

PUTTING THE SCIENCE IN FICTION

EXPERT ADVICE FOR WRITING WITH AUTHENTICITY IN
SCIENCE FICTION, FANTASY, & OTHER GENRES

EDITED BY DAN KOBOLDT

FOREWORD BY CHUCK WENDIG



DEDICATION

To those who work or teach in S.T.E.M. fields.

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INTRODUCTION

by Dan Koboldt

Science, medicine, and technology have starring roles in a wide range of genres, most notably science fiction, but in other genres as well. Unfortunately, many depictions of technical subjects in literature, film, and television are pure fiction. This is perhaps not very surprising, since most writers don't hold advance technical degrees or have years of laboratory training under their belts. Furthermore, popular myths about scientific and technological concepts have pervaded mass media for decades.

Public misconceptions are especially common in the field of genetics, which happens to be my area of expertise. Most often, nonexperts tend to simplify the concepts of genetic inheritance to the point where first-degree relatives are expected to have the same eyes. Or hair. Or nose. Also prevalent is the idea that someone's entire future is written in his genetic code (à la the 1997 SF thriller *Gattaca*). In reality, genetics is usually more complex than most people realize, and there's so much we don't know. I felt it was my duty, as a scientist and SF writer, to try to help others avoid these pitfalls in their own writing.

So I wrote an article for *Apex Magazine* called "Eye-Based Paternity Testing and Other Human Genetics Myths," which debunked some of the worst of them (simple inheritance, mutations being "good," etc.). The response to that article was astonishing. I began asking people who worked in other disciplines to share their expertise. And so the Science in Sci-fi blog series was born. Each week, I discuss the scientific, medical, or technological aspects of science fiction with help from an expert in the field. Over a few years, I gathered a wealth of material, much of which you hold in your hands.

The forty or so contributors in this anthology represent a wide array of scientific, technological, and medical expertise. They've collectively endured more than one hundred years of graduate study in their chosen fields so you don't have to. They won't bore you with dense treatises on the latest scientific theory. Instead, they're going to cover the fundamentals of each topic, addressing common misconceptions and offering tips on how to get the details right. In other words, they'll teach you just enough to be dangerous.

This book aims to be a reference for the genre fiction writer. While your story doesn't have to adhere to every scientific fact—it is *fiction*, after all—a basic understanding of biology, physics, engineering, and medicine empowers you to create more realistic stories that satisfy even the most discerning readers. It will not only help you write realistic, compelling technical elements (and avoid common pitfalls), but might provide the seeds of new story ideas by showcasing the current state of the art. Whether you're writing about mutant monsters, rogue viruses, giant spaceships, or even murders and espionage, *Putting the Science in Fiction* will have something to help you craft better fiction.



PART ONE

RESEARCH LABS, HOSPITALS, AND REALLY BAD WAYS TO DIE

HOW TO ASK AN EXPERT

By Eric Primm

Stories require a delicate balance between too much and too little world building. Authors must always know more about their fictional setting than the reader, but the story needs only the information necessary to make the reader believe it is real. Authors research and research and research a subject necessary to their stories to increase the verisimilitude. One possible research method is asking an expert, and the following tips will help you ask more efficient questions.

PREPARATION

When seeking information, make sure to contact the correct expert. As the world gets more and more technologically advanced, professions become increasingly specialized. For example, while engineers have general knowledge of other fields, an aerospace engineer probably won't know the answer to a chemical engineering question. Just as no one would go to a doctor to learn why a car engine is rattling, they also wouldn't go to a mechanic for a flu shot. Specialization matters. Therefore, seek an expert with experience and knowledge in the relevant field. If your "go-to" expert can't help, it's acceptable to politely ask if she knows anyone who can, but the author needs to respect the expert's right to say no. Finding the correct source is as important as finding the information itself. Some questions are general enough that the expert may not need graduate-level knowledge to explain some basics, but the author should follow up with an expert who understands both the basics and the complexities of the subject. For example, a doctor may be able to explain how brake systems work, but it's best to verify that information with a mechanic who knows for sure. Just like precision jobs need the correct tool, a smart author needs the correct expert.

