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Notes on

Theories of Science

and

Research Methodologies

Notes on Theories of Science and Research Methodologies

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Preface

The basis for the activity (i.e. education and research) at all universities in the world is, or is at least assumed to be, or should be, science. Therefore, it is important for university teachers as well as students to reflect about science; what it is, why it is such a universal used method, how to conduct scientific work, how science is applied at the own university, and how to perform research.

This booklet was written in order to provide an introduction to theories of science and research methodologies to be used at Woalita Sodo University, Sodo, Ethiopia. The goal is to introduce and stimulate to research attempts within different fields of science, and to stimulate to further reading of science- and research-related literature.

Thus, this booklet does not claim to be a complete literature for university courses covering principles of science, research and methods, but it aims at being a tool for such courses; especially in programs concerning agriculture, environmental science, rural development, natural resources, ecology or biology. Hopefully, it also functions as a source of inspiration for research; for students as well as for teachers, in the beginning of a scientific career.

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NOTES ON THEORIES OF SCIENCE AND RESEARCH METHODOLOGIES

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THEORIES OF SCIENCE

Introduction

Definition

There is a gap between the scientific community and the public community regarding the interpretation of the words "science" and "research".

Within the public, there are often references to "science" or "research" as something nearly magical or super natural. In advertisements, one can be exposed to a man dressed in a white laboratory gown, holding a probe, and claiming "it is scientifically proved that you will live longer if adding this to your diet", "results from new research show that this substance will make your hair shining lively", or similar. The terms "science" and "research" are used to indicate trustfulness and perfection, something absolutely true beyond any doubt.

In daily talk, the term "research" is sometimes used in the opposite way to the use in the public as it is described above. When saying "I will do some research to find that book" or "after doing some research, I found out from his friends that he really will appreciate to get an electric stove as his graduate gift" the person use the word "research" in a way that is not specified, but just indicate that the person take some action (looking for that book in shelves of book stores, asking the friends of that person, for example). Thus, the word "research" is sometimes used for whatever action a person take for finding out something he/she does not know for the moment.

Within the scientific community (i.e. among people considered as scientists), science is about the understanding of nature (in a wide sense). Science is the striving toward true explanations to observed phenomena, while being aware of additional observations may lead to another explanation being required; thus accepting that previously formulated explanations should be discarded if not fulfilling the requirement of being a complete explanation to the phenomenon aiming at. Science of today may be described as a large, dynamic, puzzle that is laid by scientists performing research with scientific methods. However, this description is obviously a non-scientific circle reasoning; it uses the terms "scientists" and "scientific methods" to define "science", but of course "science" has first to be defined before these terms become meaningful. In dictionaries, one will find explanations of the word "science" as: "the systematic study of the nature and behaviour of the material and physical universe, based on observation, experiment and measurement" and of the word "research" as: "systematic investigation to establish facts or collect information on a subject".

A definition of "science" suggested by JJ Davis in 1968 is: *"an explanatory structure built on observed facts"*, and, following that spirit, "research" can be defined as: "*the systematic work striving to find fact-based explanations to observed phenomena*". Thus, science does not deal with telling the eternal truth. When a scientific explanation to any evidence is found to be wrong to any extent, it has to be discarded by scientists, and they have to begin the work to find a better, hopefully true, explanation that includes all evidences supposed to be explained. Science is not a faith, a belief, or an opinion, neither a way to decide about morally or ethically rights or wrongs, nor a way to determine the arrangement of a society, even though scientific outcomes may be guidelines for decisions concerning both individuals and societies.

