges glow with what seems to be an independent luminosity. Because of the translucency of the material of which these works are constructed they have an elusive quality. Sharp angles are in some cases softened almost to extinction with exiting light, while the spaces appear to have mass. This triad, meant to be worn separately and to hang as a unit, shows variations on a central theme and begins to suggest the multiplicity of solutions possible with one basic form, much in the way light permits variation from a single source.

With the exception of the final piece in this series, which
is a small wall sculpture, the works represented are all brooches. To call these pieces brooches is taking a liberty with nomenclature, for brooches traditionally have been devices which combine ornamentation with function and were used in lieu of the more contemporary fixture systems such as zippers, buttons and velcro. Since these pieces are not designed to perform a practical function of closure but to be purely ornamental, they should probably be called pins, but that term lacks elegance, so the term brooch will be used henceforth.

Although not constructed of historically traditional materials, the brooches shown are all at least marginally wearable despite the fact that the function of the pieces is not readily visually apparent. The thought of making jewelry is especially appealing because it allows work to be viewed in a variety of environments and dictates scale so that pieces have a constant human reference point. However, many of the pieces in this series are provided with wall mounts. Since the basis for the work is light it seems only fitting that they should be viewed with the aid of the agent that influenced their inception, instead of being confined to boxes. In addition, the duality of purpose is an enjoyable concept.

The brooch format was chosen because it seems to be the most versatile of all jewelry. It has no predetermined external form and the function is, in many ways, less demanding than that of a ring, bracelet or neckpiece. From the vantage point of a chest, brooches

can see the world and be protected from much of the harm and abuse to which other forms of jewelry are subjected. Also, the brooch format conjures up in my mind a void which is crying to be filled and is a challenge similar to that of the painter's naked canvas.

Figure 19 shows a piece which is, in a sense, chest clothing. A relatively large brooch, it fairly dominates the chest area for which it was designed. The scale used was necessary to convey the concept which inspired the brooch, for this piece marks a slightly altered employment of light theories.

Previous brooches had been based fairly seriously on those scientific findings that explain light combined with a personal concern for form and sound design. As I began to have a better grasp of light concepts, I began to take greater liberties with them. The brooch in Figure 19 is an example of that divergence.

Light is a very cosmic concept governed by theory and those beliefs we tend to label fact but which are really shared illusions, for there is no ultimate reality. For this reason the acceptance of scientific disclosure concerning light is much like believing in a supreme being. Much must be taken on faith.

... 'Ultimate reality' is so far removed still from our awareness that we have only contemporary illusions on which to erect our forms. It is irrelevant whether they come from science or somewhere else. The delight of science at this point is its surprise with its discovery that
Fig. 19. Light Dance. Acrylic and acetate brooch on wall mount. Brooch size is $5\frac{1}{4} \times 3\frac{1}{4}$".
it too is only a small illusion in the mind of man.28

If all our knowledge is a shared illusion I decided that there was room for a personal illusion within the structure of those shared. With my personal awareness of the wave particle theory of light based on quantum mechanics (which states that light is believed to travel as a wave but upon encountering opposition acts as a particle, jumping to a higher orbit, returning and in the process emitting a photon of light), I began to glamorize the action of light. The thought of so much action and interaction seemed to be similar to the patterns of a dance with leaps, pivots, and interweaving of participants. "Light Dance" is an expression of that rather fanciful viewpoint in which color plays a primary role and is similar in approach to the brooch shown in Figure 20.

Unlike any of the other pieces in this series, this brooch, entitled Quantum Jump, includes a material other than acrylic or acetate. The maple with its swirling wave patterns seemed a fitting background for the light particle caught on the seesaw in that instant before it returns to its original orbit.