How the question is asked matters as much as the information you are looking for. Requirements analysis is one phase of project planning. This is an attempt to clarify what is really needed. In the example question "Would water, telephone lines, and other utilities function in a postapocalyptic world without a major power grid?" the requirement is information about how utilities operate. Information about utilities or the definition of a power grid is unnecessary to

fulfill the minimum requirement. You could likely get to the needed information with a more general question—“How would utilities and power grids function in a postapocalyptic world?”—but it’s a less efficient use of time and the expert’s expertise. By understanding what is really needed, you can create a succinct question that allows the expert to provide the appropriate answer. Only meeting the minimum requirement leaves more questions and more information to wade through.

FILL IN THE BACKGROUND

To avoid a vague answer, provide the expert with a little background information. Details direct the expert toward a response that best fits the story. The example question defines a requirement: utility function. But many different methods of failure will cause nonfunctional utilities. As the question stands, there are too many unknowns for a useful answer. This isn’t to say it’s a bad question; it’s an example showing how laypeople often communicate with experts. While the requirement is how utilities function, the phrase “postapocalyptic world without a major power grid” is vague and needs clarification to determine whether utilities could function. In other words, the cause changes the answer. For the example question, clarification of the following questions changes the story as well:

1. What does “without a major power grid” mean? Does this mean that the power stations are no longer working? Or are the power stations working but the “grid” itself—the wires and transformers—are somehow destroyed?
2. What caused the power grid to go down? For example, a hacker shutting down power generation plants has different physical consequences than if an electromagnetic pulse (EMP) is the cause of the apocalypse. Whereas a hacker can shut down the generation of power, an EMP will fry nonshielded circuits in all electronics. Massive tornadoes could tear apart the wires while missing the power generation stations.

A plot synopsis is not necessary to answer the question well. A sentence or two should suffice. The expert doesn’t need to know about the terrorists’ years of being dosed with LSD by the CIA to understand why they distributed the zombie plague upon the world. But the expert does need to know that the power plant doesn’t work because instead of doing their jobs, the uninfected workers chose to hide out in their local Costco to wait out their eventual death. (In this scenario, the power plant would eventually shut down, and the electricity used in the utility plants would shut off at some point. But the grid is not affected, and the wires in-

side Costco are not harmed. Thus, with a few generators, the last humans in Costco can party like Prince did in 1999.) Be careful of providing too much plot detail because red herrings work well for the story, but not for research.

THE RESPONSE

Expect to receive more information than will end up in the story. An expert is an expert for a reason; he has invested time and effort into his chosen profession. The information provided will contain nuggets that are important for the world building but may not be necessary for the story. Remember that you need to know more than the reader. It's your job to figure out what is and isn't pertinent. If necessary, ask the expert whether she believes a certain piece is necessary to support the story. For example, in the power grid question, you could ask if Faraday cages would shield electrical equipment from an EMP blast. In answering that, the expert might note that the cage is made from copper. Is that really important? Maybe—it depends on how you use it. Ultimately, the author determines what ends up in the story, but more information allows for better, more realistic choices.

You should not expect a one-stop solution. Asking an expert isn't as easy as googling an answer, but it's an opportunity for a more holistic knowledge than just reading a Web page. Follow-up questions might be required to get the answer that works. If so, patience on both sides is the key. Ask for clarification where needed; this may lead to more questions. By asking an expert, a deeper knowledge of the subject is possible.

Depending on how much information is needed, the expert may point you to a different resource. Experts don't know everything and use resources to bolster their own knowledge. Part of becoming an expert is learning how and where to find the correct information. Take advantage of this by asking for books, articles, websites, etc. on which experts rely. Then, the expert can clarify specific questions about information found in the sources. Going to the same sources as an expert is more efficient and allows you to ask specific questions.

If the expert's reply doesn't answer the question, it probably asked a different question than you intended. In this case, it's likely you didn't fully understand your own requirements. Asking the expert why she provided the answer she did lets you see into her process. So, the next time you ask a question, it will be clear enough for the expert to answer.