This text is addressing "science" and "research" as it is interpreted within the scientific community. That said, one may ask what science in its scientific meaning includes. Sometimes, one will find, exclusively, the subjects physics, chemistry and (parts of) biology included when there are references to "science"; in this case the demand is that whatever there is to be investigated (i.e. observed and explained), it should be possible to measure exactly and there should be controlled experiments before drawing any conclusion. Sometimes, one will find all subjects which may be investigated, by measuring, by approximating, or by evaluating subjectively, included in "science", even when controlled experiments hardly can be done. In the latter case, the different main subjects may be separated by descriptions as, for example, "natural sciences", "social sciences" and "medical sciences". There is no universal agreed on right or wrong regarding what subject to include as possible to study scientifically (as long opinions, faiths, believes and all kinds of presumptions that are not based on evidence are excluded); but there are different ways to relate to science, and it is therefore important to keep in mind which way that is used each time when reading about or discussing "science".

This text follows the latter principle, i.e. it does not exclude any field of study from the definition of science, but regard "observed facts" as including difficult-to-measure things like the dynamics of animals of all species (from the smallest soil living ant and tree-top living spider to elephants) in a natural reserve, human behaviour and historical events; some of these things could theoretically be measured precisely, even if seldom possible in practice. The animals in the natural reserve could probably be investigated if given sufficient resources, while experiments with humans are restricted because they are in most cases regarded unethical. Regarding history, it is, as far as we know, impossible to turn back time; historians have to rely on oral traditions, written sources, and other traces from previous generations for conclusions.

Research of Different Kinds

General

Science do not appear unconnected to the rest of the society, instead there are a lot of connections (Figure 1). For example, before human beings, long ago, began to cultivate soil, probably no one thought about the effect of soil disturbance on soil water content, nor tried to investigate how to perform in order to reduce or increase it by soil cultivation. Instead, people may have noted that a special species of hunted birds could be found only at a special time of the year, and they may have thought about why this occurred (for a long period of time, it was in fact concluded in northern Europe that swallows spend the cold winter periods on the bottom of lakes; now we know that they migrate to Africa). Because we all are, to some extent, a result of the community we have been exposed to, there are surely a lot of scientific questions remaining that we, humans, not even have thought about. Most probably there are also a number of things that are wrongly interpreted; as it was with the swallows hibernating in lakes.

The connection between scientific work and the society is sometimes obvious, and sometimes subtle. Examples of obvious connections to between societies of science are scientific attempts to find solutions to problems, as finding new and better medicines, more energy efficient cars, or ways in which weeds can be reduced in crop fields. More subtle connections between societies and science have scientific work in order to understand things like: the mechanisms of the hormone signalling from pancreas to the liver, the flow of air around an item, and the germination pattern of weed seeds. However, the things listed as subtle here, can be important for each of the things listed as obvious. The pancreas-liver mechanism may be crucial to understand for developing that medicine, the car may be more energy-efficient by being constructed according to the findings about how air flow around it, and the knowledge of weed seed germination may lead to development of proper methods for reduction of the number of weedy plants. Thus, different kinds of research are needed within the worldwide society, even tough not all scientific work lead to immediate use of the results.

The above described different kinds of research, with more or less obvious connections to the surrounding society, are sometimes referred to "applied research" (with obvious connection to the needs of the society) and "basic research" (with not so obvious connection to the needs of the society).

