Chapter 1

Basic Choices

Sections of this Chapter

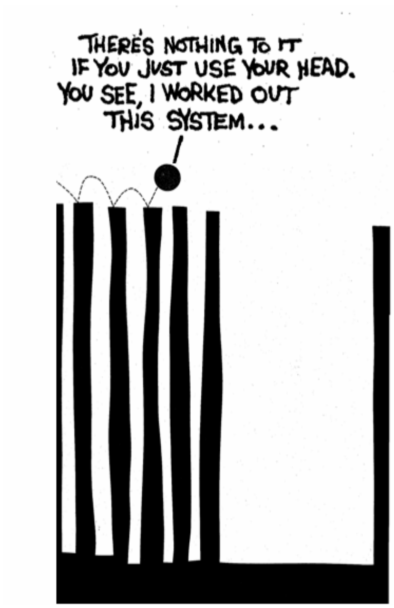
1.1 "Know thyself" so you can set realizable goals

Make the effort to "Know thyself"[a] so that your goals are realistic and will indeed satisfy you when you attain them. What should be your career goals as a scientist? This should include not just what you would like to achieve as a scientist, but how to advance in your career so as to have the means to do what you want. Asking yourself this question openly, critically and realistically at each stage of your career (preferably well before the next stage is to begin) is extremely important. It may save you from a lot of trouble and frustration, later on. Of course you should not forget to ask yourself this basic question from time to time later in your development as a scientist (say every few months at least), and not

[a]"Know Thyself." This famous Greek maxim is attributed to any number of ancient Greek philosophers, including the great Socrates. However, according to the ancient historian Plutarch, "Know Thyself" was originally the admonition Γνώθι σεαυτόν pronounced "*Gnothi se auton*" ("Know Thyself") inscribed on the Sun god Apollo's Oracle of Delphi temple in ancient Greece. Plutarch should know about the inscription on the Oracle, since he was once one of its caretakers. In deference to Socrates, it is known that Apollo's Oracle of Delphi identified him as being the wisest of all men.

just at the moment when you begin to think of a career change. Update your self-examination and your goals and not just your *resumé*. Your position is not unlike a young artist in the Renaissance. It was not enough to develop your skills and your vision, it was equally necessary to plan to get into the good graces of a patron to support you in the pursuit of your art.

Did you ever ask yourself, what are the goals of a scientist in general, and what should be your own goals? Remember that the whole point is to help you become what you want to be.



Success is of course not guaranteed, as is illustrated in a brilliant 1966 cartoon by Jack Wohl,[b] shown here. (He had earlier made the deep discovery that one can often get away by representing people with simple shapes like circles.) However do not be deterred by this image from planning at all. After all, if you form a good plan and act on it, you will usually to better than if you do not plan at all. All the message that you should draw from this is that no plan is likely to work for ever.

As you will see, we found that much of what we have to say has its humorous side with some sources[1] coming up quite frequently: the cartoonist Sidney Harris, Robert Weber who produced two impressive anthologies of science humor and Stanley Krantz who has done something similar for mathematics.

Even more basic questions are "*Why* do you want to become a scientist? *What* will you be able to contribute?" If you have not yet asked yourself these simple questions, you should definitely do that immediately. It does not make much sense to try to become a scientist if you do not know what your deep objectives are.

[b]Jack Wohl, *The Conformers*, P-S Books, Pocket Books New York, NY (1966).

Unfortunately many young people keep on with a topic because it feels good to do, but when it becomes difficult (as it will), they can be quite shocked, almost like falling out of love. Thinking of the early love affair with science that we have all had, this really means thinking about whether you want to marry your lover and stay together for life. If you do not come up with what you think is a reasonable answer, it is wiser *not* to pursue a scientific career before too much time is wasted. (However, you should by all means at least finish your degree if you are still a student, and then look for a different way to use your talents.).

Many (including ourselves) believe that the main goal of a pure scientist is to investigate the laws of nature, and to provide new knowledge and insight into the physical, chemical and biological processes of systems which either exist already or which you create.

"Real scientists" are those who burn with the desire to unravel the mysteries of nature. The other aspects of the job are essentially the means to achieve this end. A real scientist, if offered the same salary by an intelligent philanthropist, but without the necessity of having to do anything specific for this money, would choose to carry on in the same way as at present. A real scientist is, in fact, addicted to the science.

