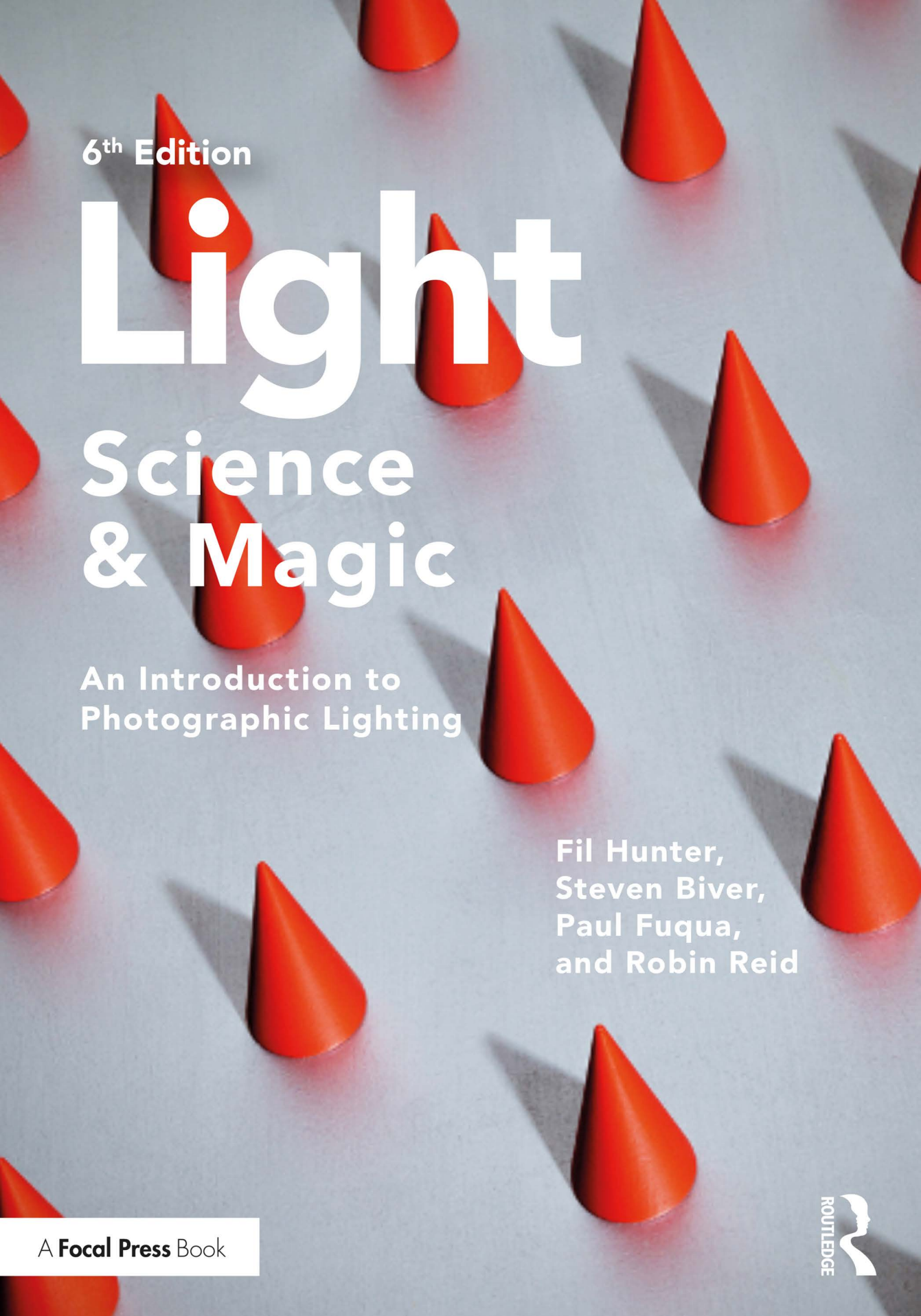
6th Edition
Light
Science
& Magic
An Introduction to
Photographic Lighting
Fil Hunter,
Steven Biver,
Paul Fuqua,
and Robin Reid
A Focal Press Book
ROUTLEDGE

Light–Science & Magic

Photographic lighting is a topic that will never go out of style, no matter how sophisticated cameras and other technology get. Even with the most high-tech gear, photographers still need to put a lot of thought and vision into lighting their photographs in order to get great results. Mastering this key skill has the power to dramatically and quickly improve your photographs as well as your efficiency.

Light—Science & Magic provides you with a comprehensive theory of the nature and principles of light, with examples and instructions for practical application. Featuring photographs, diagrams, and step-by-step instructions, this book speaks to photographers of varying levels. It provides invaluable information on how to light the most difficult subjects, such as surfaces, metal, glass, liquids, extremes (black-on-black and white-on-white), and portraits.

This new edition includes:

- Expanded chapters on portraiture and lighting equipment
- Chapters on necessary equipment when working on location versus in the studio
- An updated appendix of reliable photo gear sources
- Over 100 new photographs and informational sidebars
- Updated information about advances in flash equipment, LED panels, and fluorescent lights

Lighting styles will evolve, but the science of light will always remain the same. Once photographers understand the basic physics of lighting (without having to become physicists), they can apply that knowledge to a broad range of photographic styles.

