Wondering Why: Limitless Curiosity

Sara Patterson

Abstract What is science? For me it is curiosity and the study of almost anything. I believe that in contrast to an engineer or a physician, as a scientist I ask questions that I have no idea as to what the answer is; and then I try to solve the mystery. It can be inspired by the need to know more about something to inspire or facilitate new solutions to challenging problems (such as understanding plant growth in order to improve yields of food crops under dynamic climate conditions) or specific knowledge regarding how things were created or work.

1 Motivations: How I Developed an Interest in Science

I grew up in Cleveland Ohio in a suburban neighborhood with excellent public schools. On weekends, the family would attend church and then travel to one of the Cleveland Metropolitan Parks to hike and have brunch. I recall learning how to identify fungi, plants, birds and many creatures. In the summer we would spend five to six weeks traveling across the US—hiking, camping, and exploring the National Parks. I recall fishing with my dad in the early mornings, grilling fresh caught wild salmon and even a huckleberry pie that we cooked in a reflector oven. We would periodically stay in a motel so all could shower and my father would disappear for a couple days of business meetings. It was pretty idyllic and firmly established my love of the outdoors.

Once home, I would wander in the nearby woods and collect plants to transplant to a small space in my parents' yard where I was permitted to have my own garden. Often, I would experiment in making dyes from different plant parts including petals, leaves, stems and roots. I remember collecting campanula, bloodroots, violets, dandelions, and buttercups. Some worked well and others not so great: an auspicious beginning to my scientific inquiry. My interests expanded and I remember becoming obsessed with mushroom and fungi as well as hunting for salamanders in the woods.

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When unable to go to the woods, I would climb to the top of the tall sugar maples in our yard and read for hours in the upper boughs.

Once every couple months, the family would travel to Indianapolis to visit my mother's parents. My grandfather was my hero and still is. He was a quiet soft-spoken journalist who was passionate about curtailing nuclear proliferation. I'd never known about his story as a journalist and only after he died did I learn that he had witnessed the atomic bomb tests and how they had impacted his life. I had known that he'd grown up in the foothills of the Appalachian Mountains and worked many jobs to help support the family. One job included working on a commuter train that resulted in helping and befriending a philanthropist who ultimately funded his college education. As a grandfather, he told stories of giants, trolls, and fairies and how they lived in the woods hidden from view. My grandfather and I often took walks in southern Indiana collecting geodes and crayfish, and on these excursions he enhanced my knowledge and respect for nature. There were fruit trees and a small vegetable garden at the house. I had two cousins who lived with my grandparents and their dad. We would always publish a mini-newspaper with columns by each grandchild and news of the visit. My grandmother had been a home economics teacher and I recall the kitchen always filled with incredible smells.

In high school, I volunteered teaching math in inner city Cleveland schools, demonstrated in protests against the Viet Nam War, participated as a Nader Rader and even boycotted the local grocery store. My sister shared many of my views and although our parents were often embarrassed, they accepted our differences with grace. I recall buying a backpack with some Christmas money that I had received and the angst and dismay my parents expressed. They couldn't understand how a young woman would want to go camping or trek across the east coast on a bicycle. I was always pushing boundaries, and did surprisingly well in all subjects in school: and thus I felt that the world was open to me. Little did I really understand about discrimination whether it is family, class, religion, race or sex.

As an undergraduate, it was a time of dissent in the United States and the Viet Nam War. I avoided the sciences and leaned heavily to the humanities focusing on intercultural studies, religion, and majored in English. My curiosity and love of learning was undiminished and I obtained a teaching certificate for K-12. I also took some upper level graduate courses in English, but unfortunately was dissuaded by the focus on critique of critiques of recognized literature. Although science and math were always easy subjects for me, I narrowly believed that the only careers for those who studied the sciences would be engineering, military, or the medical field. My goal was to become a teacher and share my love of learning and it seemed as though the humanities would be the path.

That path was redirected after listening to a talk by Frances Moore Lappé, who wrote *Diet for a Small Planet.* Thus, my Senior Year in college, I took as many science and math courses as possible and applied to graduate schools in the plant sciences. I was going to "help solve the world's food crisis and protect the environment". It was an exciting time socially and politically. Many of us were starting to worry about the environment, becoming vegetarian and conservationists. My family and friends had known me as the outdoors tom-girl with her own small garden and curious about everything, so they were not surprised.