While personal remuneration is not the primary motivation to the real scientist, money is not irrelevant, though in an unusual sense. To the real scientist "money" means the funds to pursue the desired research. Of course, without enough funding it is very hard and challenging (though not altogether impossible) to do good science, so the funding is a necessary (but never completely adequate) means for an end. (This said, it is true that some people in research do consider money, in the sense of funding, an end in itself.[c])

Having a lot of funding is not enough, however. There are many scientists (and most of us can easily bring a few to mind), who have substantial money flowing into their research accounts, and yet produce disappointingly little in terms of interesting science of high quality. Their groups are often so large that they have a hard time managing them, and

[c]This seems to be especially true in North America. In Europe, your peer's respect is earned by means of a long publication list in prestigious scientific journals. It is rare (though not unheard of) for scientists in Europe to boast about their level of funding.

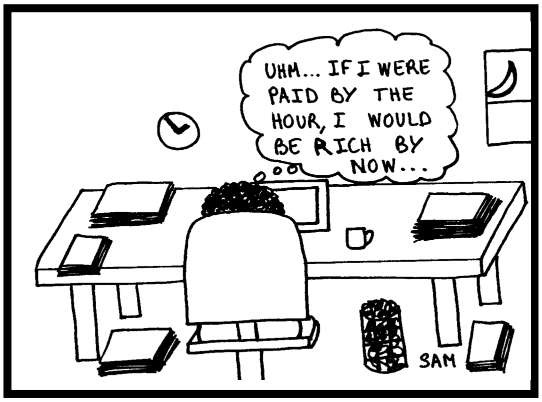
their productivity (in the sense of published papers per year and per member of the group) suffers enormously from this. The point is that it is the new, original ideas that are the most important ingredients for successful science. There are also colleagues who have relatively little money, and yet their output — perhaps normalized with respect to the amount of research money they have — is incredibly high. (This is not limited to theoreticians, particularly analytical ones, who only need good ideas, a pen and some paper, besides some travel money to go to conferences. Some experimentalists, for example in Italy, Federico's home country, do wonders with the little funding they have.)

If your basic real goal is to become rich[d] and famous, not in terms of your research accounts but in terms of your own bank account, we strongly suggest that you pick another career that will let you attain those goals and fulfill your aspirations in a simpler and faster way. (Perhaps you should try to become a techno-industrial wizard like the co-founders of Google). Since there are already more than enough *prima donnas* and empire-builders in science who are really driving for the best science; there is no need for more who are mistakenly counting on science to become rich. True, the odd scientist does win the Nobel Prize, and may thus become famous[e] and moderately rich. A very small proportion of scientists who founded companies manage to do rather well and earn the scientist considerable sums. However these people are nearly always

[d]One of Sidney Harris' cartoons (as shown on p. 90 of his *Chalk Up Another One*, Rutgers University Press (1992)) shows a dispirited scientist at a cocktail party saying, "My big mistake was going into cosmology just for the money."

[e]The concept of fame here is very relative. If you meet someone on the street, and ask them who, say, Tiger Woods is, they will probably know a lot about him, including some of his greatest feats, some details of his personal life and advertising. On the other hand, if you ask who Albert Einstein was, they may have a vague notion of a funny scientist who said that *everything is relative*. They will probably also joke about it, saying that it is quite obvious to them that everything is relative, and that giving a Nobel Prize to someone for such a trivial discovery is an exaggeration. (In case you did not know, Einstein was awarded one Nobel Prize in Physics, in 1921, for his description of the photoelectric effect (published in 1905). By contrast, both his theories of relativity, the special and the general one, were not widely accepted by the senior scientific community until long after he formulated them. Now General Relativity is an essential element in the programme used for Global Position Satellite (GPS) operation, so we all use Einstein's general relativity, whether we know it or not!)

"real scientists" (in the sense that there may be exceptions of which we have no knowledge) who encountered an opportunity and managed to profit by it. Going into science in the hopes of finding such an opportunity is a poor bet and not worth considering as a realistic possibility. (See below, hand drawn by Sabine A. Minsky.)



Even if you are unlikely to become rich in science, and if you are likely to work long hours, at least a scientific career will not be a work of boring and safe routine, like an office job. In an active research program with several components it is extremely rare to have two days that look alike. If you are upset without a steady routine, do not try to be a successful scientist. The activities that a scientist is engaged in are so various and different that they are rarely repetitive (although some of them are boring, of course). You should expect to work long hours, perhaps even spend many weekends working (especially if you work in academia), and hopefully you should even take pleasure in it. Generally speaking, this is definitely *not* the type of job in which you work from nine to five each working day and then go home, forget about all your problems at work and concentrate on your family and/or your hobbies. (A completely free weekend may be a rarity.)