FIL HUNTER was a highly respected commercial photographer specializing in still life and special effects photographs for advertising and editorial illustration. During a career spanning over three decades, he worked for such clients as America Online (AOL), US News, Time-Life Books, *Life Magazine* (27 covers), the National Science Foundation, and *National Geographic*. He taught photography at university level and served as technical consultant on a number of photographic publications. Mr. Hunter won the Virginia Professional Photographer's Grand Photographic Award three times. He co-authored *Focus on Lighting Photos* with Robin Reid.

STEVEN BIVER has over 20 years of experience as a commercial photographer specializing in portraits, still life, photomontage, and digital manipulation. His client list includes Johnson & Johnson, USDA, William & Mary College, Condé Nast, and IBM. He has been honored with awards from Communication Arts, *Graphis*, *HOW Magazine*, and Adobe, who have also included his work on a Photoshop 'extras' disc to inspire other photographers. He is also the co-author of *FACES: Photography and the Art of Portraiture*.

PAUL FUQUA has worked as an editorial and wildlife photographer for more than 35 years. He started his own production company in 1970 and is dedicated to teaching through the use of visuals. Paul has written and produced educational and training material in a variety of fields including law, public safety, history, science, and the environment. For the last 10 years he has produced educational material dealing with the natural sciences and the need for global habitat stewardship. Paul is also a co-author of *FACES: Photography and the Art of Portraiture*.

ROBIN REID has been a professional photographer for over 30 years. She has worked for many federal courts (US Supreme Court, US Tax Court, and US Court of Appeals for the Federal Circuit and others), as well as Domino's Pizza, Time-Life Books, McGraw-Hill, American Management Corporation, Diabetes Forecast, and Heckler & Koch. Ms. Reid has won various awards from the Virginia Professional Photographers Association, including Best Portrait of a Child. She taught both Studio Portraiture and Tools of Photography classes for the Art League of Alexandria for many years. She co-authored *Focus on Lighting Photos* with Fil Hunter.

Light–Science & Magic

An Introduction to Photographic Lighting

SIXTH EDITION

Fil Hunter
Steven Biver
Paul Fuqua
Robin Reid

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Dedications

We dedicate this book to all the wonderful teachers who *fully* share their knowledge. These are special people. Fil Hunter, whose pioneering vision this book so largely reflects, taught everything he knew *without* reservation. Steve, Paul, and I happily continue that tradition and appreciate all the other teachers, whatever their field of expertise, who do so also.

We want to acknowledge two such teachers in particular—Ross Scroggs, Sr., who taught Fil not only about photography, but also about being human, and Robert Yarborough, who was a life-long influence for Paul.

Steven Biver, Paul Fuqua and Robin Reid

Thanks to my wife Gina and my kids Jade, Nigel and Tessa.

Steven Biver

Thanks to my ever patient wife.

Paul Fuqua

I would like to thank Suzanne Arden for being my shooting buddy and best cheerleader on my experimental work with printing on gold (and for introducing me to a new passion, fused glass); Elaine Ligelis and John M. Hartman for supplying many of my props; and my models—Kizita, Forrest, Robin (not me), Gabriel, Kim, Eliza, Kwan, Isabel, David, and Valentine. And, of course, Fil. Sorely missed and remembered every day.