So, I moved across country from the East Coast to the Pacific Northwest and began graduate school in the plant sciences at Oregon State University. The work was relatively dull but did not subdue my love of Botany or growing food crops. Shortly after finishing my Masters degree, I spent two years in Seattle teaching Introduction to Horticulture, Botany, and Plant Tissue Culture at a Community College. A newborn and a partner looking for a job limited my opportunities; and after two years in Seattle, I found myself in Philadelphia. There I also garnered a part-time faculty position at a small four-year college an hour north of Philadelphia. The commute was long and with a young newborn at home, I looked for work closer to Philly and found a research position in a plant science lab at the University of Pennsylvania. I combined my field skills, my plant tissue culture and basic plant biochemistry and was quickly introduced to the rapidly evolving world of plant molecular biology and protein tools. It was an exciting project transferring the *Bacillus thuringiensis* (BT) insect resistance gene into tomato and analyzing the stability across generations and functionality. I was in the right place at the time, as I was one of the few scientists with a strong plant biology background as most plant molecular biologists at that time came from animal, yeast or bacterial studies. The project introduced me to the world of patent battles, depositions, and what it felt like to be drilled by five Monsanto lawyers.

Again we moved, and I followed my husband to North Carolina State University where I started my Ph.D. work on *Zea mays* (corn). Unfortunately things did not work out there, and a year later I found myself in Madison, WI at a Biotech Company as a single parent. But life's ups and downs can be a blessing and the disappointing Biotech job evolved to a new partner, more kids, my Ph.D., and a faculty position at the University of Wisconsin. Research was exciting as the field was rapidly changing and we cloned and characterized the first receptor kinase, TMK1 (Chang et al. 1992). I diverged from the lab's main research and began my inquiries on abscission and cell separation using Arabidopsis as a model plant. It was by chance that one of the mutant plants that I was characterizing had a delayed abscission phenotype and provided the avenue to a unique niche of research that was the foundation of much of my academic career.

Somehow, I've balanced family life, friendships, gardening, baking bread, research, teaching, and mentoring over the last several decades. In general, it's been a joy with new discoveries at many steps. I've been fortunate to be able to travel and maintain contacts with colleagues around the world and enjoy their foods and culture. All of life has been an adventure for me. And, sharing those moments has been so much of the journey.

2 Work Done: My Personal Scientific Approach

How to describe a personal approach? I like to think of each experiment as an empty canvas with an infinite number of possibilities. Often the question is unexpected, as it may have evolved from new observations. While a young graduate student at Oregon State, I found myself making novel observations and asking unexpected questions. While researching disease resistance in green beans, I identified progeny from random field crosses that generated beautiful bright red edible bean pods. Unfortunately these were hybrids and the brilliant red pods were lost after several generations. Even years later, I tried to repeat the cross but I never determined the parentage or the genes responsible for the flavor and coloring. Sometimes, I believe my diverse background provided a naivety and openness to see things differently and ask questions outside the mainstream. Being a scientist seemed so much easier than studying English literature or Philosophy as I always felt I could challenge my assumptions and determine if they were incorrect.

For me, scientific inquiry takes passion, commitment, technical expertise, lots of energy, attention to detail, and a bit of serendipity. One must add “wonder” and curiosity. The Scottish philosopher Adam Smith wrote of “wonder” as the “quality of experience with a distinctive bodily feeling—‘that staring, and sometimes that rolling of the eyes, that suspension of the breath, and that swelling of the heart’” (Prinz 2013). And for me it is so true, as there seems to be nothing more exciting than the unexpected discovery. Descartes and Socrates also wrote of “wonder” as a motivation for philosophical inquiry. So, for me as a scientist “wonder” has always motivated me: leading to questioning, and the willingness to challenge the dogma and consider new perspectives.

Another critical factor inspiring me as a scientist is love of learning and being able to convey that love, curiosity and wonder to others. The desire to understand and learn new concepts rather than memorize facts is so important. Not only does this develop a deeper understanding, but leads to new questions and further exploration of ideas. Similarly, one should never hesitate to admit lack of understanding. I was an English major who embraced science upon graduation from college and thus, I had many gaps in my knowledge. While this could initially be viewed as a handicap, I believe it was an asset allowing me to feel less encumbered about my lack of understanding or knowledge.

