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What Are the Research Needs in Science?

I believe the real issue today is: "Is it worth your time?"

Brad Keister:

The discipline of science, I think, is consistent with God's creation of the world and of humanity created in his image. Furthermore, the roots of modern science and the scientific method owe a considerable debt to Christian thought, notably the Reformers. For example, seven out of ten of the founders of the Royal Society were Puritans. The burden of proof, I believe, is for the non-Christian to demonstrate philosophically a consistent world view which allows for a system of inquiry based on rational thought and experimentation that leads to new knowledge. I think that the secular community has co-opted the scientific method as its own and treated it as a victory in the progress of science over religious-based world views. This idea is important to say and is also important in determining choices of research topics and areas of need.

The nature of "call" reflects on the purpose of research and on gauging potential impact. A related issue, particularly in universities, is the education of students, which is a role you will play if you remain in the university. Let's apply the five conference bases to areas of research need.

Basis 1: *We are stewards answerable to God for his creation of minds and other resources.*

Basis 2: *Do all that we do to the glory of God.*

Combining these two bases, I see two issues. One is the nature of "call," and for that I would recommend the book, *The Call* by Os Guinness. Guinness stresses that we are called to *be* rather than to *do.* I think that diffuses the issue of what you should do or what topic you should choose. I see two main purposes of basic research. First, basic research provides the potential for ultimate, practical applications. That may not drive what we do, but we can be confident that some of the things we do will have practical applications. Second, basic research can change the way we think about the world. For example, the taxi driver may be interested in knowing how super novae work. Thus, everyone can participate in some of the outcomes of basic research even if it does not have immediate practical application. Basic research is consistent with our charge to understand the world and be stewards of it.

The other issue is the potential impact of your chosen work. Need is one element, but I don't think it is the main issue. I believe the real issue today is: "Is it worth your time?" You're going to spend eight, ten, or twelve hours a day on a basic research area. Never mind whether anybody gives you any money for it or whether it's trendy. Is it worth, before God, spending that much time for two or three years? That's really the first question.

Basis 3: *Be disciples of Jesus as you go about doing good.*

This involves exhibiting the fruits of the Spirit. How would Jesus as professor, compared to Jesus as carpenter, apply his trade? One issue involves being a source of grace for those around us in the university community. Being a source of grace is actually a rarity if you spend any time in a university, particularly with people like support staff, undergraduates, and other people who are sort of at the bottom of the food chain.

The choice of research topics should involve its educational value and long-term

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benefit to the student. The time and energy spent by a professor with students goes to the heart of the university's value system. The university's value system is not in the speeches of the president or in alumni magazine articles, but in how tenure decisions are made and where money is spent. Money is often at the heart of what drives the university. A young faculty member has to make very, very difficult choices because he or she won't be able to do it all, but the university expects it! I think this is more significant as a choice than "Do I work on super novae or neutron stars?" I think God cares deeply that you do one of them, but I'm not sure that it matters to God which one you choose.

Basis 4: *Resist the strong temptation to choose as research questions only those areas that are most easily funded or trendy.*

I think there are two ways of looking at what governs trendiness. One way is to see if the research area is mission related, which means that an agency sees societal benefits that affect their charge. The other way is to determine its potential for intellectual impact.

Some attractive trendy subjects, such as string theory, need only a few people. However, other areas open up because they are entirely new and provide many opportunities for exploration. In those situations, Christians can have a real impact on shaping the field, not just through seminal papers, but by saying, "Here's where we think it should go," by the kind of research that they do.

Beware of the trap of searching for a distinctly Christian research topic. That gets back to why I made the original statement as to the scientific method having Christian roots. If you then turn around and say, "Oh no, I want to do something that's distinctly Christian; I don't want to do something that's like my colleague down the hall," you may undercut the whole basis for why you're doing it. The most likely overarching goal of most universities is money intake in contrast to things like truth, education, and other issues. Decisions about hiring and tenure really pinpoint where the university's value system lies and that is the toughest thing you may have to face as a faculty member.

Basis 5: *The rising concern about technical developments in our day and the lack of ethical directions for them.*

Let me recommend three books. One is *The Call* by Os Guinness, to which I've already referred. Another is George Marsden's, *The Soul of the American University*, which traces the movement of many institutions in America from Christian roots to a secular basis, which he calls "the scientific method." I would add that the final step is the focus of many research universities on money. The third book is *Pasteur's Quadrant* by Donald Stokes. It's about the impression most people have that there is a one-dimensional scale between basic research and applied research. So, if you're in basic research you are at one end of the scale. If you're in applied research, you're at the other end of the scale. You have to pick between the two and move around. Stokes argues that it is a two-dimensional plot: (1) the contribution to basic knowledge; and (2) the contribution to ultimate end use. You can be in some sense positive on both of them like Pasteur, or you can be strong in the basic end of things like Bohr, or you can be strong on the end use like Edison. It's not an either/or situation. I think that's important because it eliminates the fallacy that if you're doing basic research then you're not doing full-time Christian service because there's no end use to it. Basic research is a legitimate thing to pursue if it's within the will of God and if he provides an open door for you.

One of the things that struck me at a *Following Christ; Shaping our World Conference* in Chicago, was the last lecture by N. T. Wright. Wright called on Christians, as perhaps their biggest task, to work alongside their colleagues by struggling where they struggle and thereby understanding the pains and the dilemmas of their field. Part of your credibility in some sense is earned by engaging that community and by working alongside them rather than pulling yourself out and arguing with them.