Robin Reid

Contents

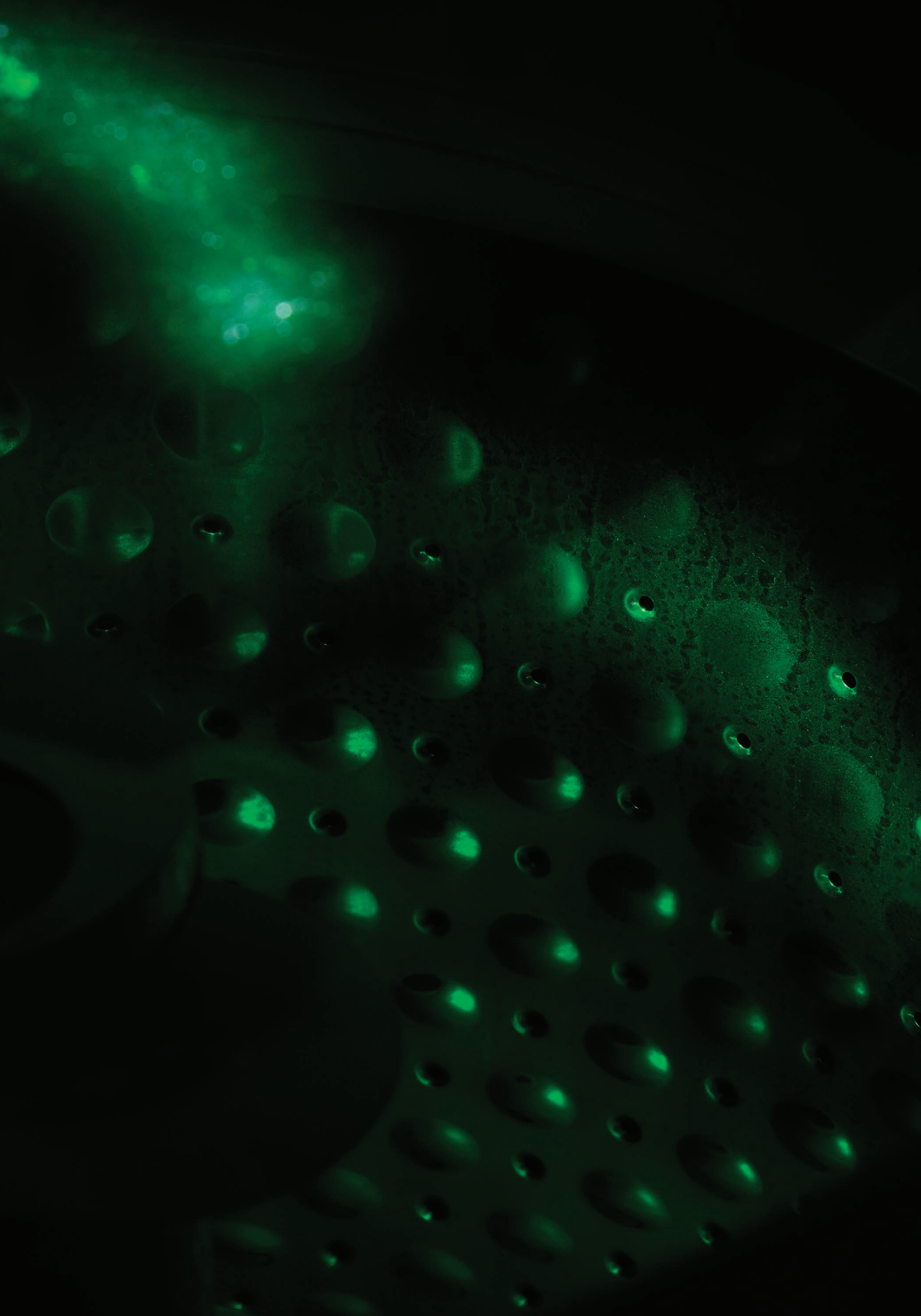
Introduction

Our aim in this sixth edition of *Light—Science & Magic* remains true to the intent of the first—present the key lighting concepts in a clear, readily understandable way. Lighting is at the very heart of photography. Having a gorgeous model or working with talented stylists won't insure a great photograph. It must be well lit.

This is *not* a "how to" book in the sense that the term is generally used. In it, we rarely, if ever, suggest appropriate lens apertures, shutter speeds, flash settings or other such information—information that is often an important part of the currently popular "recipe" approach to teaching lighting. If that is what you are looking for, you must look elsewhere. (We would recommend the brilliantly done *Digital Photography Book* series by Scott Kelby.)

What we do offer is an understanding of the underlying nature of light and show how to employ its key characteristics for the lighting of any sort of subject in any location or circumstance. In it, we present an overarching approach to photographic lighting. Applying it will enable you to *understand* why a subject looks the way it does when it is illuminated by any given "light," and how to *use this understanding* to make exactly the picture you are after.

We also include chapters dealing with the peculiarities associated with using hot-shoe and similar flashes, and suggestions for those of you who may be considering setting up your first studio. Finally, in a brief appendix, we list some of the photographic suppliers from whom we have received particularly good services over the years.



CHAPTER 1

Light: the Beginning

Light—Science & Magic is a discussion, not a lecture. You bring to this discussion your own opinions about art, beauty, and aesthetics. We do not intend to change those opinions and may not even influence them very much. We will be more annoyed than flattered if reading this book causes you to make pictures that do nothing but mirror ours. For better or worse, you have to build your own pictures on your own vision.

Most beginning photographers find lighting mysterious, incredibly tedious, and frustrating. The good news is light follows rules, and, when we understand these rules, it all gets easier! We can create mysterious pictures, as seen here at the beginning of the chapter, but lighting doesn't have to be a mystery. And, if you are wondering about this photo, we explain it at the end of the book.

Here, we offer you *a set of tools*. This book is about the *science* of light. Brass tacks. It is information for you to use when you please, if you please, and how you please. This does not, however, mean that this book is not also about *ideas*, because it is.

The basic tools of lighting are principles, not hardware. Shakespeare's tool was the Elizabethan English language, not the quill pen he used. A photographer without mastery of lighting is like a Shakespeare who could speak only the language of the people in the Globe Theatre pit. Being Shakespeare, he still might have come up with a decent play, but it certainly would have taken a lot more work and, very likely, more blind luck than most people are entitled to expect.

LIGHTING IS THE LANGUAGE OF PHOTOGRAPHY

Patterns of light convey information just as surely as do spoken words. The information that light conveys is clear and specific. It includes definite statements, such as "The bark of this tree is rough" or "This utensil is made of stainless steel, but that one is sterling."

Lighting, like any other language, has a grammar and a vocabulary. Good photographers need to learn both. Fortunately, photographic lighting is a lot easier to master than a foreign language. This is because physics, not social whim, dictates its rules.

The tools we have included in this book are the grammar and vocabulary of light. Whatever we say about specific technique is important only to the extent that it proves the principles. *Please, do not memorize the lighting diagrams in this book—rather, learn the theories behind them.*

It is entirely possible to put a light in exactly the same spot as shown in one of the diagrams and still make a bad picture—especially if the subject is not identical to that in the diagram. But, if you learn the principles, you may well see several other good ways to light the same subject that we never mention and, perhaps, have never even occurred to us.