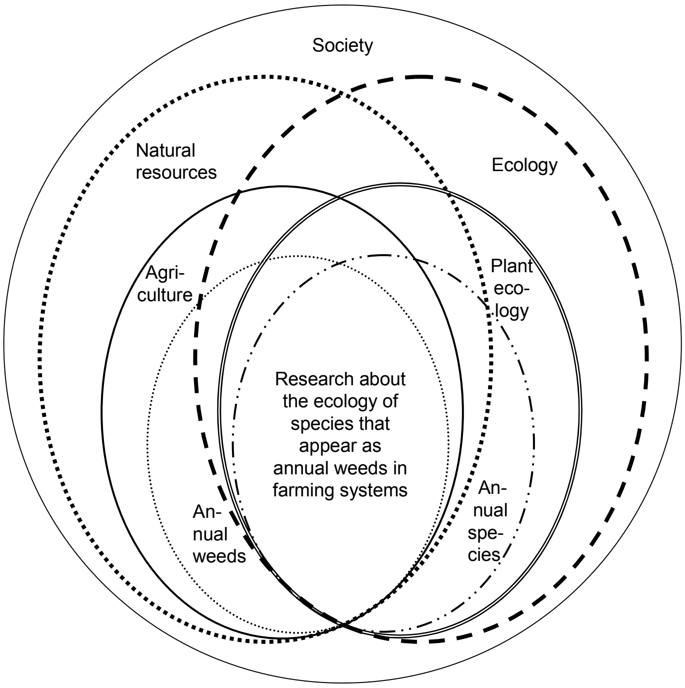

Figure 1. Principles for connections between science and other parts of the community, exemplified with the scientific subject "ecology" and its sub-subject "plant ecology". Questions raised within agriculture may be answered by plant ecology research, and results from plant ecology research may help in improving agricultural practice.

Basic Research

Basic research, also sometimes called "pure" research or "fundamental" research, is research undertaken without any other specific goal than to understand, to explain, what is observed. Sometimes basic research is referred to as "curiosity research", which may sounds like this is something the scientist does simply for his or hers own joy, not as something that is of importance for the society as a whole. It is true that most basic research attempts require a certain amount of curiosity of the researcher, but that does not imply that the research is useless for the society.

Basic research produces the building blocks for further research; such research that has the goal to solve specific issues. Thus, if there is no basic research, there will be no new building blocks delivered, and the possibility to achieve whished goals in the future will decrease. This argument is the straight-forward utilization argument for why there must be some basic research done within a community. A more philosophical argument is that basic research seems to fulfil an internal need for humans - as a species we seem to be interested in understanding why things happen, we are not satisfied with only observing that they happen, and we are interested in being able to predict what will happen after any certain intervention; a task that require knowledge about why and how the actual process works.

When performing basic research, it is rarely possible to know from the beginning if there will be a direct application of the results - it is not known if the produced building blocks will be suitable for putting into use at the time they are delivered. However, building blocks from basic research can be stored for long times. An example is radio waves: this character was theoretically understood by a man named Maxwell who published his findings in 1861, and another man, Hertz, managed to send radio waves in practice in 1886. Even then, there was no understanding of how this could be used in practice within the society (Hertz himself thought there was no use at all) but today it is obvious that there are a lot of uses of wireless links; for radio, television, mobile telephones, wireless communication between computers, and so on. Thus, we should not regard new knowledge without immediately applications as unusable. We, i.e. the society, also have to accept that some basic research attempts will never lead to applications. From the utilization point of view, results from basic research that never are used in an application can be regarded as a necessary cost to gain all the other results (which are used in applications). From the more philosophical point of view, also not applicable knowledge is meaningful.

Applied Research

Applied research is research done with a utilization goal; to find methods and technologies that can be used in practice, as research aiming at increasing crop yield, reducing natural resource degradation, improving human health, and increasing efficiency of resource use, thus; applied research has the goal to solve a specific problem - not at sometime far into the future but relatively soon. The word "applied" indicate that something already available will be used to reach that goal, that "something" is the building blocks delivered from basic research.

In the case of radio waves described above, applied research was done to figure out how to use the knowledge gained from basic research in practice; how to build sending and receiving units. Applied research is thus the research that is leading to practical use. A lot of additional examples can be given, here are a few: [1] Basic research was done to understand how the DNA is packed in cells of living organisms, and how the four repeatedly occurring subunits (the nucleotides) are combined to give the genes that code for different characters, and applied research has lead to the possibility to insert an alien gene in an organism (which for example often used in medical research, e.g. by getting rats that surely will get the sickness that is studied). [2] Basic research gives the knowledge about how pigs perform in nature, and applied research is done to understand how artificial environments should be built to allow pigs to perform in, at least, a semi-natural way in captivity. [3] Basic research gives knowledge about plant ecology, and applied research is done to optimize management against weeds using the understanding of performance of wild plants species occurring as weeds. [4] Basic research gives knowledge about atom nuclei characters, and applied research was done to understand how the energy released when splitting large atoms can be used for nuclear power or atom bombs. [5] Basic research was done to understand how smallpox spreads, and applied research was done to find methods to efficiently combat the disease.