A BETTER EXAMPLE

Taking into account all of this advice, the example question from earlier should look something like this: “Would utilities function in a postapocalyptic world where major power grids were destroyed by nuclear detonations in the atmosphere? A war between Belgium and Costa Rica escalates to a global conflagration. Nuclear nations set off enough nukes to ensure that the entire surface of the earth is bathed in EMP. Would cell phones still work? Would home faucets have running water?” Another example might be: “Tornados rip through the middle of Kansas, shearing all power lines between Opolis and the Wichita power plant. Would utilities function if all power transmission lines were destroyed?”

To answer the question, utilities require electricity. So, if the power goes down, water will only flow for as long as the pressure in the pipes remains because the pumps will be without power. The electricity required to power switchboards and server farms will eventually run out, leaving phones useless. (For the EMP scenario, all the circuits would be fried by the magnetic blast, thus, nonfunctional.) Either way, if the electricity stops flowing or the paths that the electricity travels are damaged, the ending is the same.

Asking an expert is a powerful, interactive research tool for an author. It can help speed up fictional world building. Talking about ourselves is a universal human trait, and experts are no different. Most enjoy spreading knowledge about where they excel and are willing to help educate others. For fiction, the best use of an expert’s knowledge is to make the author think deeply about the story. Because in the end, the more thought-out the author’s world, the better the story.

RESEARCHERS GONE WILD

By Gabriel Vidrine

We've read it before: mad scientists, weird science, and horrific experiments. Or maybe it's heroic scientists working in state-of-the-art laboratories who produce miracles in minutes. Both of these portrayals of science are misguided; research just isn't done that way. Here are some common myths about scientists and research.

MYTH #1: EXPERIMENTS TAKE A FEW MINUTES

We're all pretty familiar with *CSI: Crime Scene Investigation* (the books are actually better than the TV show, in my opinion; Max Allan Collins and Jeff Mariotte are fantastic writers). The criminalists collect their samples from the crime scene, get them sent back to the lab, and within pages (or minutes) are getting their results. Of course, to hold a reader's interest, an author can't really say six months go by while Nick, Greg, and Sara work other cases and wait for the lab to work through the backlog to their samples. But that's really what happens.

Science takes time. Even a fairly simple experiment can take days. Gene sequencing? Even with the best, most advanced equipment, it can take hours. And that doesn't include the backlog, which can stretch that time out to months.

MYTH #2: SCIENTISTS ARE GREEDY AND HAVE NO MORALS

I find this one to be personally insulting. How many books have been published that paint scientists as greedy, amoral jerks who run whatever experiment seems likely to gain them the most money? How many books have an apocalypse caused by the release of a deadly virus by a careless or crazy scientist?

Hey, come on people, scientists are just like anyone else. We go to work, do our jobs, and collect our paychecks. Most of us aren't in it for the fame (haha!), riches (HAHA!), or the power to destroy the human race. We do it for the science. News flash: Science doesn't (usually) pay that well.

MYTH #3: SCIENTISTS DO RIDICULOUS, ILLOGICAL EXPERIMENTS FOR FUN

Ever wonder why scientists are putting human genes into plants and animals? No, it's not for fun, or because we're amoral, weird, or evil. The reasons depend on what gene we're talking about, but there's almost always a logical reason, like trying to understand cancer or improving the food supply. "Frankenanimals" or "Frankenfood" are not "part-human" or "part-animal," though some mice are considered "humanized" (due to the expression of human-like genes in some tissues).

This does not mean that the strawberry you are eating is part fish. DNA is DNA, and a "fish" gene is not inherently "fishy" any more than any of your genes are fundamentally "human." There are many gene sequences, called *conserved*, that are extremely similar across multiple species, so the DNA itself is not human or animal.

So while that strawberry is expressing a protein normally found in fish, it is not "part fish." It's not ridiculous to put some gene into an animal or plant it normally wouldn't be found in; that "fish gene" actually protects that strawberry from a killing frost and has nothing to do with "being a fish." Scientists don't do ridiculous experiments. There's not enough funding for that.

When I read Kim Harrison's *Dead Witch Walking* (Harper Voyager, 2008) I nearly threw the book across the room when I realized her apocalypse was caused by an attack of the killer tomato. While it is true that animal and human genes are used in plants or bacteria (and yes, sometimes animals like mice or rabbits), it is not true that a human virus put into a tomato plant can kill the vast majority of humans on the planet.