WHAT ARE THE "PRINCIPLES"?

To photographers, the important principles of light are those that predict *how it will behave*. Some of these principles are especially powerful. You will, however, probably be surprised to find how few they are, how simple they are to learn, and how much they explain.

We discuss these key principles in detail in Chapters 2 and 3. They are the tools we use for everything else. Then, in later chapters, we put them to work lighting a wide range of subjects. At this point we will simply list them:

1. The effective *size of the light source* is the single most important decision in lighting a photograph. It determines what types of shadows are produced and may also affect the type of reflection.
2. Three *types of reflections* are possible from any surface: direct reflection, diffuse reflection, and polarized direct reflection. They determine why any surface looks the way it does.
3. Some of these reflections occur only if light strikes the surface from within a limited *family of angles*. After we decide what type of reflection is important, the family of angles determines where the light should or should not be.

Just think about that for a minute. If you think lighting is an art, you're exactly right—but it's also a technology that even a bad artist can learn to do well. These are the most important concepts in this book. If you pay close attention to them whenever they come up, you will find they will usually account for any other details you may overlook or we forget to mention.

WORKING WITH LIGHT

Figures 1.1 These four images—very different pictures—are a small sample of some of the many different ways photographers have worked with light, be it either in a studio or in the outside world.

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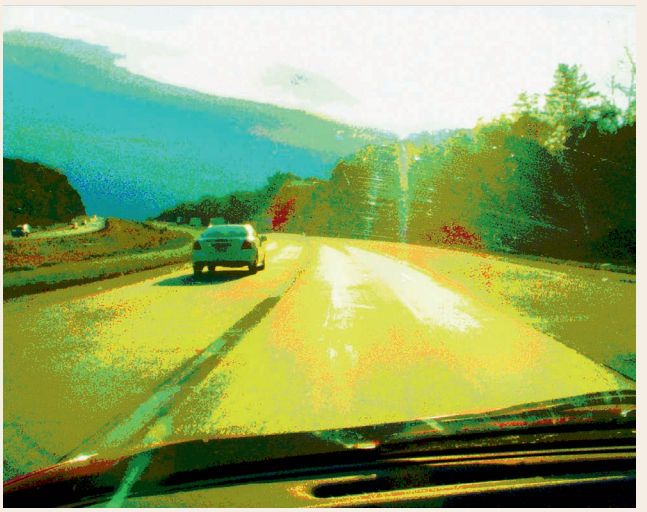

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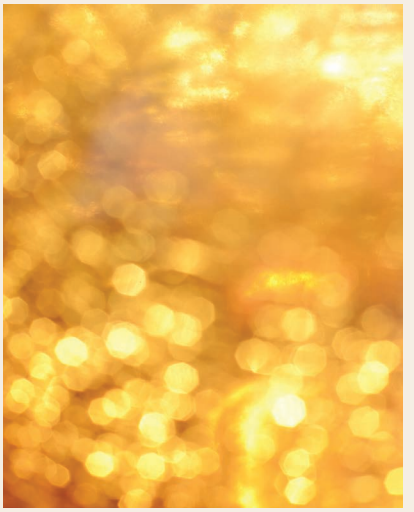
CREDIT: JOHN M. HARTMAN



CREDIT: ROBIN REID

1.1
Some examples of the different photographers who have worked with light.

WHY ARE THE PRINCIPLES IMPORTANT?

The three principles we have just given are statements of physical laws that have not changed since the universe began. They apply to all sources of light and have nothing to do with style, taste, or fad. The timelessness of these principles is exactly what makes them so useful.

Consider, for example, how they apply to portrait style. A representative 1952 portrait does not look like most portraits made in 1852 or 2020. However, and this is the important point, *a photographer who understands light could duplicate either of them*.

Chapter 8 presents a number of useful approaches to lighting a portrait. Some photographers will not want to adopt those approaches, and even fewer will do so in 20 years. We do not care whether or not you use the methods of portrait lighting we chose to demonstrate.

We do, however, care very much that you understand exactly *how* and *why* we did what we did. It is the answers to those very "hows" and "whys" that will allow you to produce your own pictures your own way. Good tools do not limit creative freedom. They make it possible.

Good photographs take planning, and lighting is an essential part of that planning. For this reason, the most important part of good lighting happens *before* we turn on the first lights. This planning can take many days or it can happen a fraction of a second before pressing the shutter release. It does not matter when you plan or how long it takes, as long as you get the planning done. The more you accomplish with your head, the less work you have to do with your hands.

Understanding the principles we presented above enables us to decide what lights need to be where before we begin to place them. This is the important part. The rest is just fine-tuning.

HOW DID WE CHOOSE THE EXAMPLES FOR THIS BOOK?

The portrait is but one of the several basic photographic subjects we discuss. We each chose to prove something about the basic principles. We also lit the subject to show the principle, regardless of whether there might be other good ways to light the same thing. If you master the principles, you will discover the other ways without any help from us.

The above means that you should give at least some attention to every representative subject. Even if you have no interest in a particular subject, it probably relates to something you do want to photograph.

We also chose some of the subjects because they are rumored to be difficult. Such rumors are spread usually by people who lack the conceptual

tools needed to deal with such subjects. This book dispels the rumors by giving you those tools.