When performing applied research, it is not always obvious what basic research result that is the building block or blocks. When a researcher investigate the effect of a new inorganic fertilizer on wheat, he or she may not be thinking about that basic research that has been done to understand the effect of fertilizers in general, to understand what components that are the active parts needed for plant growth, and how different chemicals react which each other during different circumstances (knowledge used to produce fertilizers of different kinds using chemical methods). Still, the basic research result is there in the background.

A field of study where basic and applied research is interwoven is agriculture. There was practically no agricultural research until about the middle of 19th century. Before this time, the Greeks made important contributions to science, including basic plant science. The first agricultural experiment station was established in France in 1834 by J.B. Boussingault. He carefully planned and carried out field experiment on use of manures and rotation of crops. He was first person to prove by means of experimentation that legumes are able to obtain nitrogen from sources not available to other plants (nitrogen fixation). In 1843, Rothamsted Experiment Station was established near London, and it is still in use. The first experiments at Rothamsted dealt mostly with fertilizers for crops including farm yard manure and inorganic fertilizers. By alternations between basic research and applied research, the 20th century could bring revolution to agriculture. The outcome include: mechanization of farm operations (increasing efficiency), better control of animal and plant diseases, pest insects and weeds, occurrence of animals and crops species better suited to what human beings ask for through concisions breeding, and improved quality (yield, taste, nutrient content...) in several products. As result of increased productivity, being a result of basic and applied research, in most developed countries currently less than 3% of the population feed the others and even produce excess; this may be compared to about 80% of the population in Ethiopia are farmers in one way or another.

Adaptive Research

Adaptive research attempts aim at adjusting technologies to specific set of environmental conditions. It involves bringing the results of applied research elsewhere and adapting them to a specific situation or environment. Adaptive research involves also the testing of different types of living organisms on places where they have not been established. Thus, adaptive research was done for example when rice was first tested for cultivation in Ethiopia. The practice to cultivate rice is very old, and there have been a lot of research aiming at practices and varieties, but to figure out in what way it can be successfully cultivated in a new environment requires research. In adaptive research, no new scientific principles are supposed to be discovered.

Case Studies

Case studies are often done to investigate the effect of one method or another on a group of people, like trying a pedagogical method on a class of school children or introduce a household waste sorting technique in a village, and following what happen. That means that case studies are not conclusive from a general point of view; they can only tell "at this occasion, this was the result". Some case studies are closely related to adaptive research. If a pedagogical method is known, or assumed, to be efficient in Mexico, and if trying it in Ethiopia, a case study can be done in order to evaluate its suitability locally. However, case studies may also be done to test novel ideas, as introducing a pedagogical method never used before to a class of Ethiopian school children. Case studies can also be done on other units than people, like following what happen with the discharge composition when a new production method is introduced in a fabric or how the yield is influenced when a new routine for harvesting is tried on a farm. In any case, the result from a case study is not possible to use for general conclusions, but show what happened in the actual case.

Not Everything is Research

Questions, Problems and Dreams

There are a lot of un-known things, problems and wishes in the world, and it is important to be aware of that a lot of these cannot be solved or answered with research.

Un-known things that never will be explained by any research are questions like "why am I here (on earth)?" or "will he get cancer if he doesn't stop smoking?". In the first example, the question is existential; the answer depends on the person and the situation - we may regard our existence on earth as a punishment, as a favour, as an obligation to help others, as the simple result of reproduction by human beings, or something else. No researcher can tell what is right or wrong with such personal convenience (but research can be done to get knowledge about why people think they are here on earth). The second example can be answered by research on a general level but not on the specific personal level. Research can show that, and explain why, people who smoke have an increased risk for getting cancer.