Martin Price:

The group with which I work, Educational Concerns for Hunger Organizations (ECHO), is a Christian nonprofit organization in the warm part of southwest Florida, where we can grow tropical plants. Our goal is to give technical backup to missionaries in the national church and, in fact, anyone. We're especially pleased when missionaries are working through the church with people in poor rural communities who almost always struggle to make a living under difficult conditions.

While I was working on my doctorate in biochemistry from Indiana University, I had an opportunity to visit a missionary and some people with whom he worked. I was quite taken by the level of need. It was hard to get that out of my mind. I returned to my work at the laboratory, where I was trying to look for the mechanism of an organic reaction involving the addition of an ion to a complex molecule. Now there's nothing at all wrong with that kind of research, but I came to the point where it wasn't where I "was at" anymore. I wanted to find a more direct way to meet human need. Gradually that evolved into the question of "How can I as a scientist help the poor?" Foreign missions became a special concern of mine. So you might say that my mid-life crisis began at the age of twenty-four! That's a good time to start because now at

How can I as a scientist help the poor?

fifty-seven, I'm utterly happy and fulfilled. However, I had twelve pretty rough years, making some wild lurches in career direction. I remember praying once, "I don't mind being a fool for Christ but what if *he* thinks I'm a fool." I wasn't always certain which kind of "fool" I was.

What would science look like in helping the poor? We're so blessed by science, not just because we study it, but because it affects our lives. It is generally true that we receive benefits of science because we pay for them or a government pays for them or some third party pays for them on our behalf. To help the poorest of the poor, the benefits need to be something that will cost them nothing. So what kind of thing can you come up with in science where the poor can get benefits from it that will cost them nothing? At first it might sound hard, but it's really pretty easy to think of examples.

One example is to develop a nonhybrid seed that is resistant to certain diseases or yields extra heavily in the tropics. This has been done many times. If the new seed introduced to a small farm community is productive and liked by the people, then a positive situation exists. The farmers only need to multiply the seed and continue to use it. If the seed is really good, a missionary couldn't keep it from spreading around if he wanted to. That's one way for science to help the poor. I'm a little frustrated that many agricultural scientists at universities are looking, not to develop nonhybrid breeds, but to develop either something on contract that will be patented (because it's hard to get money to do research) or a hybrid seed that will be sold to someone.

There's still lots of opportunity in plant breeding and the development of plant varieties. That's one of the principle things that ECHO is doing—not developing plants—but acquiring them, putting them in our seed bank, and then distributing trial packets for the workers around the world to evaluate. In that sense, we're helping missionaries to be experimenters. We can't just start with something totally new to an area and safely introduce it. We have to evaluate it first to see what it will do.

Let me give you a really good example of scientific research that has helped the poor. A graduate student from Tanzania, working at Michigan State University, was looking at the problem of a certain weevil that got into beans. It is very frustrating to go through all the hassle of growing food, protecting it, and storing it, and then when you take it out of storage, to find empty bean shells! That was commonly happening. So this student decided to investigate how the little weevil got in through the hard shell. She found that the weevil rubs with a part of its mouth against a certain spot. But it can't do that on just one bean. It has to prop itself up against another bean or against the side of the container and then work with its little mouth parts for about 19 to 24 hours to get through the bean shell.

Then she hit on a very simple idea to control the beans: Roll the bean bag. So two or three times a day for a few weeks they rolled the bean storage bags so that the weevil, who has enough energy to work for about 28 hours, was whirled in chaos! The beans flipped everywhere and the weevil had to start on a new bean. It can only do this for 28 hours and it takes 19–24 hours to get through. They found that the bean loss plummeted by that simple technique. That is research that can benefit the poor.

Since part of me is still a biochemist and a research scientist, I like to collect ideas. I think one of the hottest ideas concerns the use of a coconut as an incubator or fermentation chamber for bacteria cultures. Gardeners know about an organic method of insect control that uses "Dipel," a bacterium that is very widely sprayed on crops. One bite of it is enough to give a fatal intestinal disease to a caterpillar. Another strain of the same bacteria will kill mosquito larva. A Peruvian scientist discovered that he could use a coconut as an incubation chamber for this bacterium. Inject the bacterium in the coconut, leave it for a certain

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number of days, and then open the coconut and pour the coconut milk in mosquito infested water to kill the mosquitoes.

The obvious question, which to my knowledge no one has ever researched, is: "Can you do this with the other strains of bio-insecticides?" This is something that anybody should be able to work on who has a reasonably equipped laboratory at a Christian college. It would be a lot of work. There are many unanswered questions dealing with length of storage, exactly how to do the procedure, and so forth. But if it works, we could simply send one little bacteria packet to a community somewhere and have somebody trained to be the local insecticide maker—maybe in a micro-enterprise. Then they are off and running.

What can I do that's significant in terms of research in the setting of a small college?

I'd be glad to talk to any of you who might be considering a move to a Christian college where the issue might be, "What can I do that's significant in terms of research in the setting of a small college?" I'm emphasizing Christian colleges because I don't think universities are going to pick up on this. Doing research in a small Christian college requires that you be more nimble! Small colleges typically have low research budgets. However, significant research projects can be done on a low budget. At Geneva College where I taught for four years, we required our graduates in chemistry to do a senior research project. When I inquired what my budget was, the answer was, "Oh, $200 or $300." But we had a lot of instruments and a well-equipped stock room. You really can do significant research even at that level.