Having taken such a lighthearted and capricious view of a subject that I felt science dealt with in a clinical and serious manner, I was almost disappointed to encounter a source in which my sentiments and mental imagery were echoed and eloquently expressed. In The Magic Rays,

Fig. 20. *Quantum Jump*. Brooch of acrylic, maple, and pink veneer. $1 \times \frac{4}{3}$".
Johannes Dogili writes:

The slightest changes among the atoms within a molecular structure, the omission or addition of one type of atom or another, can turn a brilliant red into blue. We thus gain a glimpse of two worlds that will always mysteriously confront each other: on the outside, detached from man's sight and feeling, a frenzied dervish dance of electrons in the shell of atoms, a swirling and weaving of atoms in matter, an eternal back and forth of attraction and repulsion a constant interchange of tiny forces, all ruled by code laws of number, ordered and determined by size, mass, position, and strength; and within ourselves, the other world of colors, of tones, of perception in all its richness.²⁹

The brooch in Figure 21 differs from the preceding two in that it is not as fancifully based and from the first three in that it alludes to intensities of light as tangible segments. The references for this piece came from two different sources. The first, scientifically oriented, includes those theories that deal with the production of color by reflection. The second is a study of the penetration of sunlight into a veranda shaded room. (See Figure 22 from The Japanese House and Garden by Telsuro Yoshida.)

The last piece in this series, Figures 24 and 25, is not a brooch but a wall piece. This function was chosen because the work needs to be properly displayed to have the desired impact. The small vertical rods which support the bending acetate planes are all but invisible

Fig. 21. Waning Light. Acrylic and acetate brooch. 3½ X 3".
Fig. 22. Angle of sunlight in the forenoon in a room with veranda facing south, in Tōkyō, hourly at three different seasons. a) summer solstice, b) equinox, c) winter solstice.
under any but ideal conditions.

The wall sculpture entitled "Phototropism" no longer deals solely with light diverted from its path but with light and its biological impact.

To understand some of the facets of that invisible energy called light it was necessary for me to view it in isolation. The effects of light are so varied that I would have found them much too overwhelming of a subject for investigation unless I narrowed my field of inquiry. Thus far I have only touched the subject, as a blossom touches the hand, but that paucity of knowledge has altered my perception to increase my visual vocabulary and enrich my view of existence. However, light does not exist as something divorced from what we term reality. Artificial light can be produced by the flick of a switch or the striking of a match or flint and sunlight is always in evidence somewhere on our planet. So it is that I began to move light back into the world of tangible things and felt the most natural transition would be one of the ways in which light affects biological growth.

The "Phototropism" piece was influenced by the illustration in Figure 23 from The Science of Life, which shows the manner in which light causes the growth force of a seedling to be diverted in the direction of the light. The smoky acetate plane on the left side of the sculpture shown in Figure 24 theoretically represents absorbed light so that the curving acetate planes do not receive illumination from that directions. The piece has about it the feeling of airy lightness despite the confines of a rectangular frame (see Figure 25) which is
Fig. 23. Phototropism in coleoptile of a grass seedling, illustrating the hormonal explanation. Auxin-producing region is shaded; distribution of auxin within coleoptile is indicated by stippling. Note that the difference in auxin concentration on the two sides arises at the tip, which is the light sensitive sight, and moves down the coleoptile as a result of transport of auxin toward the base. As a result, curvature begins just below the tip and progresses toward the base of the coleoptile. The events illustrated would occur in about two hours in a coleoptile 2 cm high. The difference between auxin concentrations on the two sides in response to light is exaggerated in the diagram.
Fig. 24. Phototropism. Side view of a wall sculpture based on biological diversion caused by light.
Fig. 25. Front view of the wall sculpture shown in Fig. 24. Total size of the piece is $7\frac{1}{2} \times 8 \frac{5}{8}\text{"}$. Acrylic and acetate.
not unlike natural laws of order; rigid structures within which change can and does occur.

With this final work I feel as if I have received a gift. I now have a basic system through which to approach my visual world in a manner that is closer to the systematic than it is to the chaotic. I have a vocabulary of visual forms and a grasp of a material (Plastics) that is singularly suited to those forms that I did not possess prior to this exploration.

Light will continue to be, for me, an aesthetic consideration and is a subject I may return to time and again. But, since I can now answer some of the questions that used to so puzzle me I can begin exploration into some of the other fascinations of a world made possible by light.
SELECTED BIBLIOGRAPHY