In addition, we tried to use studio examples whenever possible. This, however, does not mean *Light—Science & Magic* is only about studio lighting. Far from it! Light behaves the same way everywhere, whether it is controlled by the photographer, by the building designer, or by nature. But you can set up indoor experiments like ours at any hour of any day, regardless of the weather. Later, when you use the same lighting in a landscape, on a public building, or at a press conference, you will recognize it because you will have seen it before.

Finally, we chose each example to be as simple as possible. If you are learning photography, you will not have to leave the set-up in your living room or in your employer's studio for days at a time to master it. If you teach photography, you will find that you can do any of these demonstrations in a single class session.

TO DO OR NOT TO DO?

If you are learning photography without any formal instruction, we suggest you try all of the basic examples in this book. Do not simply read about them. What happens in your head is the most important part of lighting, but the eye and the hand are still essential. Guided experience coordinates the three.

When we talk about soft shadows or polarized direct reflections, for example, you already know how they look. They happen in the world, and you see them every day. But you will know them and see them still better once you have made them happen.

If you are a student, your class assignments will keep you busy enough without any further demands from us. Your teacher may use the exercises here or invent new ones. Either way, you will learn the principles in the book because they are basic. They happen in all lighting situations.

If you are a professional photographer trying to expand your expertise, your judgment about what exercises you need is better than ours. Generally, these will be those that are least like the things you are already photographing. You may find our basic examples too simple to be an entertaining challenge. Try complicating things a bit. Add an unexpected prop, an unusual viewpoint, or a special effect to our basic example. You might as well get a striking portfolio piece out of the effort while you are at it.

If you are a teacher, you can look at this book and see that most of the exercises show at least one good, simple, easy-to-master way to light even

those subjects with reputations for maximum difficulty: metal, glass, white-on-white, and black-on-black. Notice, however, that, although we've done this in almost every case, we weren't able to do it in absolutely every one of them.

The "invisible light" exercise in Chapter 6, for example, is pretty difficult for most beginners. Some students may also find the secondary background behind the glass of liquid in Chapter 7 to be beyond the limit of their patience. For this reason, if you find anything in this book that you haven't already done with your own hands and eyes, we strongly encourage you to try it yourself before deciding whether it is appropriate to the skills of your students.

WHAT KIND OF CAMERA DO I NEED?

Asking "What kind of camera do I need?" may seem silly to experienced photographers. But we have taught this material. We know how many students ask it, and we have to answer it. There are two good answers, and they contradict each other slightly. The weight we place on each answer matters more than the answers themselves.

Successful photographs depend on the photographer more than the equipment. Inexperienced photographers work best with the camera with which they are familiar. Experienced photographers work best with the camera they like. These human factors sometimes have more to do with the success of a photograph than purely technical principles.

Ideally, people learning photography should shoot digitally for the instant feedback this approach provides. Shooting digitally is also far less expensive, and the quality that most of today's digital cameras provide borders on amazing. Of the many photographs in this book, we made all but a handful digitally. The only downside of shooting digitally is the natural tendency to overshoot, which adds up to a lot of postproduction editing. The better you master the principles, the more likely you'll get the lighting right in far less time and without shooting endless versions.

Just which digital camera you should get is up to you. Fortunately, most manufacturers offer a number of reasonably priced models. Check out the many reviews that you will find in photography magazines and on the web. Talk to other photographers and, if possible, deal with a camera store whose sales staff know what they are talking about. Camera clubs are also another good source of information, and, if you are in school, your instructor will also be able to help you select the camera that best fits your needs and budget. If possible, buddy up with a fellow student with a similar camera and share

equipment. If your fellow student has a long lens and you have a short one, you can switch with each other to see if you like the other lens well enough to purchase one for yourself. Every photographer has purchased equipment they find they don't like, even though it sounded essential in the advertising. By renting or borrowing items first, you can avoid unnecessary expenses.

Today, even cell phone cameras are increasingly capable. They don't have the controls that digital cameras have, or the resolution for 40 × 60-inch prints. However, people are doing some great photography with these little cameras. I recently needed uncommon dental surgery, which the endodontist wanted to photograph. I, of course, said, yes. I wanted to see what camera and lights she would use. She simply pulled out her cell phone fitted with a close-up lens and used the existing lighting. These were not artistic photographs—in fact, they were, to my eye, rather gruesome. However, they were a good record of the surgery. They didn't have the resolution to make wall displays—but who would want one? Cell phone cameras continue to improve and can be part of our arsenal.

A WORD OF CAUTION

Any way you look at it, the advent of the digital world has been a wonderful thing for students. It has not, however, resulted in a totally win–win situation. Digital cameras are, at their hearts, computers. Because of this, camera makers can program the camera to alter the image they take without the foreknowledge or consent of the photographer! This is often a good thing. The camera's decisions are, in our experience, more often than not correct. Sometimes, however, they are not.

A still bigger problem is that it is hard for students to know whether what has happened, for better and for worse, is because of the camera's decision or because of the photographer's decision. You may make mistakes that the camera fixes, costing you a learning experience, or the camera can make a mistake, and you innocently blame yourself for it.