However, this does not imply that anything is known about the specific case - this special smoking man may be one of the smokers that live until the age of 100 years without any sign of cancer.

In a lot of cases, solutions to problems may require decisions in parliaments (or by other governmental level) and/or re-organisation, not research. Such cases are nearly all cases involving a "shall"; like "what shall be done to increase food availability for poor people?". To solve this problem, distribution of recourses (food and money) in a more even way than at present is the usual suggestion, and to decide to, for example, increase taxes for the rich to give food to the poor is a decision that must be taken on a national or international organisational level; it cannot be done by researchers. However, such decisions may require research as a basis. Research can explain how the situation will be for different levels of tax increase. Thus, parliaments take decisions based on their convenience of what is the best for the society as a whole. Research can provide decision-takers with knowledge of the outcome of different alternatives, but researchers are not the ones to decide how to manage a society.

Research is not implementation of knowledge - research is to gain new knowledge.

An example of a problem that involves decisions: whatever organism we consider, nutrients are required for growth. For all organisms, it holds true that growth increase quickly when increasing the amount of available nutrients from close to zero to slightly more (compare the growth response curve in Figure 2, where 0N on the X-axis symbolize the situation when the organism in question uses only the nutrients naturally available). Within agriculture, it is well known that animals as well as plants increase yield when supplied with more nutrients than what occurs naturally. Further, it is known that the increase rate is slowing down when more and more nutrients are supplied (compare Figure 2: going from 0N to 1N increase yield more than going from 1N to 2N, and the yield increase from 4N to 5N is very small), even though the yield continues to increase until a certain point where it first level out, and then decrease, because of toxic effects by too much nutrients. Thus, the general growth response curve in Figure 2 is a known fact, and no further research is needed to establish these facts (but a lot of research was done in order to establish these facts; i.e. to figure the general effect of nutrient input on growth). However, to fill in the specific numbers (how much nutrients, to what cost, that give how much yield of a certain species in a certain situation) require research.

Suppose that the government of a country wants to quickly increase the production of maize in an specific area, in order to offer people plenty of cheap maize flour, and the government plans to use common resources (i.e. money from taxpayers) to fund this. The government turns to agricultural experts and ask how this can be done. The experts answer (without any need for doing research, but based on what is already known) that for increasing yield quickly, the only possible way is to increase nutrient input at the sites of cultivation (solutions like increase irrigation or develop new varieties take long time). The next question from the governmental people may be how much it would cost to increase the yield from the present 0.25Y (Figure 2), "Y" being a constant, to the maximum possible yield. To answer that question in detail requires research if, but only if, the growth response curves of varieties used in the area, during present environmental conditions, are not known. After proper research, the constants N and Y, and their relation (Figure 2) are known, and the cost for different amount of yield can easily be calculated.

In practice, the solution would most probably be to use estimations: the agricultural experts use available data and present general fertilization recommendations for maize in similar environment, their personal experience, and rules of thumb to give an approximation of the constants N and Y, and their relation (Figure 2). To make such an approximation does not require research and it is not research. However, research has been done before; to get the data for maize grow in different environments and to and formulate the fertilization recommendations.