My experiences in the field of abscission, the loss of organs from a plant, were amazing. It was an open book, as previous scientific research had been quite focused with researchers using limited approaches. I was able to use the model plant Arabidopsis and develop a genetic approach and use newly established molecular tools. We could order mutants that had identified gene knockouts or create an individualized population of plants by mutagenizing with multiple approaches. These tools included chemical mutagens, mutant populations created by random DNA insertions using Agrobacterium and irradiation. My lab applied an array of approaches characterizing plants based on morphology, physiology and genetics. I always emphasized the importance of “knowing your organism” to all my students. Even in daily walks, I find that I repeatedly see new things that have always been there. Sometimes it is the direction from which I have approached, while other times it might be changes in sunlight or shadows, or just pausing in a new location. Most recently, I discovered that I could see Mt. Rainer, the highest volcanic peak in the contiguous United States, on my daily walk if I paused and looked southeast. I had been taking this same walk for almost two years and never seen the mountain. It was awesome, and a fact I now share with dozens of neighbors. In the lab, similar experiences can be identified as I find that often when we take a fresh look at results with an open mind, we may see new things. And, this can lead to new questions and discoveries.

Viewing scientific inquiry as a process rather than a single task is a valuable lesson. Learning versus memorizing, the ability to accept uncertainty, to consider new approaches, the willingness to be challenged as well as patience were critical to my success as a scientist. Careful experimental design (limiting variables), persistence, resilience, learning from each mistake or unexpected result, designing new experiments, and ongoing critical reflection are all part of the process. Again, patience and careful reflection.

As a scientist, not only do I love asking questions, learning new things, and discovering the unexpected; but, I also am motivated by inspiring others and sharing my scientific approach. Opening new doors to students, postdocs and colleagues is a critical part of my approach. Sometimes presenting one's scientific findings at a meeting easily does this. This not only leads to learning moments, but also can help establish collaborations, and develop respect and long lasting friendships. These friendships may be departmental or within the University, but often are across borders around the world. The ability to inspire young scientists and exchange ideas with others that have diverse backgrounds has been an incredible benefit throughout my career.

Last, I believe that the scientific process should ultimately lead to unifying concepts resulting from inquiry and reasoning. Data is collected using a variety of techniques and hypotheses are formed. These hypotheses are tested by new experiments and additional data collected as needed. Often the simplest explanation may be the best, yet it is always important to have an open mind. This belief is shared by many scientists and has guided many; and examples include Descartes, Galileo, Newton, Darwin, Einstein and dozens of others. For more on scientific philosophy read "Why Simplicity Works" by McFadden 2021. In many ways my scientific inquiry has always followed the principles above, but it has also been spiritual—looking for meaning.

3 Science Today and Tomorrow

Science and its future can sometimes be incredibly discouraging. There are challenges for funding; failed experiments; disrespectful and unethical colleagues; 'dead-wood', lazy and seemingly incompetent lab members; and public disdain for science. Yet despite these challenges, the future of science continues to be promising as new high-impact and transformative research advances are made. In the US, this process is threatened by the public's eroding trust in science, lack of transparency, and lack of oversight. Despite the gloomy picture, I believe that scientific inquiry will always continue to make advances.

In the US, the competitive process for federal funding of scientific research is generally considered quite good. Foundations such as the National Institute of Health (NIH) and National Science Foundation (NSF) have provided funds for scientific research for decades. NSF was established in May 1950 and its mission was to promote basic scientific research. And, although NIH was established in 1887, funding of basic scientific research has routinely declined over the last century. However, in 2002 a new directive to fund basic science was implemented; thus providing additional funds for new transformative science. While I applaud the U.S. funding agencies, I might suggest more frequently replacing some of the permanent program officers in the funding agencies, as sometimes they develop a narrow vision after years at the job and biases towards specific investigators or universities. Too many researchers receive funding because they previously received funds and their publications are greater in number. This can all be a consequence of the fact that since they have previously received funding, then they have more people to conduct the science, and thus more publications. There are often limited reviewers willing to critique the science and some have prejudices against a competitor, an institution, or implicit gender or racial bias. As scientists, we can step-up by volunteering our services to review and advocate for revised guidelines to guarantee impartiality.