In light of the preceding paragraphs, we offer the following suggestions:

1. *Develop at least a minimal competence in postproduction skills*. You do not have to be a whiz-bang Photoshop genius to be an effective digital shooter. You do, however, need to learn at least the basics of one of the numerous (and often amazingly inexpensive) digital editing programs now available.
2. *Shoot in the "Manual" mode*. This will prevent your camera from "helping" you to get a technically satisfactory shot. It will, however, go a

long way in that direction by leaving most of the decision making up to you and not your camera's computer "brain."

3. *Shoot in the Raw format*. Because of its minimal in-camera compression, it stores far more of the visual information that reaches your camera's sensor than does the alternate JPEG format. Thus, during postproduction, when you are fine-tuning your images, your software has far more digital information with which to work. And this can make a big difference—a *very* big difference.

A RAW ADVANTAGE

We shot Figure 1.2 in the Raw format. While adequate, we feel that it lacks the tonal range and color, in other words the "snap," needed for visual impact.

1.2
Farm boy from the Dominican Republic as shot in the Raw format before any postprocessing.

Figure 1.3, by comparison, shows our young friend after we did some work on his image during postproduction. Because we shot the original in Raw, we had the flexibility we needed to produce the color and contrast treatment we wanted.

Figure 1.4 is a monotone variation on the above theme.

A RAW ADVANTAGE (*continued*)

1.3
The same image as Figure 1.2, but after we did some postprocessing on it.

1.4
Here we see a variation on the previous theme. Once again, it was our use of the Raw format that gave us the flexibility needed to produce this black and white image.

Unfortunately, this book does not have the space needed to deal with the above three issues in detail. The "A Raw Advantage" box is but a quick look at some of the things you can do when shooting in Raw. For more complete information, please consult one of the many fine books on the subject available today.

If you are a student, the remedy for this is a close, ongoing talk with your instructor about what's happening in your pictures. If you are an experienced photographer, you can already tell when the camera is helping you and when it is hurting you.

The hardest path is that of a novice photographer attempting to learn the material in this book without the benefit of formal instruction. What we *can* offer all photographers is the assurance that the material we present in the following pages can, indeed, be learned in that very way. All four of the authors of this book did so. Talk with other photographers as much as possible. Ask questions, and always share with others whatever you have learned.

WHAT LIGHTING EQUIPMENT DO I NEED?

We expect you to ask this question, and we offer this two-part answer:

1. *No photographer has enough lighting equipment to do every assignment as well as possible.* No matter how much lighting equipment you have, there will be times when you want more. Suppose, for example, you can illuminate a large set to shoot at f/96 at 1/5000 a second. (Please call the fire department before turning on this apparatus.) You will probably then find that you want still more light in a particular shadow, or you may find that you need to light a yet larger area to fit the required composition.
2. *Most photographers have enough equipment to do almost every assignment well.* Even if you have no lighting equipment at all, you may be able to get the job done. Can the subject be photographed outdoors? If not, sunlight through a window may be a good light source. Inexpensive tools, such as white cloth, black paper, foam board, black gaffer tape, and aluminum foil, can allow you to control sunlight as effectively as the best manufactured equipment.

The above said, there is no dispute that good lighting equipment can be a great convenience. If the sun moves too far across the sky before you are ready to expose, you may have to wait until it returns the next day and hope there is no more and no less cloud cover the second time around.

Professional photographers know that convenience becomes necessity when they have to photograph what the client wants when the client wants.

This message is not aimed at professionals, however. They already know how to do whatever is needed with whatever is available. We are more interested in encouraging students now. You have advantages that professionals do not. Within broad limits, you can select the size of your subject.

Small scenes require less light. You may not have a 3 × 4-foot soft box, but a desk lamp with a 60-watt bulb and a tracing paper diffuser can light a small subject nearly as well.

Lack of equipment is, no doubt, a handicap. You know it, and we know it. But it is not necessarily an insurmountable obstacle. A good dose of creativity may well overcome it. Just remember that creative lighting is the result of planning the lighting. Part of that creativity means anticipating the limitations you face and deciding how best to work within them.

WHAT ELSE DO I NEED TO KNOW TO USE THIS BOOK?

We assume you know basic photography. You know how to determine a reasonable exposure, at least close enough that bracketing can cover errors. You understand depth of field. You have mastered the basic operation of your camera.

That is all. We have no intention of being ruthless in our examination of your background credentials. Just to be safe, however, we suggest you keep a good basic photography book on hand as you read this one. (We did when we wrote it.) We do not want you to find easy material difficult just because we unknowingly use a technical term you have not seen before.

Finally, do not overlook the internet. There is a wealth of information to be found there about lighting and photography in general. A search here and a search there are moments well spent by any photographer—advanced or beginner.

WHAT IS THE "MAGIC" PART OF THIS BOOK?

Learn about the light and the science. Then the magic happens!

CHAPTER 2

Light: the Raw Material of Photography

In some ways, photographers resemble musicians more than painters, sculptors, and other visual artists. This is because photographers, like musicians, are more interested in the manipulation of energy than that of matter.

Photography begins the moment light is emitted from a source. It climaxes with still more light reflected from a printed page or beaming from a monitor and striking a human eye. All steps in between involve the manipulation of light—whether to control it, to record it, or, ultimately, to present it to a viewer.

Photography, at its heart, is the manipulation of light. Whether the manipulations serve artistic or technical purposes hardly matters; the two are often synonymous. Whether the manipulations are physical, chemical, electrical, or electronic, they are all motivated by the same mission and guided by the same understanding of how light behaves.