Problem-solving research in big universities tends to be interdisciplinary. If a researcher receives a grant for do something and then discovered that help was needed from another department, it wouldn't make the department chair real happy to learn that the research was going to give half of the grant money to somebody else. Whereas, if you are on low budget research to begin with, nobody cares. You could even collaborate with other Christian colleges.

I will share a final example. Dr. Rolf Myhrman, at Judson College, creatively picked up on an interesting research idea. I was recently at an invitation conference for the Rockefeller Foundation in Honduras. Dr. Myhrman was there. The conference subject was the exact theme that he was working on with some other scientists. He had developed a method to analyze for the presence of a particularly harmful substance in an otherwise wonderful bean. Several Third World scientists also presented papers there. Probably three-fourths of them had their research backed up by Myhrman doing their analyses in his lab. Was it elegant? No, it needn't be elegant. Did it require him to show his brilliance? No, but he has a mission statement to use his laboratory and his students to help the poor. He does most of the work in the summers and he has a "post bachelors research associate" position that brings in young graduates full of energy and enthusiasm who will work for less money and get a lot done.

Mark Foster:

When I was first thinking about research needs in science, I came also to the question of "call." I recommend reading the book *Courage and Calling* by Gordon Smith that was published in 1999, by InterVarsity Press. Smith makes some of the same points that are in Os Guinness's book.

Let's focus on more discipline specific thoughts. I think the most important issue is not whether a given research project is fundamental or whether it's applied, but whether it glorifies God and serves others out of the love for Christ. When I was trying to think of different topics in the material science area that would be good areas for Christian researchers to work in, I used five different "sieves" in my thinking process.

1. Our Fundamental Research Interests

I'd like to make the argument that it's not wrong to study hot topics if we're studying them for the right reasons. I think there's a lot to be done in the area of materials that are in systems of very small dimensions, that is, atomic or near molecular dimensions. This happens to be an area that interests me because I study surfaces and interfaces. (Certainly the topics that I'm suggesting here represent a strong influence of my own bias and my own expertise.)

A second general area is complex materials and phenomena. My research approach, which has been very successful, is to take difficult problems and break them down into simple problems with model systems. But there are some problems that simply can't be tackled that way. They have to be tackled with their complexity right up front. As a person who's not too familiar with biological sciences, it strikes me that many biomaterials problems and biophysics problems have a complexity that simply can't be avoided. With recent advances in computational capabilities and with characterization techniques, it's now possible to go at some difficult phenomena and systems that we haven't dealt with before.

The third area, again an area of particular interest to me, is how molecular architecture affects the behavior of large molecules, macromolecules. With advances that have been made in synthesis in the last ten to twenty years, we can now control the architecture of molecules in ways that

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we couldn't before. This offers very interesting possibilities for controlling their behavior. I think that's still an area where there are opportunities to get in at the ground level.

2. Technology-Driven Research Areas

For the second "sieve," I ask myself what areas might be of interest for technology-driven research. I would submit that quite a bit of materials research is actually driven by other technologies. To make advances in technology, people come to materials scientists and ask for thus and such a material. Two important areas of such technology-driven research have been technologies for transportation and technologies for information.

I think the most important issue is not whether a given research project is fundamental or whether it's applied, but whether it glorifies God and serves others out of the love for Christ.

In transportation technologies, I see the opportunity for the stewardship of scarce fuel resources. If I'm going to do a good job of stewarding fuel resources, I would work on high temperature engines. That means making high temperature ceramic components for engines because, if I can increase the engine temperature, I can improve the thermodynamic efficiency. If I'm going to increase the temperature of the engine, I need high temperature plastics and elastomers for so-called "under-the-hood" applications. I could also work on lightweight batteries, not only for transportation that is electrically driven, but also for transportation with internal combustion engines. Lightweight batteries improve fuel economy. And then, finally, I go to an area touching on my own expertise and interests: creating plastic parts for automobiles and for many other things requires the use of a lot of fuel. By tinkering with the architecture of the molecules in that plastic, it may be possible to reduce the amount of fuel required to do the processing. That's another way to save fuel resources.

In information technologies, I see the opportunity for the stewardship of finite time. Information technology calls for ever denser storage media and the ability to read and write things faster and faster. This would be particularly helpful in combinatorial science, where we generate tremendous amounts of data in short times that have to be stored and recalled in a reasonable way. This will require some advances. But I think that it is important as a Christian to remember that data, even large amounts of data, are not the same things as knowledge and wisdom. We want to keep those ideas distinct as we think through the real implications of what our work in information technology might be.

3. Research that Serves Others

Moving to the third "sieve," what are some obvious areas where I as a materials scientist can contribute to the well-being of others? One area is making materials for improved safety. My family and I recently survived a house fire and we learned that the flammability of vinyl house siding is a big problem. There's important work to be done there. The issue of low flammability garments is another area where work could be done, as is reduced flammability for aircraft interiors. If there's a fire on an aircraft, people have three minutes to get out, that is, if they survive the toxic combustion products. In the medical area, we need a more puncture resistant material for gloves, materials for prosthetics, and materials to contact the body or bodily fluids.

I echo remarks that I've heard earlier in the conference. It's not enough for Christians to avoid or to say no to certain kinds of technologies, like stem cell technology. Rather Christians need to proactively come up with alternative and better approaches.