To repeat, if you are not prepared for commitment far beyond nine-to-five routine, you should seriously think of looking into different job prospects.

In spite of what has just been said, there are exceptions, but ones for which this book is irrelevant, since it is intended as an aid for those who are determined on climbing the ladder of success in science. These exceptions are people who are settled in the science niches in which a routine "nine-to-five" scientist without some considerable "fire in the belly" can operate in a limited way. If we have alpha scientists and beta scientists perhaps these are delta scientists who are not even thinking of being gamma (= sub-beta) scientists. The point is that these positions are just that, niches, and not way stations on a path to success in science.

In taking such a position in a way that is more or less permanent, you should realize that you would be essentially joining the ranks of the many middle and lower level scientists (often called research associates) in the world who are essentially well-educated technicians. Such people have reached a stable niche position. Their names are on the papers (naturally in subordinate positions); they may lead small technical projects, and they have accepted that they will work on projects decided by others. By way of compensation and to use energy which did not seem to work in pure science, they often become happily addicted to some pursuit outside science.

This is a perfectly valid role for those that choose it, but it should be a conscious choice, "I really like science, but I like my family and my other activities just as much or more, and so I willingly choose this useful, enjoyable but secondary role as my compromise." What you should not do is to try vainly to be a top (or at least excellent) scientist (an alpha or beta scientist so to speak) and then settle resentfully into such a tertiary position, working in a "nine-to-five" work-to-rule as an implicit protest at the loss of an early dream. In this context "Know thyself" means to accept that your fate or your true desire is perhaps other than what you had in mind as an undergraduate.

If that is your choice, if you have dropped out of the race and into a non-competitive niche, then this book is only of sociological interest for you, perhaps as an aid to understanding what the "upwardly mobile" people around you are doing.

In essence, then, this book is really addressed to those who want to be highly successful in science. Whether you are successful or not may then depend on external factors such as pure luck, like in most human endeavors (Look at Jack Wohl's cartoon on page 2 again!), but if you are on this path you should be trying as hard as you can.[f]

If you are a true scientist, your enthusiasm will clearly be displayed when you give a talk, or when you write a scientific article or even a

[f]Would it make sense to want, say, to become a professional tennis player, without aspiring to be number one?

grant proposal. Your peers will look up to you with respect, sometimes even with awe, and consider you as a source of inspiration (except that unfortunately large fraction who are jealous or envious). You will get very excited[g] (a science "rush" in fact) when you or your students acquire new results and now understand something that nobody has ever understood before. This excitement and enthusiasm are the true rewards of a scientist, and they make up, or at least should make up, for most of the drawbacks, pitfalls and "sacrifices" that come with the job. It is important to keep this in mind to face the rough times that undoubtedly lie ahead. A scientific career is tough, and full of unknowns, especially at the beginning. However, very few people love their jobs as much as scientists do, and this is to be considered as an enormous fringe benefit.

A scientific career can be extremely demanding in terms of the total number of hours you work and the little vacation you feel comfortable taking. There is always something interesting to do, and new ideas and challenges turn up at an astonishing rate. At the same time, you will be traveling frequently to attend meetings and conferences, and give seminars on your work, which may seem pleasant for you, but which will not make your family terribly happy (if you managed to find the time to start a family in the first place, that is), unless you systematically bring your family with you, of course (which is rarely practical, unfortunately).

In fact, if you consider these demands on your time as sacrifices, and you are not willing to accept them to advance your career, we emphasize yet again that you should seriously consider looking for another type of employment. Most good scientists tend to work 10-12 hours per day, often including weekends.[h] They feel comfortable with this situation, because they literally love their job and have loads of fun while working.

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[g]This is the same excitement that seizes children when they receive a new toy. We have seen this happen to colleagues a great number of times!

[h]It sometimes feels somewhat frustrating to know that if scientists were being paid by the hour instead of monthly, they would soon become rich. However one of the reasons for choosing this career in the first place is that money is *not* at the top of our priority list. Indeed, if money is important for you, you are certainly better off choosing a different career. There are other important fringe benefits in a scientific career, and perhaps the most important one is that you actually have fun while you are working. In fact, it is not uncommon for me to describe my job as "Playing with atoms and molecules" (not to my peers, who know it only too well, but to the layman). Just imagine that I get paid for it!