In this chapter, we are going to talk about light, the raw material from which we make pictures. You are already familiar with most of the ideas we will discuss. This is because you have been learning to see since the day you were born. Even if you happen to be a novice photographer, your brain has already absorbed enough information about the behavior of light for you to be a master.

Throughout this chapter, we aim to attach words and labels to some of this unconscious and semiconscious information. This will make it easier for you to talk about light with other photographers, just as musicians find it easier to say "b flat" or "4/4 time" instead of humming a scale or tapping a rhythm.

This is the most theoretical chapter in this book. It is also the most important, because it is the foundation for all that follows.

WHAT IS LIGHT?

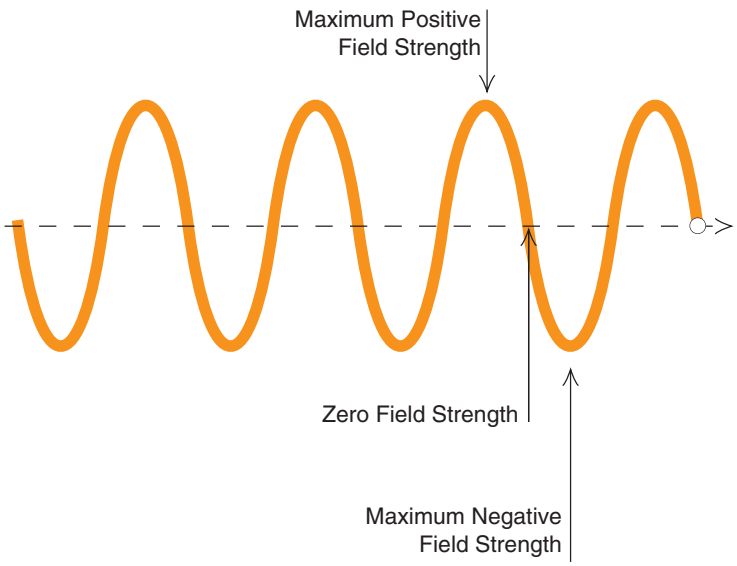
A complete definition of the nature of light is complex. In fact, several Nobel Prizes have been awarded for various contributions to the working definition we use today. We will simplify our discussion by using a definition adequate for applied photography. If you are still curious after reading this, see any basic physics text.

Light is a type of energy called *electromagnetic radiation*. Electromagnetic radiation travels through space in tiny "bundles" called *photons*. A photon is pure energy and has no mass when at rest. A box of photons the size of an elephant weighs nothing.

The energy of the photon produces an *electromagnetic field* around the photon. A field is invisible and cannot be detected unless there is a material object in the field on which it can exert a force. All this sounds pretty mysterious until one realizes that one common example of a field is the magnetic field surrounding an ordinary magnet. We cannot tell the field exists unless we move a nail close enough for the magnet to attract it. Then, the effect of the field is apparent: the nail jumps to the magnet.

Unlike the field around the magnet, however, the electromagnetic field around the photon is not constant in strength. Instead, it fluctuates as the photon travels. If we could see this change in the strength of the field, it would look something like Figure 2.1.

Notice that the strength of the field moves from zero to its maximum-positive strength and then back to zero; it then repeats the pattern in the negative direction. This is why the field around a beam of light does not attract metal like an iron magnet does. The field around a photon of light is



2.1
The magnetic field around a photon fluctuates from its maximum-positive to its maximum-negative strength as the photon travels. The electrical field behaves exactly the same but out of phase with the magnetic field; whenever one field is at its maximum, the other is at its minimum strength.

positive half of the time and negative the rest of the time. Thus, the average charge of the two states is zero.

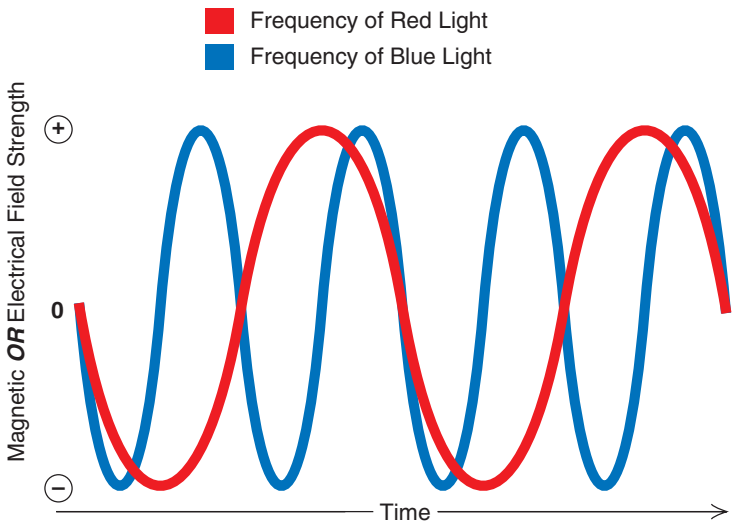
As the term implies, an "electromagnetic field" has both an electrical component and a magnetic one. Each component has the same pattern of fluctuation: zero to positive, to zero, to negative, and back to zero again. The electrical component is perpendicular to the magnetic one.