4. The Study of Natural Materials

My fourth "sieve" is that God said that everything he made was good. So every material I could study would be a legitimate research object for a Christian. I think there are not only important technological lessons to learn, but there are lessons for me in looking at every material that God has

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made. One lesson is that God makes things which are beautiful, and it is wonderful to look at the beauty of God's nature in what he has made and the materials he has made. A second lesson is that God loves complexity. One example is collagen which has a wonderful structure that gives it particular properties dependent upon its complex hierarchical structure.

5. Peculiarly Christian Topics

My fifth "sieve" is intentionally provocative: "Are there materials science topics that I might take on as a Christian that are somehow peculiarly Christian?" When I was looking at the biblical records to see if materials science was a legitimate area of research, I looked at the materials used in worship. Should we still be using the same materials we have always used to worship? If I'm to give God the best of what he has given me, should I as a materials scientist perhaps think of new materials that might address needs in worship or that I might simply make to give God glory? What does it mean to have a need for a new material? Certainly worshiping God is a legitimate reason to create a material. In the Old Testament, God gave certain materials that were to be used specifically in worship.

In a more problematic sense, are there Christian ministries I could assist in materials science? Those that come immediately to mind are frontier missions, disaster relief, and medical missions. Certainly frontier missions have benefitted from a number of technologies that have been developed due to driving forces which were not Christian. But isn't world evangelization an important enough reason to develop specific materials that support frontier missions?

Much of materials research requires tremendous capital investment. Are there investors who would be willing to put money into work for specific kinds of materials for missions? It strikes me that maybe many missions require materials that aren't so complex or technologies that aren't so prestigious. Unfortunately, that might be one reason why I'm not so interested in what my medical missions colleagues have in mind. I can think of two possibilities which would be good topics. One would be puncture resistant gloves and membrane materials for water treatment or remediation.

By rushing through this long list, I was trying to generate a laundry list of ideas in materials science, some of which overlap a little bit with some other areas. I think God does give us, in the freedom of his grace, an opportunity to study many different topics. There are some good questions we can ask when we consider the details. I think in particular it would be nice to think about what opportunities there are for materials research in areas that are specifically Christian.

Brent Seales:

I've also thought about worship from the information technology or computer science point of view. I see two emerging trends in information technology and computer science. Let me give key words to these trends and some examples so that you can apply them to other areas.

Two Emerging Trends in Information Technology and Computer Science

1. Scale

The first trend I see is one of scale. Scale in information technology wasn't an issue in the early days because just getting anything to work was the basic idea. So, for example, people didn't think a lot farther than the emergence of the arpanet, a network that worked originally at getting two machines to talk to each other. Now, when you think about networks, we're worried about having global access to the Internet, which is a completely different ball game from the original intent of how the network had emerged. Therefore, some redesign is important to handle the emergence of this idea of scale. It applies to other areas of information technology as well, such as data management. Your data archives are huge, and even if you're not in information technology per se, you generate huge amounts of data that you need to save and then mine in a very rapid way. The number of users, the number of machines, everything is just rapidly increasing in scale. Let me give you two examples of large scale problems that I think are moving the field forward and are really interesting for us to consider.

One large scale problem is the global Internet, and a second is the extension of the Internet to space. I heard a talk by an information science leader this week at the opening of our new building. He is recognized as one of the early developers of IP, which is the protocol underneath most of the network technology now. He's working on a protocol for deep space communication anticipating that interplanetary probes will communicate and when they do, they'll need a long haul type protocol to make that communication possible. So in the area of large scale problems, we need to think beyond where we are and push technology in that direction.

Another large scale idea is massively parallel computation e.g., Napster. It's an idea that emerged from college kids wanting to play music without buying more CD's. It's an example of harnessing parallel computation effectively and efficiently. This is an area of ongoing research. I heard someone at the University of Wisconsin say a while back that parking garages may well become the super computers of the future because, when people drive their car to work, they could plug it in, and the computers

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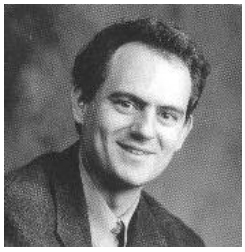
inside the cars could be harnessed all across the nation as a super computer. That's an example of another emerging trend toward large scale systems and the problems in the systems that are important to examine.

2. Convergence

A second trend is convergence. I call it vertical integration, which is bringing to bear separate solutions and technologies into a complete system to solve a very big problem. I have a couple of examples, one of which is the human genome project. Lots of different technologies combined and lots of different solutions for this technology were working together to try to build this data base, solve problems and then provide some meaningful results from those problems.



We need to position ourselves to be ready to make [ethical] policy statements, to develop those concerns, and then articulate and enforce them, if necessary, as part of the community at large.

The second example I'm interested in is the digital library. Emergence of a digital library is something that has been funded by the National Science Federation only over the past several years. A lot of movement in that direction has been done and there are various parts of the digital library problem where convergence is necessary to get a viable solution. For example, when you enter data into a digital library, you have to consider how that happens, the quantity of data that you generate, and how to manage it. Then there are steps in the middle that need to converge in terms of bringing new technology to bear. The final piece is actually looking at the data. Do you really want it to come into your small computer screen and try to look at a piece of data that's been digitized in incredibly good resolution? It's like going to a museum and being given a tiny peephole to observe everything that's in the museum. It's not very satisfying. So new technologies have to be brought to bear there and I call that convergence. Those two general trends encompass a lot.

Three Ethical Concerns

Along with those two trends I'd like to identify some ethical concerns and policies and impacts that will have to be assessed and developed. This is especially critical, and a Christian perspective is really important. We need to position ourselves to be ready to make those policy statements, to develop those concerns, and then articulate and enforce them, if necessary, as part of the community at large. There are three issues here to which I want to point.

