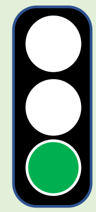
Good Science: Know When to Ask Questions

The following are **Green Flag** characteristics of good science and are adapted from Farnam Street Media[1]

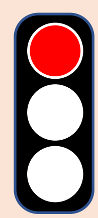
Green Flag Characteristics



- Published by a reputable journal
- Peer reviewed
- Researchers have relevant experience and qualifications
- Part of a larger body of work
- Doesn’t promise a panacea or miraculous cure
- Doesn’t claim to prove anything based on a single study
- Results are interpreted cautiously and reflect study design, people studies, and sample size
- The study is well presented and formatted
- The interpretation doesn’t confuse correlation and causation

The following are **Red Flag** issues that should be asked, and be a trigger for further questions to clarify the legitimacy of the science & research[2]

Red Flag Questions:



- Are the study findings applied to the same type of people that were in the study?
- How would this study square in the real world?
- Who funded the research?
- How well does the study design support casual inference?
- How big is the study?
- How do the findings relate to other studies on the same topic?
- Is the interpretation based on the study finding’s or does it go beyond them?
- Does the interpretation use emotional appeal instead of science?

---

[1] 2021: “How To Spot Bad Science”, , https://fs.blog/2020/01/spot-bad-science/, cited 30/Jun/2021):

[2] Source: “Good Science vs. Bad Science”, J. Belluz, 10/Jan/2013, https://www.macleans.ca/uncategorized/good-science-vs-bad-science/, cited 3//Jun/2021):

This information compiled by Casey Grant, P.E., of DSRAE LLC. This is Version 1.3, generated on 27/August/2021.

Why this is important for the fire service and other stakeholders.

Fire Department leadership and members, stakeholders, and similar end-users are continually faced with innovative technology, programs and approaches that claim to address specific needs and gaps. These innovations are important for improvements and advancements. Progress is critically dependent on these innovations.

But as new materials and activities are implemented, or existing and/or obsolete equipment replaced, there are potential downsides, especially when they are not developed using evidence-based science – or 'good science'. These are contingent on multiple factors. Examples of potential downsides are:

Limited Resources (e.g., money, time, etc.) which must be used as effectively and efficiently as possible by end-users.

(e.g., investing in equipment or approaches that are ultimately never realized due to hidden costs such as high maintenance or minimal reliability)

Hidden negative characteristics can ultimately solve one problem but create another, possibly worse.

(e.g., fire station decontamination methods that could cause unintended heat stress on individuals).

Premature Action could require the replacing of equipment that are unsuitable to fully solve the motivating problem (leading to substitution regret and replacement anxiety).

(e.g., non-fluorinated fire fighting foams that solve one barrier like fire extinguishing performance but ignore other barriers like health impact or environmental impact).

Ineffective results can sometimes cause harm in unanticipated ways, and create new problems.

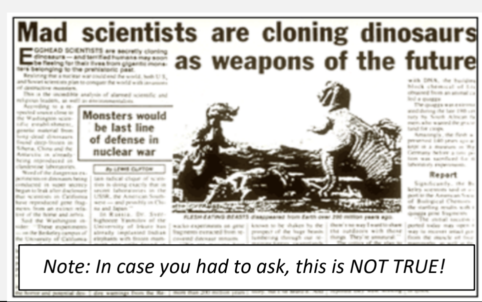
(e.g., unproven health screening processes with high rates of false positives, creating challenging emotional distress and related implications).

What is "Good Science"?

While there are multiple definitions of 'good science', one is offered here because of its simplicity, universality, relevance, candor, succinctness, and humorous backdrop. The following is taken from the University of California Berkley Museum of Paleontology[3]

What is "Good Science" (University of California Berkley Museum of Paleontology)***Disclaimer:*** *This is a gross generalization of what science is about; science is actually much more complex than how it is described here, but this will give you a basic background if you need it.*

i. **Science is a human endeavor.** Scientists are all human, with the typical faults and foibles that non-scientists have. Sociology, politics, psychology, and similar aspects of human nature all have a profound influence on how science is conducted.



[3] 2021: "How To Spot Bad Science", , https://fs.blog/2020/01/spot-bad-science/, cited 30/Jun/2021)

ii. **Science follows certain rules and guidelines.** Exactly what these rules and guidelines are depends on what area of science a specific scientific procedure falls within. The **scientific method** (i.e. hypotheses are formulated from observations, and theories develop from these hypotheses), sometimes cited as the one and only way that science is conducted, is not the paradigm that scientific inquiry must always follow, but it often is the best objective procedure. Science is not so monolithic and mechanical; it defies simple explanations, just like many other human endeavors.

> ***Red Flag**: Claims on social media, no matter how popular or viral, are NOT a credible source for "good science".*

iii. **Facts versus opinions.** An important distinction to make clear when science is an issue is the difference between fact and opinion. "Fact" in a scientific context is a generally accepted reality. Facts are always open to scientific inquiry, as opposed to an absolute truth, which is not, and hence not a part of science. Hypotheses and theories are generally based on objective inferences, unlike opinions, which are generally based on subjective influences. For example, "I am a humorous person" is certainly an opinion, whereas "if I drop this glass, it will break" could best be called a hypothesis, while "the Earth orbits the Sun," or "evolution occurs over time," or "gravity exists" are all today considered to be both facts and theories (and could possibly turn out to be wrong). Opinions are neither fact nor theory; they are not officially the domain of science (but don't go thinking that scientists don't have opinions — they are only human, and opinions often help to guide their research). Thus, science cannot directly address such issues as whether God exists or whether people are good or bad.