The relationship between these two components is easier to see if we assume that Figure 2.1 represents just the magnetic component. Then, if you turn this book so that the edge of the page is toward you, the same diagram will represent the electrical field. Whenever the strength of either the magnetic or the electrical component is at its maximum, the other is at its minimum, so that the total field strength remains constant.

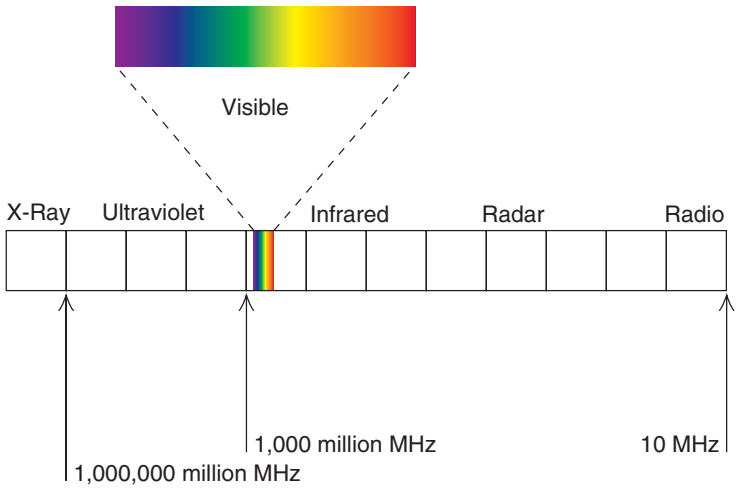
All photons travel through space at the same speed, but the electromagnetic fields of some photons fluctuate faster than those of others. The more energy a photon has, the faster the fluctuation. Human eyes can see the effect of this difference in photon energy levels and in the rate of field fluctuation.

We call the effect *color* (Figure 2.2). Red light, for example, has less energy than blue light, and so the rate of its electromagnetic field fluctuation is only about two-thirds as fast.

We call the rate of fluctuation of the electromagnetic field its *frequency* and we measure it with the unit called *hertz*, or, for convenience, megahertz (1 megahertz = 1,000,000 hertz). Frequency is the number of complete wavelengths that pass a point in space each second. Visible light is only one narrow range out of all the many possible electromagnetic frequencies.



2.2
The rate at which the electromagnetic field fluctuates varies. We perceive this variation as different colors.



2.3
This diagram shows the electromagnetic spectrum. Notice that visible light is but one small part of it.

Electromagnetic radiation can travel through a vacuum and through some forms of matter. We know that light, for example, can pass through transparent glass.

Electromagnetic radiation is not closely related to mechanically transmitted energy, such as sound or heat, which can travel *only* through matter. (Infrared radiation and heat are often confused because they tend to accompany one another.) Sunlight reaches Earth, and very much beyond, without any fiber-optic lines to get it here.

Modern cameras are sensitive to a far wider range of electromagnetic frequencies than the human eye can perceive (Figure 2.3). This is why a picture can be degraded by ultraviolet light, which we cannot see in a landscape, and film can be degraded by X-rays, which we cannot see emitted by a machine at an airport.

HOW PHOTOGRAPHERS DESCRIBE LIGHT

Even if we confine our attention to the visible portion of the electromagnetic spectrum, everyone knows that the effect of one group of photons may be radically different from that of another.

Examining our album of mental images, we all see the difference between an autumn sunset, a welder's arc, and an early morning fog. Even in a standard office location, the decision to install fluorescent tubes, tungsten spots, or large skylights can have a major effect on the décor of a room (as well as on the mood and the productivity of the occupants).

Photographers, however, are interested in more than just the mental images of a given lighting effect. They need technical descriptions of the

effect. Being able to describe the light is the first step in being able to control it. Or, if the light is not controllable, as is the case in a landscape or an architectural picture, describing the light implies seeing the light well enough to know whether to shoot or to wait until conditions improve.

As photographers, we are primarily concerned with the *brightness*, *color*, and *contrast* of a light. In the following pages, we will take a brief look at each.

Brightness

To a photographer, the single most important quality of a light source is its brightness. A brighter light is almost always a better light. At the most basic level, if the light is not bright enough, we cannot get a picture. If the light is brighter than the minimum we must have, then we can probably get a better picture.

Those photographers who still use film can use a smaller aperture or a faster shutter speed if they have more light. If they do not need, or want, a smaller lens opening or a shorter exposure time, then more light allows using a slower, finer-grained film. Either way, the image quality improves. Digital cameras allow for similar adjustments.

Color

We can use light of any color we please, and very strongly colored lights frequently make an artistic contribution to the photograph. Nevertheless, most pictures are made with white light. However, even this so-called "white" light comes in a range of colors.

Photographers consider light to be "white" when it is a roughly even mix of the three primary colors: red, blue, and green. Human beings perceive this combination of light colors to be colorless.

The proportions of the color mixture may vary to a great extent, and people still cannot perceive any difference, unless they have the different light sources side by side for comparison. The eye can detect a very slight change in the color mixture, but the brain refuses to admit the difference. As long as there is a reasonable amount of each primary color, the brain says, "This light is white."

Digital cameras make the same automatic adjustment to color that the brain does, but often not as reliably. Photographers must therefore pay attention to the differences between various white light sources. To classify variations in the color of white light, photographers borrow the *color temperature scale* from physicists.