1. Privacy

The first issue is privacy. There is going to be a huge impact on all of our privacy in the next ten to fifteen years, especially related to the world wide web and the development of the Internet. Homes will have a large number of individual Internet addresses. For example, your furnace will probably have an Internet stack so that the power company can observe the proper function of your furnace and so that you, from a remote site, can control your thermostat. All of those things are well and good. Your refrigerator may have networks so that it can communicate to the grocery store that you're getting low on milk. There is a prototype refrigerator already that has an email screen connected to the Internet. You may be wearing monitors for health concerns that transmit data across the Internet to your doctor. But imagine how bad that could be if your health monitor Internet stack told your refrigerator not to open the door because you're on a diet! That's a humorous example of a bigger problem about losing privacy and in the process maybe marginalizing people and reducing all of us to objects for the bean counters. You can imagine all kinds of other reasons why people would use data that they would collect from those kinds of things, so we'll need strong policies about how to move forward.

2. Data Provenance

The second issue is data provenance [data origin]. Repositories of data will become the library, the foundation of our research, and the primary document. How that data changes, who changes it, who's allowed to change it, and how it migrates over time become extremely important. Policy about how to allow changes to data and how to

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track and record changes to that data will become very important.

3. Virtualization

The third issue is virtualization. Large displays, which liberate you from the computer monitor, open up a simulation world that appeals to the senses and becomes much more compelling than the kind of medium we have right now with the computer. Virtualization will make a huge social impact, not only for us as researchers, but more so for the naive user and the user who is the focus of a commercial endeavor. I think virtualization—its future impact and policy development—is going to be really, really important.

Cal DeWitt:

I guess if I were a graduate student right now, I'd be a little overwhelmed. And if I really were the graduate student I once was, I would now go down into my basement and I'd look at my parakeets. I'd look at my little aquarium and tropical fish, get my tweezers out and drop a few worms to the fish, watch them eat, and reflect on how beautiful a world it is in this little aquarium. I might reflect on what really is happening over there on the Amazon River where these fish come from. Anyway, I like to think my own experience as a graduate student, and as a pre-graduate student as well, was fundamental to doing research: to have a love for what you're doing.

This started with me at age three with my first turtle in a growing backyard zoo. My field notes, probably from my early years of high school, show I was a scientist then as well. My field notes were typed and all the scientific names were spelled properly. Keep your mind and eyes open to wonder! And record what you see.

Start with Wonder

The first thing I'd like to say to you is: Put on the mind of a student of God's creation and don't get captured by what is popular. That is your very first step. Be captured by your work as a student in God's creation. Start with wonder. I say to my students, "I like your individual research projects very much. They're absolutely the most critical thing you could be doing." The reason I say that is that you have to start where you are and you have to start with a love for what you're doing. If you love what you're doing, you will want to do it very well. If you want to do it very well, you're going to work hard to make sure you do it very well, which means you're going to consult with people. Perhaps you are one who is afraid normally to meet with another professor but you love what you're doing so much that you will make the appointment, go over, and discuss your project with him or her because research is in your heart.

Sense your Research as Being a Psalm You're Singing to the Lord

What drives you as a Christian is that your research is really a psalm that you're singing to the Lord! If you don't sense your research as being a psalm you're singing to the Lord, you have to stop a bit and ask if you are on the right page or the right verse. If you don't have the love for your research, then you have to do something to make sure that it is something that is lovable and that inspires you. If you do what you love to do, and you try then to do it very well and you do it very well, what Dad told me is true. Someone will eventually pay you for it!

However, don't first seek the money; seek the dream. If you're a geologist, go out and look at rocks. Do as I did as a boy, go out to Postma's gravel pit and pick up as many fossils as you can and put them on your dresser and wonder about them. Or do as I did when I sat for hours looking at the desert iguana and wondered how this organism really functions. How does it manage to survive in an area where surface temperatures often reach 170° F. in the summer? You have to keep shifting your feet around so as not to burn them. It's so hot you can't even pick up a screwdriver to reconnect your thermocouples to your recorder, but the lizard is living there and never sees free water. Wonder at that. I think research comes from wonder and from that wonder you want to know. If you're a Christian, you will want to do it as a psalm.

Research with Side Branches in Place or Available so that You Can Move

Another thing I would suggest: pick a problem or nurture a problem so that it will have connections to other problems so that you do not get stuck in the place you began. Many of my colleagues have produced students who are just like themselves. They continue to be just like themselves for the whole career and they produce others just like themselves. Scientists sometimes dig trenches, get in them, and then assure themselves that they are looking at the world as they look at each other. As the trenches get deeper and deeper, they fail to see the whole landscape. Do your research with side branches in place or available so that you can move. You cannot see the future. You cannot know what you're going to discover and once in a while you discover things that are marvelous simply as a result of pursuing another question. When my graduate students say, "Look what new thing I found!" I have responded, "Oh, you're going to have to redefine your question, for which this is the answer." Be ready to make those shifts.

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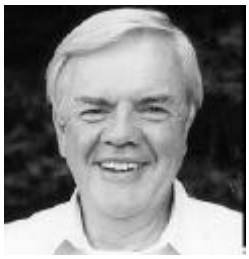

As you're doing your research, you should do it as a companion to consulting the Word and as a companion to prayer, because your research itself not only is a psalm but it is also a prayer.