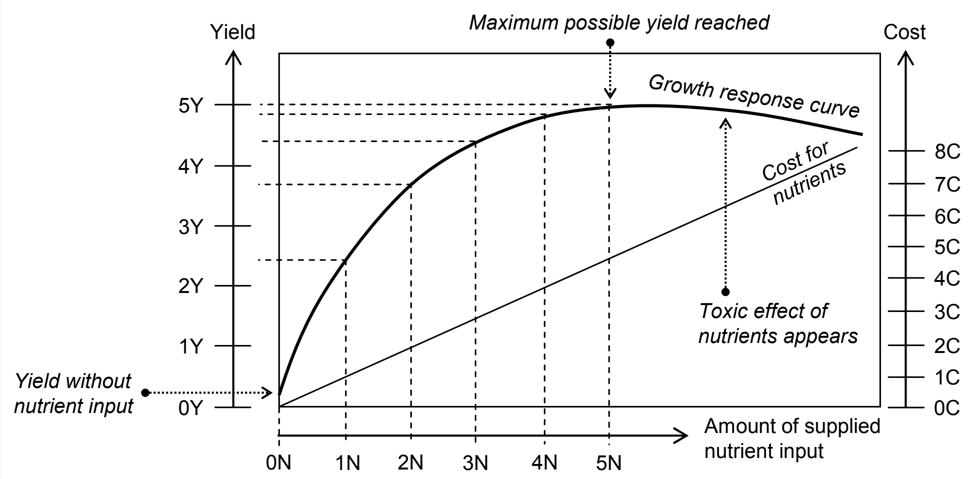

Figure 2. Principal, general, growth response curve and hypothetical relation between nutrient input, nutrient cost, and yield for a certain species in a certain agricultural situation.

Thus, either by drawing approximate conclusions from research done earlier, or by getting detailed knowledge from new research, the agricultural experts can now inform the government, with less or more confidence, respectively, that they will get additional yield of more than 2Y increase (totally 2.5Y) if providing the farmers with fertilizer for the cost of 1C. If adding additional 1C cost of fertilizer, the additional increase will be slightly more than 1Y (totally 3.75Y for 2C). To reach the maximum possible yield of 5Y will require a cost of 5C, a slightly smaller yield (4.8Y) will be achieved with 4C, and 3C will give nearly 4.5Y.

When such facts are established, the government has to determine what to do. Shall they increase taxes to such extent that they can get the 5Y yield, or shall they go for a nearly as much yield but less tax increase, or even less tax increase and a yield of 4.5Y? Or maybe less than half the tax increase needed for 5Y and a yield of 3.75Y is the best way? The facts that the agricultural researchers contributed with may well be combined with facts from social researchers that can investigate the amount of maize flour needed, the prices possible to pay for people in need, and the effect in the society of tax increase to different levels. Such a combination may be a proper basis for the governmental decision. *It is important to remember that this step, the decision, is not research!* Research has given the basal facts, but in what way to organize the society is not to be determined by researchers. Research can never tell governments what to do or how a specific problem shall be solved, research can only tell what will happen during different circumstances.

A lot of problems that occur in societies are very complex, like: "the forest is declining rapidly", "the fresh water in lakes are diminishing in increasing rate" and "the living standard difference between poor and rich people in towns is increasing". None of theses cases are due to one single easily identified factor. In all cases, research is probably needed to solve the problem, but research cannot be done to find a solution directly. Instead, researchers have to identify specific parts of the complex problem; such parts where present lack of knowledge may be a part of the reason to the problem to persist. Thus, to solve complex problems in society, usually several research attempts combined with several governmental decisions is needed.

Dreams, wishes and visions are commonly reasons for doing research, but are seldom possible to do research about directly. Such dreams may be "electricity should be produced without cost and without any affect on nature", "let's eradicate all sicknesses", "think if we had grass crops that supply humans with enough protein without need of fertilizer", "cattle that produce only meat and no bones would be more resource-efficient than the present" or "we need more, and more evenly distributed, rain during the year". It is probably obvious that these dreams will not come true - not because of lack of research but because they are totally unrealistic. However, such visions or dreams may lead to research being undertaken, as for the complex problems described above, which may make some smaller parts of the large dream come true.

Engineering

Engineering is about constructing and using technical solutions. Engineering is based on findings from research and knowledge gained thorough experience. Normally engineering is not research itself, but it is commonly a part in implementing practices or methods suggested from research attempts. Engineering may lead to research; for example if one scientist ask an engineer for a machine that can roll over fields and produce a certain kind of effect on the soil (that he/she have find increase water holding capacity), the engineer may first have to do research in order to get certain knowledge for developing that kind of novel construction.