Securing funding for basic scientific research has always been an uphill battle and federal budgets often swing with administrations; and yet, I continue to be hopeful. Communication with legislators and the general public has contributed to general interest and increased funding. In addition, the elimination of wasteful government spending or pork-barrel projects would free up additional funds. Senator William Proxmire of Wisconsin was well known for his "Golden Fleece Award" which he bestowed upon what he considered the government's most wasteful spending. Similarly, the automatic yearly allocation of funds to a plethora of areas should be revisited more frequently and more carefully evaluated. Also, encouraging for the future of science is that philanthropic support for basic sciences has been increasing. Significant sources include the Gates Foundation, the Paul G. Allen Family Foundation, the Rogovy Foundation and individuals such as Jeff Bezos and MacKenzie Scott. The University of Wisconsin College of Agriculture and Life Sciences lists over 600 sources for funding including federal and private foundations. So, despite challenges to obtain funding, resources are actually increasing and more and more projects funded. Many are truly transformative, and the National Science Foundation website has a list of the "Nifty 50" or discoveries that have become familiar to most of society. Some of these include the discovery of antifreeze glycoproteins, understanding the effects of acid rain, the value of circadian rhythms, plant growth and heavy metal and salt resistance, and edible plants as vaccines. As society embraces basic scientific breakthroughs such as these, the appreciation for science will continue to expand.

However, there is also a critical need to review and update ethical guidelines as well as provide more transparency to the public on the research that is funded. The integrity of scientific research is dependent upon the design, presentation and interpretation of experiments; and scientists need to be trusted and honest. Environmental ethics are also a concern and as scientists we must recognize our responsibility to the community and society. Unfortunately, not all scientists are ethical and institutions need to do a better job training our young scientists. This can include required classes, workshops and discussion groups. Recognition of other's rights, undue pressures for publication, funding, and international recognition can be addressed. Additional issues to be discussed can include fabrication of data, taking credit for another researcher's data, observation of misconduct and whistle blowing. Universities need to establish strong guidelines and ethical review boards for inquiries regarding misconduct or mistreatment of researchers. Although a slow process, this is happening across the US.

If science will continue to thrive, it will be important to question the reliance on quantitative metrics as these are subject to manipulation and bias. Metrics including number publications, citations, patents, and students trained can have significant effects on hiring, successful grant writing, and promotion. Having been in a department where many of the faculty publications were incremental, it was confounding and frustrating to compete when one's goal was a quality publication rather than just quantity. The good news is that here are initiatives to curtail the promotion of quantitative metrics including the San Francisco Declaration on Research Assessment (DORA).

Historically Americans have voiced objections to certain types of research. As a scientist, I have worked at several places where protests turned violent resulting in building destruction and loss of life. At the University of Wisconsin protests have emerged repeatedly against specific research. The bombing of Sterling Hall in 1970 targeting the Army Math Research Center, killing one and injuring others, forced many to re-evaluate attitudes towards military research and trust in the administration. Subsequent protests on campus over brain trauma research with simians and studies on deadly flu viruses using 'gain of function' technology have further deteriorated community trust. Public oversight in the U.S. has been consistently eroded since major policy changes in 2017. In the US, both Francis Collins, the Director of the National Institute of Health, and Anthony Fauci, Director of the National Institute of Allergy and Infectious Diseases, feel that gains from this research far outweigh the risks. This opinion is not shared by all scientists and there are many who believe that poor experimental design or accidents could inadvertently create lethal pathogens. The distrust in science by much of the American public clearly contributed to recent vaccine hesitancy and rejection of predicted consequences of climate change. We must curtail this trend of increased secrecy and less rigorous ethical review and insist on more transparency.

My faith in the future of science is both my enthusiasm as a scientist and the incredible breakthroughs made in the last decade. Discoveries about the brain and sleep are revolutionary and previously unimaginable. Similarly, insights into the human gut and its role in health and susceptibility to disease are equally impressive. For, the astronomer, one might cite the recent photos of black holes. As scientists continue to collaborate and exchange ideas across borders, these discoveries will flourish. It takes incredible persistence as well as creativity, skill and luck to develop new ideas and redirect. But, the scientific advances made in the last several decades are truly impressive. I believe that despite all the challenges; science will always continue to advance, as the quest for meaning is so fundamental to humans.

4 Advice to the Next Generation of Scientists

My advice to a young scientist is work in a lab (or field work) for an extended time as an undergraduate or a technician (maybe more than one, but best to get an in-depth experience rather than jumping lab to lab). When looking for employment, consider volunteering, as once a mentor sees your commitment and zeal, they will often find a hidden source of funding. Writing grants and presenting your research no matter how inconsequential it may seem will also serve you well. I was in my 40s when I finally went back to get my Ph.D.; and I had worked in 5 different labs, so I felt that I knew what research was about and different approaches. I knew that I wanted an advisor that would allow me to make mistakes while learning, yet one who would engage in heated discussions and theorize. My research experiences were fairly broad and I'd also taught large University classes, classes at a small college, and classes at a Community College. I'd mentored over fifty individual students and I loved it all. I wanted a Ph.D. and stayed in academia so I could keep doing what I loved: definitely not for the salary.