Do your Research as a Companion to Consulting the Word and as a Companion to Prayer

"The earth is the Lord's and the fullness thereof, the world and all that dwell therein" Ps. 24:1. First, this brings to mind that as you're doing your research, you should do it as a companion to consulting the Word and as a companion to prayer, because your research itself not only is a psalm but it is also a prayer. It's a prayer of praise to God. Sometimes it's a prayer for persistence. Sometimes it's a prayer to make me look in the right direction so that I will be able to see what's there. If you read some of Einstein's biography you will see that he did that a lot. Second, pay real attention to some of the things you're reading in the Scriptures in the light of what you're doing. For example, you could use one of the interlinear Bibles that has Hebrew and Greek in it and find that passage in the Hebrew. It would be translated as "'*eres*' is the Lord and the fullness thereof." Then as a researcher just taking a little break, you could put your computer cursor on '*eres*' and see where all of the other verses are with that word.

Also, you can pick up your Septuagint, the Old Testament in Greek. It may give you insights to these words that are not otherwise available to you. Maybe even theologians haven't thought about it but you have because you're an investigator, a scientist. The way the Septuagint translated these words into the Greek is "the *ge* is the Lord's (i.e., geology) and the *oikoumene* and all that dwell therein." This is the model for the World Council of Churches' ecumenism. It happens to be in the Septuagint and it predates the World Council, so don't push your Septuagints off the shelf because you think they are too liberal. It's in the Bible. *Oikoumene* is translated "world and everything that dwells in it." It's the biosphere. The geological earth is the Lord's and the biosphere is the Lord's. That's the context within which we're doing our research.

Evaluate your Small Starting Projects in Light of Where You're Heading

The top research priority is biospheric physiology with integrity. Now think about that. By physiology, I mean the processes of *oikoumene*. One of the things we know is that this structure is something to which we are very strongly chained. We have become a major geological force on earth as a human species and the question we have to be asking is this: "What do we do to the earth that is the Lord's?" And if the earth is the Lord's, we have to do our research accordingly. So evaluate your small starting projects in light of where you're heading. The research and the earth is not ours. The *oekomene* is the Lord's. This answers a great number of questions we've been asking. For example, do we change our own genome so that in another 200 years we can look back at what human beings were like, now that we can see them from the perspective of post-humans, from the perspective of a genome now chosen by the market rather than by God's casting the lot? Does God make choices through Wall Street or does God make choices through the flipping of the coin or other ways? All of our research, I think, can be measured against whether this research that we're doing ultimately leads to making our psalm part of this greater Psalm.

If you're frustrated by this, get an aquarium, buy a packet of white worms, and feed fish!

Moderator:

As the panel members were sharing, it dawned on me, what an array of human variation, intellectual variation, and style variation we have seen from our speakers! That thought fills me with a great deal of hope. If the Lord has supplied folks like these to ask and answer the questions we're all concerned about and he supplied you and lots of others like you around the world, I think there's a lot of hope for the Christian community and for science. I feel more positive now than I have for a long time. ☆

Calvin DeWitt, *Ph.D. Zoology, University of Michigan is professor of environmental studies in the University of Wisconsin's Institute for Environmental Studies and director of the Au Sable Institute of Environmental Studies. He is a member of the University of Wisconsin-Madison graduate faculty of land resources, conservation biology and sustainable development, water resources management and oceanography limnology; a Fellow of the University of Wisconsin Teaching Academy; and a recipient of the Chancellor's Award for Distinguished Teaching.*

Discussion Session

Audience: *How do you maintain a sense of wonder when working on your research? What about the saying that familiarity breeds contempt?*

DeWitt: *Albert Szent Györgyi, who is a Nobel Prize winner and physiologist, wrote an essay in* Perspectives in Biology and Medicine *when he was 65 or 70. He described how he was in love with rabbits and wanted to really understand them. He began to study rabbit muscle and tried to find a straight muscle with parallel fibers. He further examined the biophyics of the rabbit psoas muscle by investigating its structural components, actin and myosin. Then late in his career, he discovered that he'd lost something, his love for rabbits! In his essay, he described trying to ascend the ladder back to discover where he lost what he lost. He also said that there were some scientific areas of great interest that he intentionally did not study so that he could maintain his sense of awe and wonder.*

I think you can maintain your sense of awe and wonder about things you really know, but Szent Györgyi discovered just what you're saying. Things became routine even though they were initially wonderful. So he kept some things unstudied so that his wonder would continue. He was like a child right on through to his death. I think that a researcher needs to be a person with childlike wonder that bubbles over when sharing information with others.

Audience: *I'd like to hear from other members of the panel about how they maintain their sense of wonder.*

Keister: *Sometimes that you have to push through a routine and finish something. There is a sense of wonder but it doesn't always carry the day. Robert Bly wrote a book that deals with various personal characteristics that one can cultivate and strengthen. One of them is what Bly calls "the warrior." He particularly gives examples of what a warrior trait is and it's not simply going into battle with a machine gun. It's things like finishing your Ph.D. dissertation. He mentions that explicitly. I think there's a place where one has to say, "Yeah, this is wonderful and all that but I have to finish it." At some level the loss of wonder is simply a consequence of "the fall." I don't know anybody in any profession who maintains wonder 24 hours a day. We all stumble, and the thorns of life come up and beat us down.*

Price: *In my work at ECHO, it is easy because we are dealing with some of the incredible living resources that God has created and put on the earth. These resources can be a benefit to the poor. I strongly suspect that there's no need for anybody to be poor if we just adequately studied the universe and learn how to make use of it. I don't believe God has put more people in the world than we are capable of feeding. In many ways, it's a worship experience when I walk around the farm.*

The moringa tree from India is one example of God's resources. The moringa tree is pretty widely spread around the world. It grows very fast, the first year to about 18 feet, stops at around maybe 30 feet, and the leaves are very nutritious. In fact, a number of people now are making leaf powder and using it in hospitals and clinics in the Third World for malnourished babies, mothers who are pregnant that have had a bad history with giving birth, and mothers who cannot give enough milk to feed their babies. If you go to a hospital, you expect to get a shot or medicine. But if you are told to eat a leaf of a tree, that might not make you too excited. The Church World Service in Senegal got amazing results prescribing moringa tree extracts. They give patients a little baggie with green powder from the moringa tree leaves and prescribed adding a quantity to baby food.