Proteins from viruses can, and have been, expressed in tomatoes and other plants. But there is no scientifically valid reason to grow a full human virus in a tomato. There are human cell lines designed for that (this is called *in vitro* culture, where cells are grown in flasks, which is much simpler than growing an entire organism, like a tomato).

GETTING RESEARCH RIGHT IN FICTION

1. YOUR SCIENCE—AND YOUR SCIENTIST!—SHOULDN'T BE RIDICULOUS

Think like a scientist! There needs to be a reason why the experiment is being done. If you can think of no reason other than "My bad guy is a scientist, so he needs to do icky things like putting human eyeballs on tomato plants," you may need to rethink your plot. Your villain should have more dimension

than that anyway, and scientists aren't typically evil geniuses bent on world domination.

2. SCIENCE SHOULD BE (A LITTLE BIT) BORING

Yeah, it might not be fun to read, but it will be much more realistic. Think of that time kind of like when your characters are going to the bathroom or eating lunch. Readers know it happens, but it doesn't need to be in the story in detail (or even there at all). Plan your plot to include the time it takes for major discoveries (years, not hours), and if it just drags the story down, rearrange the timeline so your characters have already put in the work before the book starts.

There are ways to work pacing into science so the exciting stuff happens in the story. But make it clear that it took a lot of time and work to get there.

3. ASK A SCIENTIST OR DO RESEARCH ON YOUR OWN

Look up what the scientific method is and why it's important to science. Researchers are happy (usually) to share their knowledge about research methods, so contact one with questions. The Internet is now one of the most powerful research tools on Earth. While Wikipedia or Google itself might be of limited use, Google Scholar can link you to many published research articles. You might need a license to access them (try your local college library), but many are available for free.

All of the articles on PubMed Central are free and available to anyone and everyone to access. If you think someone might have done research similar to what you are writing about, check it out, and make your fiction much more realistic! (And keep scientists from chucking your book across the room.)

PROPER LAB TECHNIQUE

By Rebecca Enzor

Whether it's the first semester of chemistry class in high school, any laboratory course in college, or the first day at a new job, every lab experience starts with a class on proper lab technique and safety. Which means, if you have a character who works in a lab, she's gone through at least three lab safety courses to get there.

At the environmental testing lab where I work, we have an entire week of safety courses before we ever step foot in the lab. My job is to test water, soil, and tissue samples for radioactivity, pesticides, herbicides, and polychlorinated biphenyls (PCBs). There are a lot of steps in this process—a lot of places where it can go dangerously wrong—and we have to have defensible data in court (sometimes needed by our clients), so I have to be very careful when I'm working. Which is why it bugs me so much when scientists in books and movies have a *laissez-faire* attitude toward how they use their equipment.

What are some of the things you need to keep in mind when writing about lab work? Let's start with proper protective equipment (PPE).

PROPER PROTECTIVE EQUIPMENT (PPE)

Most books and movies get at least the basics of PPE right. After all, what's a scientist without the white lab coat and oversized safety glasses? And gloves, because no self-respecting scientist is going to touch anything in a lab without gloves on.

But did you know that you can't wear tennis shoes in some labs? My lab requires shoes with leather on top, preferably slip-on, so if you spill something on them you can quickly slip them off. You wouldn't want to have to untie your shoes when there's hot acid all over the laces. Not to mention the hot acid will seep through the cloth quicker than you can slip the shoe off, even if you don't have laces. And if you spill hot acid anywhere on your clothing, trust me, the first thing you're going to do is strip it off as fast as you can.

Does your character have long hair? She'll have to put it in a ponytail. Long necklace? Leave it at home. Deep V-neck shirt? She should wear something else. Expose as little skin as possible. Speaking of exposing as little skin as possible: Never wear a thong in the lab. It's *really* embarrassing when you spill something

dangerous on your pants and have to rip them off, only to leave your butt cheeks flapping in the breeze for all to see.

Just trust me on that one.

LAB EQUIPMENT

Once you're properly clothed you can get to work, but depending on what you're doing, you might need some special equipment. Working with chemicals? You're going to need a fumigation hood. (Unless you're isolating radium-228, which they'll let you do on a counter with no hood, even though the acetic acid will give you a headache.)