> *We live in an age of information and misinformation. Modern communications enable the proliferation of any message, true or untrue. Always ask questions to clarify the credibility and legitimacy of your focused subject.*

iv. **Science generally uses the formulation of falsifiable hypotheses** developed via *systematic empiricism*. Hypotheses that cannot ever be disproven are not real science. Hypotheses are generally formed by observing whatever it is you are studying, with the objective of understanding the nature of the subject (this is systematic empiricism). Many scientists hold the belief that a hypothesis cannot ever be proven, only disproven. This especially holds in historical sciences like paleontology, where a time machine would be the only true way to prove a hypothesis.

> *Consider the analogy of Boxing with how the credibility of science is tested. The true champion never hesitates to enter the ring to test credibility. The false champion talks big but avoids the ring and credibility tests.*

v. **Acceptance of scientific ideas is based on a process of publication and peer review.** To become a legitimate theory (but still not established fact), a hypothesis must be subjected to the approval of a scientist's peers and published in an accredited scientific journal. The goal of peer review is to maintain the integrity of science by filtering out poor-quality articles or badly designed studies. Most significantly, this helps to maintain science as a process rather than a gradual accumulation of facts, ever creeping forward towards omniscience. Theories tend to persist until a better theory is proposed and gains broad acceptance, rather than new theories being proposed for every tiny fact that is deduced. This fact and the influence of human nature on science are running themes throughout this section of the UCMP on-line museum.

> *What is peer review? Peer review is essential in academia, government, and other forums that demand good science. This is the scrutiny of work by others in the same field. For more on Peer Review, consider the publication: "Final Information Quality Bulletin for Peer Review", OMB M-05-03 from the U.S. Government Office of Management and Budget, issued 16/Dec/2004.*

vi. **Replication is also vital to good science** — for the scientific community to accept a finding, other investigators must be able to duplicate the original investigator's findings or have similar findings in different populations. Thus, you cannot make up your data; other scientists must be able to follow the same methods you used (whether experimentation, mathematical calculations, formulating major concepts, measuring data, or whatever) and come up with the similar or supporting results.

> *As an example, fire test standards addressing building construction conform to other ASTM standards on repeatability and reproducibility, which require intra-laboratory validation within defined tolerances.*

Fundamental Principles of Good Science

Good Science is conducted by Researchers who:

1) Are not directly influenced by financial gain
2) Submit to rigorous peer review
3) Are governed by ethics.

Elaborating on each of these principles, we have the following:

1) Good science is not directly influenced by financial gain. Everyone in every arena operates according to the resources that directly support them. To remain sustainable there has to be some compensation provided back that support the research programs, and all involved. But is the overall support (e.g., money) for the research driven by a profit-making venture or similar motive? If yes, a pause and more questions are warranted. Note that arrangements are possible to utilize blind funding, in which the sponsors have no say in how the funding is used by researchers (i.e., "no strings attached"). But the "perceived optics" are very important, and the overall effort should not raise concerns of bias (i.e., pass the "smell test"). Sources of funding should be fully transparent, with research deliverables based on a sound technical and scientific basis that adheres to the overall purposes and goals. Importantly, in addressing these concerns we need to remain supportive of new innovation that promotes forward progress and widespread resolution of problems. We similarly need to remain sensitive to the dynamics of a competitive marketplace, and never unduly cause a restriction of trade in an open marketplace unless done so unequivocally for the collective good (e.g., health and safety) while clearly grounded in good science.

   Generally speaking, researchers are seeking solutions to real-world problems, and as such are often on a pathway that provides research deliverables to focused interest groups (e.g., fire service stakeholders). But they should do so without pre-conceived bias and should conduct their efforts based on objective, relevant and fair methods.

2) Good science submits to rigorous peer review. Credibility of research results is key, and the traditional method of assuring this quality control is through peer review. But what does it mean to have peer review? Governments, academia, professional societies and similar entities generally have strong requirements for peer review. These requirements are not necessarily universal, and generally speaking the larger the peer-review audience the more rigorous and robust the test for credibility. Publication in legitimate, recognized and respected peer review journals is a quick way to acknowledge the credibility of the science behind a research project.

   As an example of the differences of peer review, local governments reflecting small populations may have lesser requirements than international government bodies reflecting large populations that usually have very intense review processes. A specific example is IARC, under WHO and United Nations, which arguably provides a worthy example of the gold standard of peer review on cancer issues.

3) Good science is governed by ethics. Are the researchers governed in any way by ethics and other forms of overall guidance that support overarching core values and the better good. These are hallmarks of most government, academic, professional societies and certain other recognized entities. These organizations generally have strict codes of conduct that provide a clear moral compass and address important sub-issues like proper citation, human subject testing, plagiarism, disrespectful or unprofessional conduct, and multiple other issues. These are hallmarks in how their constituents are expected to conduct themselves as representatives of their respective organizations. Researchers absent of these are worthy of higher levels of scrutiny.

   A key foundational item for all Engineering Societies is their Code of Ethics. An example is the SFPE Code of Ethics for the Society of Fire Protection Engineers.