The seeds of the moringa tree can also be used to purify water. People along the Nile River discovered a formula for use years ago: mash the seed up, add mash from one seed per quart of water, receive clarified water by the next day

Peter Venable is a graduate student studying computer science at Carnegie Mellon University.

Megan Anderson is a graduate student in pharmaceutical chemistry at the University of Kansas.

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because the solids have settled down and 95% of the microorganisms have settled out with them. I still wouldn't want to drink that if I had other options, but it's a lot better than drinking contaminated water. The roots can be used as a horseradish substitute and are even sold that way in some cases. The blossoms taste about like a radish. The pods are a very popular vegetable in India. That's just one plant in God's creation!

Anthony Gerig is a graduate student at the University of Wisconsin studying medical physics.

Foster: *For me, the Christian life is life in tension. I wish that every morning I could get up with joy and wonder, but I don't. A lot of days I soldier through, and I think that's the way life is. On the days when it starts to bother me, I ask, "Am I in the wrong thing?" I'm a person who constantly asks questions and I don't like to take things for granted. If you are constantly asking questions about life, you're going to be asking questions about the things you really enjoy. Even when there is a sense of wonder and there is a sense of joy, the thoughtful life is a life of questions and a life of tension.*

Another possible point of tension is the question of family—relationships with a spouse and children. I have five children and I really enjoy coming home and seeing my 19-month-old come to the door. He's very excited to see me. I have to balance that with the enjoyment of seeing data at 2:00 a.m. from the neutron beam. I love being in the lab, but I love being with my kids. So I have to balance those loves. Maybe that's something like communication within the Trinity that we heard about earlier. God loved his Son and yet he gave him for us. I have a love for the work that I do, but I also have a love for my children. The Christian life balances various wonders, joys, and loves.

Henian Cao is a graduate student in cardiovascular genetics at the University of Western Ontario.

Seales: *Every time I turn on my Windows 2000 machine and it runs, I'm full of wonder! I started out working in computer vision and I worked really hard to try to build systems that could do intelligent things. The best vision system I ever built was my daughter. She sees better than anything I ever built in the lab and it happened a lot easier. I echo the comments about family. Whenever I lose the wonder with what I'm doing, I bring my kids into the lab and I show them the stuff we're doing. Seeing their reaction makes it worthwhile again because they love it. It brings the wonder back to me because I see it through their eyes.*

Keister: *C. S. Lewis writes about the joy that surprises you. He also writes that if you seek it on its own, you'll never have it.*

Audience: *Last spring, I read some of the writings of Richard Feynmen, a Nobel Prize physicist, who writes about joy and wonder! Books about science will tell you about the scientific method, hypotheses, testing, etc. Einstein took issue with that. He said science moved ahead by wonder and joy.*

Audience: *Aspects of my job are wonderful! There are other things that I have to do that aren't as wonderful. Often when I get caught up in those non-wonderful things, I start to question the bits that are really wonderful.*

Seales: *The faculty group that I pray with every week really helps me. Requests can be shared with them that are a lot more specific than what you usually do at a prayer meeting in your church. You know you can pray for the Dean and the decision that he's going to make over you and other people in the department. Working through those things helps me to realize again that God is sovereign, and that takes some of the difficulty out of it for me. That is very empowering*

DeWitt: *Don't mistake committee work for research. When I came to Wisconsin, I was so pleased and so amazed at our committee meetings. Some of them were very important committee meetings. I got the agenda, usually from a secretary, not from the scientist who was heading up the committee. We went through the entire work of the committee and finished in 1¼ hours, and we'd have the final report. I didn't think that was possible but that's the way most of my committees are at the University of Wisconsin. Sometimes we meet twice.*

I'm chairman of the Undergraduate Research Awards Committee. We dispense about two-thirds of a million dollars and we have two 1¼-hour meetings per year to do that. We love to do research, so we hire other people to do a lot of the other stuff. One of my committees hired a person to write up meeting results because we all wanted to get back to our research. It was kind of fun doing it quickly. It's a scientist thing to figure out if you can do something really important fast and well.

Keister: *It has not been my experience that acrimonious debates occur in the universities*

because the stakes are so low. Things like revising the curriculum generate enormous amounts of acrimony, including committees of very busy people.