Being a scientist often means that you learn new things almost on a daily basis, and this can be very interesting, stimulating and challenging.[i] They are very few people who are efficient and intense enough to work only 8-9 hours per day, five days a week, and yet display sufficient scientific productivity to keep them in good standing in the community. These remarks are not meant to discourage these efficient scientists, but just to point out that they tend to represent a minority in our community, so you are *a priori* unlikely to be one of their number (Are you really so efficient? Know thyself!).

At the same time, if you choose to work in academia, once you reach the level of a professorship, you will have to become a *manager* besides being a scientist. You will need to attract funds to carry out your work, and you will have to manage them properly. If you are publicly funded, you will be asked to report fairly regularly to the funding agency on how you spent the taxpayer's money. In essence, a scientific job is often multifaceted, and will expose you to many different realms of human endeavor.

Once again, all this is really a matter of many personal choices. As remarked at the outset, "*Know yourself!*" To repeat our refrain, if you know yourself well, this knowledge will help you in making the right choices, and in the long run you will be a happier person. This does not apply only to your scientific career, but to your choices at the restaurant.[j] (It would take a braver pair of authors than ourselves to suggest that this be applied to a choice of a life partner, sensible thought it might be, so we leave this concept at the restaurant from whence it came.)

A lot of young people tend to be undecided and drift along hoping that something good will turn up, like a swimmer in a large river hoping a useful boat will float to within their grasp. They avoid planning, partly because they are frightened of the future (and perhaps because they are

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[i] **Federico:** if you think that I work too much, you just have to look at what other *successful* colleagues are doing, to realize that I am not exaggerating (although I admit that finding an objective measure of success is not at all obvious). Once in a while I do take the odd weekend off, or even the odd vacation. However, this is the working style that I learned from my father, who is also a physics professor: working long continuous hours helps you keep a high level of concentration. Unless you are as bright as Albert Einstein, this seems to be one of the best approaches to succeed in this job.

[j] If you don't like chicken, don't order it!

secretly hoping that they will suddenly stumble on a gold mine). They do not yet know themselves well enough to be able to estimate how they would work in a given environment (they do not yet *know themselves*), nor do they know the workings of the world of science well enough to estimate how a particular type of employment would work for them (they do not yet *know the tradecraft*).[k] With this book we are furnishing tools to do both.

1.2 Match your goals to your character and talents

Which of your character traits are likely to lead to success? Sufficient basic scientific talent (including of course intelligence) is obviously essential to be successful as a scientist. While raw talent can be refined, it cannot be created. One tragedy that is common (but not always recognized) occurs when the talent level required for success in a particular field exceeds the raw talent of the scientist. In effect the scientist has, so to speak "run out of talent." The only real cure is to move into a different field. However, before doing this, provided the will is there, talent can be made much more effective by making best use of some particular traits and also by developing and strengthening others. In effect, "Do not quit until you have given it your best shot."

It is clear that, other things being equal, one would expect success in accomplishing science to be positively correlated with this native raw ability. While one can consciously try to explore various ways to give this ability free rein, the basic ability itself is probably not something that can be consciously learned or developed. To find one's basic level in any field it is vital to have a just opinion of one's basic ability in that field. This can be very difficult to do, and, while it is not something we will discuss here, the beginning scientist should make a serious attempt to do this.

[k]Another cartoon of Sidney Harris has a pensive garage mechanic saying to a customer, "Actually I started out in quantum mechanics, but somewhere along the way I took a wrong turn." (as shown on p. 141 of his *Chalk Up Another One*, Rutgers University Press (1992)).

Fortunately, and contrary to most people's beliefs, it is not the raw talent for science that is *the* most important trait that ultimately determines a researcher's success. It is little realized how much success in science (and in particular in experimental science) depends on other behavior which, unlike basic raw ability, can be learned, improved and developed. This book is aimed at going through what can be improved and developed, so our readers can decide for themselves how to be as good a scientist as they can. Development in this way is a means to the end just as much as the other kinds of research support. Another analogy is sailboat racing. There is a basic ability or "touch" in being able to coax a little more speed out of a sailboat, but there are also many things than can be consciously learned, anticipating tactical problems, boat preparation, weather prediction, many aspects of sail trim etc. There are books which describe what to learn about every thing except the sailing "touch."[1] This book on Survival Skills in Science is aimed at telling you about everything except the "touch" in your field of science.