The most important thing to know if you're working with a fume hood is *don't stick your head inside*. The whole point of the fume hood is to capture the dangerous fumes, and if you stick your head in there your nose will capture the fumes instead. There's also usually a glass or plastic moveable "door" on the hood that you want to keep closed as often as possible, not only because fumes will escape but because it's a great barrier to all those dangerous chemicals you're working with. When you add chemicals to other chemicals, they often splash—sometimes they explode. If you don't want them to explode all over *you*, there needs to be a barrier.

Other things you might be working with?

- **ACID DISPENSERS:** These are pumps that fit on top of 1.5-liter acid containers and are used to squirt the same amount of acid with each pump (anywhere from one to ten milliliters at a time). Definitely use these inside the hood with the barrier between you. Most acid containers are glass and can shatter if dropped (the exception being hydrofluoric acid, which eats through glass and is stored in plastic containers).
- **CENTRIFUGES:** These spinning machines are used to separate sediment from liquid by drawing the sediment to the bottom of the centrifuge tube. Make sure they've stopped before you go sticking your fingers in there.
- **SYRINGES:** I'm pretty sure you can figure this one out on your own. Don't stab yourself (or anyone else) with the needle.
- **GLASSWARE:** From beakers to flasks to graduated cylinders, these are easy to break and cut yourself. Bonus points if there's acid, radioactive contamination, or other nasty things on the glassware to infect your cut! They also make an excellent amount of noise when your character gets fed up with everything and throws them on the ground.

- **VACUUM FLASKS:** These cone-shaped glass flasks are used to separate two liquid layers, or a layer of liquid from sediment that's too large to fit in the centrifuge. When these explode they make an awful noise and an even more awful mess! Never mix acids and bases in a vacuum flask and always make sure the flow is good before you start using them. You can usually tell if the flow is good by the sound: if there's a blockage there will be a higher pitch than usual. Unfortunately that's something you have to learn through practice.

And then we get to pipettes, which is the whole reason I wrote this article on proper lab technique.

HOW NOT TO USE AN EPPENDORF PIPETTE

I'm sure most of you have seen, or at least heard of, James Cameron's *Avatar* (as opposed to the *Avatar* TV show where the characters can control the elements). That movie came out in 2009—almost ten years ago—and there's a scene in it that to this day bugs me. Sigourney Weaver is using a pipette, which is a tool we use in the lab to transfer a specifically measured amount of liquid from one container to another.

You hold the pipette upright, depress the plunger, stick it in the liquid you want to transfer, and release the plunger. It sucks the exact same amount of liquid up each time (we calibrate the pipettes daily so we know that they are, in fact, sucking the exact same amount of liquid up each time). You then place the pipette tip over the container you want to put the liquid into and depress the plunger again so all the liquid exits. It's a super easy and mostly fail-proof way to get the exact same amount of liquid into each sample. You could do the same with a syringe, but there's a lot more human error involved in a syringe and it takes much longer.

So Sigourney Weaver is using a pipette, gets the appropriate amount of liquid into it, and then *turns it upside down*. Friends, I have done this exact same thing by accident, and do you know what happens when you turn a pipette full of liquid upside down? The liquid goes into the pipette's mechanism and you can't use it anymore because it's contaminated. Part of the liquid can squirt out, too, which is very dangerous if you're using it to transfer radioactive sources or acids. I've done this—by accident—more times than I'd like to admit. And pipettes are expensive. My boss probably hates me.

I can tell you I'm not the only one who's noticed this, either. If you Google "Sigourney Weaver, pipette, Avatar" the first hit is a YouTube video entitled "How Not to Use an Eppendorf Pipette" and then pages and pages of scientists like myself gasping in utter horror over her misuse of said pipette. It would be funny if I

wasn't still horrified all these years after watching a science fiction/fantasy film. Obviously this one stuck with me.

RESPECT FOR SCIENCE

The last thing you need to know about writing a scientist in a lab? We care about what we're doing. We check constantly to make sure we're safe and the people around us are safe. We make sure we're doing every step correctly, because a misstep could lead to bad data ... or an explosion. So never, ever, ever write this sentence: "Scientists have their heads in the clouds and don't bother with maintenance."

Because I will throw your book across the room.