Foster: *I read a story about Paul Brandt's life,* Ten Fingers for God, *describing how Brandt worked several years as a carpenter. Brandt used that experience later. I wonder, "What skill does God want me to learn so that I use it later?"*

Audience: *What is technology going to look like in the future? Do we consider the perils of technology or the promise of technology? To what extent do Christians have a responsibility to exert influence in situations where there is potential peril in technology?*

Seales: *We have teamed up with an educator and a psychologist, who can do human studies for us in some of our projects. As we build technology, we do so with humans in mind. We try to analyze these preliminary studies and release the developed technologies together with our findings about how the technology impacts humans.*

DeWitt: *Two people came out on the wetland behind my house where I do much of my research. It was a great day. There were a lot of things there and as we came back, the man said, "One thing that I'm wondering about is where are all the animals?" I looked at him with amazement but he was serious! I looked at his wife and she was agreeing. It was a great day for animals. We saw lots of animals. These were very educated people. So I quizzed them and discovered that this was the first time they were really out on a wetland. But prior to that they had watched nature films on public television. If my marsh had been put into their control for a major land use decision, they would have allowed the marsh to be filled because they did not know that wetlands are peaceful places with not much happening. There aren't predators swooping out of the air all the time picking up muskrats. It's just basically a very peaceful world.*

I worry about virtual reality and about education that comes to us largely through videotapes and other visual means. Most of the world is very different than how it is being portrayed in videos. We run the risk of losing creation, while carefully preserving all the good videos!

Audience: *How does a Christian deal with intellectual property? How do you maintain control of intellectual property so that it can be used in an appropriate way rather than sold to the highest bidder?*

Price: *The botanical garden in St. Louis has a man, who at personal risk, made a collection of all the moringa species in the world. Since his graduate work would soon be done, he wanted to find a place that would love the moringas. So he sent us the cuttings of a couple of them. He later sent me an email and said, "I will be in trouble the rest of my career if these are given to anybody. I signed a collection permit that restricted the passage of this stock to others unless I could guarantee that no commercial use would ever be made of them without an authorized agreement."*

How could I ever possibly guarantee if a missionary in Nigeria wanted this plant that nothing would happen to it? I understand developing countries are upset that rich companies come in and make a lot of money from their plants, but it may also work the other way. In our case, we want to disburse things that God has made around the world. This plant doesn't belong to a particular developing country. It is part of God's creation. Such a restriction would complicate our ability to operate a free seed bank that shares God's creation. We are going to destroy these donated moringa species since we do not want to cultivate any plant that we're not allowed to give away.

Seales: *I've seen two approaches to intellectual property. One is to release things to the public domain. A second is to start a company and then dispense with it as you will.*

Audience: *Another problem is that many universities maintain ownership of intellectual property, and so they decide how to market the intellectual property.*

Foster: *It's a complex topic. I know the university's increasing interest in making money off my ideas has made it harder to get funding from industrial sources.*

Audience: *We have something new in our department. Previously we just developed crop varieties and then freely dispensed them. If there was any money, it would come back to the department in a general sort of way and go into developing new varieties. Now we have a very specific system that directs 20% of the profits back to the researchers. A researcher with a lucrative product can make a lot of money! It's not good to research something risky or that has little impact.*

I have questions about priorities in research. How can we as Christian researchers prioritize the development of high tech stuff that makes life easier with technology and that cares for people who make $2/day? How do we wrestle with this issue?

Price: *It's hard to know your own heart. If you believe God is calling you to do a particular thing, that answers the question. Otherwise, I think God gives us a lot of freedom. We need to be doing science. We need basic research, applied research, and a wide range of things.*

DeWitt: *The verse in Matthew 6:33, "Seek ye first the kingdom of God…" is good to keep in mind when you're making choices.*

Price: *I wonder about the verse in Ephesians 2:10 (NLT) "For we are God's masterpiece. He has created us anew in Christ Jesus, so that we can do the good things he planned for us long ago." If the correct interpretation of that passage is that God has prepared good works, then a particular good work might be developing non-hybrid crops for the poor part of southern Illinois. Maybe God has a whole range of good works, and we should pick some of them while not worrying about the ones we can't do.*

Keister: *While the American graduate education system is considered the best in the world, it does not convince the products, the students, that they are actually better prepared to do a lot of things other than their thesis research project. There's a need in the world for generalists and Christians are well suited for that. Your graduate school experience gives you the ability to dig deeply into something. Particularly as a Christian that ability and experience may prepare you to do something different in the future. Keep in mind again as a Christian to say, "I'm not going to be the clone of my advisor. I'm going to proceed in this project and if God calls me to do something very different five years from now, I'll have the tools to do it."*

Price: *When I was near the end of my doctoral studies, a professor told me something very liberating when he said, "Now you've shown you can master a field, go master whatever God calls you to master."*

Foster: *I was just in China where they were harvesting rice by hand. My question was, "What is my response to be to the poverty that I see?" I didn't have an answer to that question. I've asked myself, "Should I be doing my research or should I be doing something more spiritual such as feeding the poor?" God can use things that don't seem to be so spiritual. I need to be faithful in what I'm doing right now.*

I was in Ukraine speaking on the subject, "Are religion and science compatible?" A student came up to me after the main session and said, "You know, I used to be an engineer and then I became a Christian. I was convinced that the only way I could serve God was to go to seminary. Now you've come and talked about your work as a believer and as a scientist. You can present a witness to a community which I can never reach as a seminarian. Why did I give up being an engineer? I never knew this possibility existed."

There are strategic opportunities in all kinds of fields. We have to be careful we don't use that as an excuse to do anything that our whims lead us to, but there is something to be said for strategy.

Audience: *The important thing, that strikes me as being so obvious and yet is so rare in my experience, is having a Christian community that can pray through rough decisions with you. Often it's very difficult to get a church community to grasp your dilemma. It is good to pray with a peer group of believing scientists or academicians.* ☆