To drive this point home, let us make it in another way. There are many admittedly clever and ingenious research scientists who are more talented than most others but who are not as successful as you would expect them to be, based purely on their talent. Certain character traits, such as drive, patience, and the ability to work in a team or to lead one, are extremely useful and perhaps more important, in the long run, than raw talent. Luckily, for those who learn how to do it, many of these other important traits can be consciously learned and strengthened. Of course you have to know which of these traits are worth cultivating and strengthening, and how to do it. Potentially brilliant concert pianists who cannot school themselves to the discipline of relentless practice, will remain just that "potentially brilliant," while those with somewhat less talent but more discipline can fulfill all their promise. (We will return to this topic when we discuss actions which will follow the basic choices.)

[1] Curiously enough, the sailors with the "touch" are just as obsessive about boat preparation as those of us who are doing it because we are obsessed with catching up to them. It seems that although "touch" is worth far more than sandpaper hours, the touch arises in part from being very sensitive to boat performance, so the "touch" sailors are almost in pain on a poor boat. The best sailors are thus unable to forego the sanding — they are too obsessed. The analogy with science is all too evident.

In the meantime, it is obvious that, given your particular character traits, there are certainly some fields or modes of working that are more suited to your character than others. A rational way to handle this is to decide what "research style" is likely to appeal to you, since that is probably the best way to channel your energies.

1.3 Work style choices: Lone wolf, collaborator, team player, team leader? Alpha scientist or beta scientist?

1.3.1 What kinds of teams operate in your science?

One of the aspects that is important to determine is the nature of the normal method of functioning in the domain of science to which you feel called. The basic concept is the size of the typical team in the field, and this can be estimated by looking at the number of authors on a typical excellent paper, and by looking also at the author affiliations.

DIVERSION By the way, since we are talking about aggregations of scientists, it seems appropriate to indicate from the *Journal of Irreproducible Results* v. 14, n. 4 (1965)(ANON) some collective names in basic science:

A pile of nuclear physicists, a set of pure mathematicians,
a field of theoretical physicists,
an amalgamation of metallurgists, a line of spectroscopists,
a coagulation of colloid chemists,
a galaxy of cosmologists, a cloud of theoretical meteorologists,
a shower of applied meteorologists, a litter of geneticists,
a batch of fermentation chemists, a colony of bacteriologists,
a wing of ornithologists, a complex of psychologists.

One also finds more "political" varieties: an intrigue of council members, a dissonance of faculty members.

Something like five authors or less indicates a typical small team with, typically, a team leader or dominant scientist (we will be calling such people alpha scientists; they are not usually the first author), a student (or two or three, one of whom is likely to be first author), a post-doc (or two), perhaps an "intermediate" scientist (what we term here a beta scientist) and sometimes another collaborating alpha scientist, likely from another institution.

As one goes up to something like ten or more authors, the work is likely to be the result of a coalescence of smaller teams working on different aspects of the research.

Completely out of the range of these numbers are the papers on high-energy particle physics. The author lists here can reach several hundred, where the likely analogy is a military regiment. In the psychology of groups (which runs from something like three to about eighteen individuals) we are dealing with small groups, large groups and large aggregations undoubtedly composed of alliances between groups.

In a letter to *Physics Today* (November 1964) Robert A. Myers drew to the readers' notice that "Once again (F. Bulos et al., *Phys. Rev. Letters* v.13, p. 486 (1964)) the high energy physicists have presented with a paper that has more authors (27) than paragraphs (12). Can high energy really be so different?" High energy physics is indeed that different, and now even more so. In a recent paper (Abe et al. (192 authors in the Belle collaboration) in *Phys. Rev. Letters* v.95 p. 101801 (2005) produced fewer paragraphs (18) than the number of institutions involved (49).

Yet another mode is that of a scientist (perhaps with two or three local collaborators) who carries on extended collaborations with other groups as a roving specialist collaborator sub group. (This is a mode which one of the authors (Tudor Johnston) has employed for years with considerable success). You should talk to people in the groups pertinent to your science and find out how the research is carried on and compare it with what goes on wherever you happen to be. Then you can make a rational plan, which may include moving your domain of research somewhat, to be able to operate in an environment more suited to your preferences.

In answering questions of this type, you should try to assess your abilities to work with others as objectively as possible, and then see to what extent you are willing to compromise. You should not necessarily view this kind of compromise as something negative. It is very likely that you will have to live with this choice for most, if not all, of your career. It is true that at the beginning one often has little choice but to be either a sort of laboratory technician/student or a low-level team player, the possibilities for real choice emerging only somewhat later. Nonetheless you should have clear in your own mind which way you want to go well before the first opportunity arises to make your own choice.