I always want to say that one needs to "taste it" if you go on for a Ph.D. because it is hard and challenging work, and low pay. And, when I went back for my Ph.D. at the University of Wisconsin, I had the bug. Groups of us would huddle as one of our colleagues developed a Western, a Northern or waited to see if our plants had new phenotypes. We were all excited! Long hours at work might have annoyed my family, but not me as I pushed ahead or waited eagerly for the next result. It was not uncommon for me to go back to work at nine or ten in the evening and stay well past midnight after a family meal and a couple hours of down time. Designing and performing experiments, and experiencing "awe" were motivating factors. I also had the goal of becoming a professor, managing research projects, and inspiring new young scientists.

My energy was boundless as the work was fun. But, I also tried to never forget about my priorities in life. These will differ amongst people, but balancing commitment to family, friends and taking care of oneself is incredibly important and difficult. My approach was to give each "TASK" my full effort, thus being more efficient and creating more time for additional undertakings. Choosing a career is a balance of life's objectives; and choosing quality of life combined with security are often in the forefront. It is also important to realize that there is seldom a single path; and the best path will be that which permits you to blossom and flourish.

I selected the program of study based on the research possibilities, the degree requirements, and the promise of funding. I did not compare program differences in terms of funding, as for me most important was being inspired by the research; and while there were differences it seemed that over time these were fairly minimal. So, I recommend deep discussions with the potential advisor, discussions with students in the degree program, and a visit to lab meetings if possible. The publication record of the faculty is useful and conversations with current and past graduate students can always help understand what you'll be encountering and what to expect. Websites today allow one to easily see where previous lab members are and gage if that is a direction you would want to pursue.

Similarly the selection of what University to attend is incredibly important. As the Director of the Science and Medicine Graduate Research Scholars program at the University of Wisconsin from 2008 to 2019, we strove to provide a home and a community for minority underrepresented graduate students in the sciences. Thus, finding a lab and community that will allow you to feel welcome and safe is so important. In addition, finding an advisor or site of employment that will provide opportunities for professional development, networking, and additional resources on campus or in the scientific community should be considered. As individuals, we can have many mentors; so don't worry about finding all the desired qualities in one advisor. In selecting a research advisor or graduate committee, consider the strength that each faculty brings to the committee and your comfort discussing challenges with each member. All of these criteria may not be immediately obvious when considering an institution or later employment, but always remember what characteristics you value in colleagues and mentors.

Having been an English major, I had many deficiencies in undergraduate classes, so I can't emphasize how important it is to embrace those gaps in learning and expand one's understanding. Not only will it facilitate understanding of concepts, it often leads to new interests and new questions. While being self-driven and independent are strengths, never rule out asking for help. Recognize your weaknesses as well as strengths and ask questions. And at the same time, be thoughtful with questions and consider whom you are asking, the timing, and the clarity of the request and the method of communication. Always deliver questions as a request and not a demand.

In summary, as a young scientist keep an open mind, attend meetings, present, network, and always strive for the truth. Time management is critical and complete focus or 100% effort on each task will serve you well. Just as not worrying about having enough time with friends while working, I also recommend not worrying about where the next job will be as it's critical to focus on the question at hand. Resilience, persistence, and learning from mistakes are all valuable tools. There is so much anxiety today as one worries about the future. There is no denying that there is uncertainty in the world, but recognizing the value of embracing the present is important. There are many problems that we cannot instantly solve and thus prolonged worry about these issues will just consume your time. As a retired professor, a parent and a grandparent, I tell my family "baby steps". Be satisfied with incremental progress and don't expect instant transformative research results. So, work hard, play hard at times, and always remember life priorities.

References

Chang C, Schaller GE, Patterson SE, Kwok SF, Meyerowitz EM et al (1992) The *TMK1* gene from *Arabidopsis* codes for a protein with structural and biochemical characteristics of a receptor protein kinase. Plant Cell 4:1263–1271
McFadden J (2021) Why simplicity works. Aeon 11 October
Prinz J (2013) How wonder works. Aeon 21 June

Sara Patterson Professor Emerita of Horticulture. University of Wisconsin, Madison. Patterson's research focused on understanding the mechanisms that regulate cell separation and adhesion in floral organ abscission in Arabidopsis. Patterson also applied this work to economically important crops such as cold-hardy grapes, olives, and fonio (a West African orphan grain). Patterson was also the faculty director of the Science and Medicine Graduate Research Scholars program, a fellowship program for underrepresented graduate students.