Once you have analyzed the field of interest to you, the next step is to think carefully of what style of scientist and science would make you happiest.

1.3.2 What sort of player are you going to be in the game of science?

Let us begin with an obvious analogy, namely team sports and the role of the individuals on the team. In team sports, the players have their own specific role. Take soccer for example. There are eleven players on the field: typically one goalkeeper, four defenders, four midfielders, and two attackers. In a scientific career the situation is very similar, except that we maintain that there are fewer roles which we are to call alpha, beta, gamma and specialist collaborator .

In this terminology, an alpha is a scientist who likes to think creatively and to transform his thoughts into funding for his/her research. Typically, that is the role of a professor in an academic setting with a significant research output. Often enough, an alpha does not have time (and may not be interested) to spend hours in the lab or to do the actual calculations. An alpha will rather coordinate and *manage* a group of students and/or post-docs who will perform the experiments or simulations on the current concepts as seen by the alpha and the current concepts on behalf of the alpha.

This state of affairs has the advantage of allowing the alpha to pursue multiple projects in parallel, by delegating them to individual members (betas, most likely, or alphas in the making) of the team. The disadvantage is that as time passes, you (as an alpha) become more of a manager and less of a scientist, and eventually may lose contact with the laboratory (which is probably the reason you decided to become a scientist in the first place). The larger the group the more developed this trend.

A beta scientist, on the other hand, is more like an executive officer in the navy. The beta likes to spend most of the time in the lab, helping students with their experiments or even actually turning the knobs. Someone who gets things done! Occasionally a beta will help with "administrative" tasks, such as drafting grant proposals. However, a beta's heart is in the lab, or anyway a beta strongly prefers turning the knobs, doing the calculations, and so forth. This sort of figure is extremely precious, because a beta will help supervise graduate students and post-docs and will make sure that things are running smoothly while the alpha is away, teaching or otherwise busy.

The difference between an alpha and a beta can also be compared to the difference between the captain of a ship, and its executive officer or "exec". The captain is in charge of the ship, and of its overall military strategy. The ultimate responsibility for failure or success rests on his shoulders. The exec is second in command, and is there to execute the captain's will and orders, or to make sure that the sailors execute properly.

Below the beta lies the gamma scientist, who does not really want any executive responsibility and is happy to be absorbed in a particular specialty, with the occasional publication (as lead author) on the nuts and bolts of the cherished sub-system in (say) the *Review of Scientific Instruments*.

The decision of whether you will aim at being an alpha or a beta or a gamma is another critical one (just like deciding whether you want to be an experimentalist or a theoretician). You should analyze critically and *coldly* your skills and personality traits, and determine as objectively as possible if your profile better matches an alpha or a beta or a gamma. If you are in doubt, we advise you to present this issue to colleagues/friends and get their feedback. You may also want to ask your supervisor, if you are a graduate student. Make sure they understand this is a sensitive point, and that they should give you an objective answer. Scientists are all born as betas, and as long as you work for a supervisor, you will always be a beta at best. The question is whether your advisor sees you as a potential leader, i.e. as a future number one or alpha, or as a beta.

In our opinion, this is an important issue that will strongly affect your career — positively if you choose wisely, negatively otherwise. Imagine a soccer player who is good as a goalkeeper, but desperately wants to play as a midfield or a central forward. Or a centre-forward who would rather play defense. It will simply not work. Although the analogy cannot perhaps be translated 100%, the general idea is clear. Do not try to be someone you are not: it would be disastrous. Play in your role and you will have a much better chance to be happy and even to succeed.

The North American academic system is designed to host and promote alphas almost exclusively — at least for tenured positions (the few that are available). In a university in North America, a beta in a small group would be called a "*Research Associate*," but in a larger group might have a more respectable sounding position such as "research professor." These are very respectable positions, and if you decide this is your natural role, there is nothing wrong in seeking this type of job (even though the title of "professor" probably sounds more prestigious). However, you should be aware that — with few exceptions — the salary of a Research Associate typically derives from "*soft money*." The position is renewed as long as there is an alpha to bring in funds and grants. It is almost impossible to turn it into a permanent position.

In Europe, on the other hand, the academic system is more hierarchical, and groups of professors often work in teams, led by one professor at the top. In such cases, not all team members can be alphas (for obvious reasons — they would be stepping on each other's toes all the time), and thus the system allows (and to some extent favors) hiring a good number of betas into permanent faculty positions.

Jobs in industry and government labs, by their very nature, are more appropriate for betas. In these environments, the management will typically set the objectives and tell you what to do on a short term, medium term and long term basis, and you will be the one turning the knobs and executing the research, first hand. Normally there will be no graduate students to delegate to, but occasionally there can be post-docs (depending on the philosophy of your employer, among other things). In these settings, being an alpha means becoming a manager, and probably doing less and less in terms of research (although again, it is difficult to generalize).

Federico: — Over the years, I had many lively discussions on these aspects with an astronomer friend of mine, who really likes to do research but cannot see himself in a faculty position. He dislikes the idea of teaching (perhaps he would consider a little of it at most) and of writing grant proposals. When I pointed out that as a professor he could advance his ideas and projects faster, by working with several graduate students in parallel, M. replied: "*I want to DO research, not manage it*." I think this sentence, although a bit severe, more or less summarizes the key differences between an alpha (who now manages research, and does little of it himself) and a beta (who actually does it)

1.4 Choices in work climate

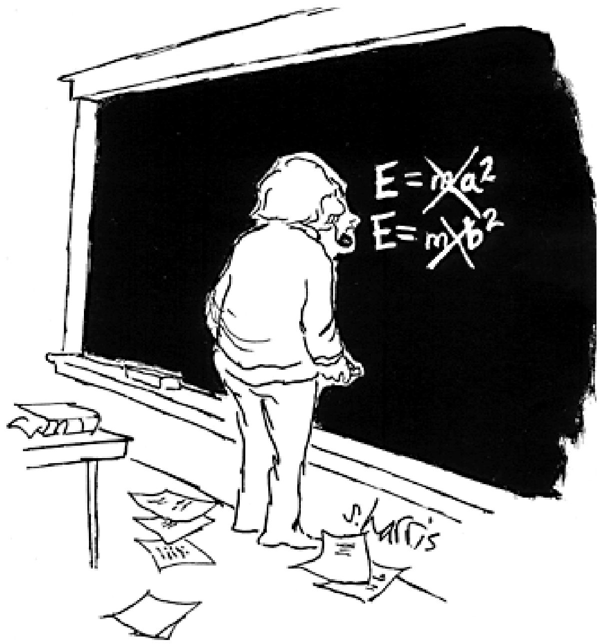
In general, doing science and research requires teamwork and coordination (among other things). If the work is done in a team format with a quasi-military hierarchy, there are many roles, such as supreme leader, group leader, team player, outside specialist and (temporary) slave labor (i.e., graduate students). While most people prefer telling other people what to do than being told, the road to the top job can be arduous, and the leader's job may well become more like the president of a small company than a scientist. If the leader's job seems too political, being a group leader may be a useful compromise. More often in science the work is done in collaborations which are much looser and more democratic, probably less stressful with more room for individual roles in a pleasant group. Things run best when everyone plays a role in which they are at ease. Unfortunately it seems to be the case that the North American (academic) system tends to evaluate everyone as if they were trying to be number ones. Even if Napoleon said that every soldier had the baton of a field marshal in his knapsack, he only meant that the top job was open to anyone with talent, and not that sergeants should be judged by their ability to command armies. The European system privileges teamwork and has room for everyone, but North American criteria for promotion and the like often seem to place too much emphasis on the scientist as individual entrepreneur.

1.5 A basic choice: Experimentalist or theoretician?

Although this is an aspect that applies mostly to physics and to chemistry (in the sense that it is a basic choice for those fields), there are aspects that apply to other fields, in which one does find a cultural divide between the experimentalists who produce the data of what might be called the "ground truth" (by analogy with aerial reconnaissance), the touchstone by which all theory constructs are tested and the people who create the theories.

In physics theorists are very well-known, but in other sciences the theorists are less prominent. Probably the most prominent chemistry theorist in the 20th century was Linus Pauling (Nobelist for the work discussed in "The Nature of the Chemical Bond"). In biochemistry, the best-known examples of what we here term "theoreticians" are the members of the Watson-Crick duo who created the DNA model concept.

DIVERSION Theory and theoreticians are hard to represent, but there is a glorious counter-example, shown on the next page. The actual object of the cartoon is an *equation*! (Guess which equation it might be before you turn to the next page.) The cartoon is by Sidney Harris[1] (naturally!) and is the only one (to our knowledge) where an equation from theory is the real point, but one where most non-scientists can get the joke. (Permission for use of this Sidney Harris cartoon received from his web site at ScienceCartoonsPlus.com.)



Federico: — As an undergraduate student, I was particularly good at theoretical coursework, and was hoping to become a theoretician as a career. (In several Mediterranean countries (perhaps for cultural or historical reasons) doing theory is considered more popular and prestigious than getting your hands dirty with experimental work. In Italy, most physics students begin by hoping to become theoretical physicists.) This early inclination is also related to the fact that I was (and still am) somewhat clumsy in the laboratory.

As time progressed however, I came to realize that all the best students of my course (and many of them were better than me, at least when comparing primitive indicators of performance such as grades) wanted to become theoreticians as well. Not only, they all wanted to pursue the theory of high T_c superconductivity, a topic in condensed matter physics that was — and still is — very hot and controversial at the time, and which I was also interested in. Moreover in the physical sciences there is often the (unfortunate) perception that doing theory is to be considered more noble and prestigious than getting your hands dirty in the laboratory.

Thus I was faced with a very common kind of dilemma: should I follow my instinct, and become a theoretician, but accept being at the end of the list? Or should I make a compromise and choose to become an experimentalist, perhaps fighting a bit against my inclination, but probably being the best experimentalist in my course? I ended up choosing the latter. It turns out that it has helped my career enormously. Obviously at first it was not an easy choice, but in hindsight it was by far the best choice for me.

The trick to being happy in science, as with life in general, is to know yourself well enough to make the right choices, choices that you will probably have to live with and that may be irreversible. Incidentally, several of my theorist colleagues were also highly successful so far; however, in the face of tough competition, more than one gifted student who stayed in theory dropped out of graduate school and ended up pursuing a completely different career, like consulting or financial mathematics. This is not necessarily a bad thing of course, and you could argue that perhaps they were not meant to be scientists after all. They may even be happier doing what they are doing now. However, if they had made a different, more rational choice like the one I did, perhaps they would have stayed in science. (I know at least one person who wonders what life would have been like if she had stayed in scientific research, and she probably will ask herself that question for a long time hereafter.)

Tudor: — My anecdote is almost the reverse. I began as an engineer (actually a hybrid called engineering physics), did an essentially experiment-plus-theory-interpretation engineering thesis at Cambridge University, and began a mixture of theory and experiment in a Research Laboratory doing contract research for the government. As time went on I realized that there were what I found to be deep mysteries in the experimental technology — vacuum leaks, electrical hum, electrical ground loops, to name the worst — which I could never master and which remained for me "wild magic." I gradually but happily abandoned my feeble attempts to master the arcana of the laboratory and became a theoretician often for experiments in which I had no direct interest, becoming in fact a *de facto* theoretical physicist in plasma physics, although holding no physics degree.

One advantage of this long love affair with experiment is that I retain a deep respect for people who can make experiments work, a lively interest in how experiments are done and how to (in effect) "diagnose" any theoretical constructs to suggest experiments. It gives me a special thrill if I can use theory to show how an experiment that appears not to be working can saved by using a different protocol and analysis procedure. A theoretician I have become indeed, but a better one for having been also an experimentalist for some ten years.

Now all this was accomplished with little conscious analysis on my part, without any real penalty, but from this I have become convinced that doing frequent "reality checks" on your comfort level in the way you function in your science is essential. Without this there is a significant risk of drifting into a way of working in which the basic mental discomfort of a poor fit between you and the way you are working leads to a dysfunction in the work for reasons that may pass unperceived.

Federico and Tudor: — To place things in perspective and make this example relevant to scientists in other fields like biology and chemistry, where theory as such may not bulk as large, we point out that each discipline has its "hot" subfield. In biology it might be molecular biology, and in chemistry something else.

In the anecdotes just reported we suggest a generalization with "hot subfield" replacing "theory."

The lesson to be drawn from the first anecdote thus becomes this. Do not go into the "hot" subfield of your discipline just because it is trendy and all the good students want to do the same. *You* have to choose what is hot for you (Know thyself!). Later, when you become a successful scientist you may even create a new trend and a new "hot" subfield. In the longer run, your goal is to become a leader, not a follower.

The lesson to be drawn from the second anecdote becomes the following.

Just because a field is "hot" is not a reason for going into it, and the competition will be fierce if you do "jump into the hot water". However, do go into the "hot" field BOTH of the following apply: (i) it is sufficiently attractive to you for its intrinsic worth and (ii) you find that you are generating interesting ideas almost in spite of yourself."