Engineering is not restricted to traditionally areas, like constructing bridges, engines and computers, but is also part of work with, for example, cells and genes. It can be to insert a gene which codes for a protein that has been shown to give some character which humans desire, in an organism not naturally having that gene. Actual examples are crops given genes that lead to resistance to a certain herbicide (when spraying with such herbicide, farmers kill all living plants except the resistant ones in the field) or to increased production of vitamins essential for human beings. To this to be possible, a lot of research have been done ahead; first all research done to understand the gene structure and the expression of genes, then the research done to understand how different genes can be selected and cut out from tissue, then how it can be placed in other tissue, and then how to find the desired genes in different cases. However, when all this things is known, and is to be used, it is not longer research but engineering to do it (thus, all complicated things are not research).

Advisory Attempts

Very often solutions to problems are already available. In such cases, there is no research needed, but advice of to implement the available solutions is enough. Commonly, there is research behind the advice, but the advices themselves are not regarded as research. Advice can be about how to cultivate rice in Ethiopia (after adaptive research has been done to figure out where and how and what varieties which are useful) or it can be about giving advice of personal hygiene as a way to reduce diseases. However, research can be done to investigate how the advises function, for example by interview farmers and control the quality of their animals one year after an advise campaign of feeding practice.

Sometimes a problem is the result of the present management/organization. It may be simple things like clashes when two different classes are given the same classroom at the same time at a university, or more complicated problems as information deficiency between different groups of people (like teachers of different subjects and administrators) working within the same organisation and with the same target group (as working at a university and being involved with the same group of students), or conflicting opinions among employees about what the management want them to do, and/or different instructions from different individuals in the management to the employees. In such cases, the acute problem cannot be solved with research, but of course different ways to manage and/or organize can be investigated and compared scientifically.

It shall be noted here that just because the solution to the actual problem is available, there may still be implementation difficulties. Such difficulties are often related to economics; people may know that they can increase their harvest and their future income by using commercial fertilizers, but may not have the money to by them initially. In such a case, research aiming at finding less costly solutions may be asked for by the society, or the government may decide to give subsidies (compare with the example around Figure 2).

Connections

The different kinds of research and the attempts not being research mentioned above are often not clearly distinguishable from each other; on the contrary, they are connected to each other. There is no strict borderline between basic and applied research, or between applied and adaptive research. Rather, there is a continuous gradient, with pure research in one end and activities not being research in the other end (Figure 3). Further, one person may well have different roles during different periods or several roles simultaneously, thus; a person can be both basic researcher and advisor, for example.

The radio waves first being regarded as useless for applications and later shown being very useful have continued to be subjected to research. Basic research (increasing understanding on waves and electrons), applied research (studying how these finding can be used to send information more efficiently) and engineering (building the units of senders and receivers that can be used by people that are not engineers or have special education), alternating with each other, have lead to smaller and smaller units for both sending and receiving; the mobile telephones in use today may weigh some 200 gram; when "mobile" telephones begun being sold to the public, back in the 1980^{th}, they weighed several kilos and were carried in bags much larger than the laptop computer bags of today. This process took place on different places around the world; sometimes people worked with the same problem without being aware of each other, sometimes people worked with the same problem as competitors, and sometimes there were co-operations. Thus, the entire process was not regulated by some specific person or group of people, but resulted from several individuals and groups that attempted to increase knowledge and usability; all using the knowledge from earlier basic research, applied research and engineering constructions present at the moment. This process is still ongoing, and will probably continue long in the future.

Also single projects may include different kinds of research as well as other activities. Thus, basic researchers, applied researchers, engineers and advisors may well work together in an organized way when striving to solve a problem. To combat a disease, for example AIDS, requires basic research to understand how it is spread, how it interact with humans when giving the sickness and how the vector (the HIV virus in this case) respond to different substances. Applied research is done to find treatments that can delay outbreak of the disease in an infected person, and how substances that decrease the seriousness of the virus can be given to infected people in a way that target the virus but is not dangerous to the person; thus making the substance a medicine. Engineering is then done to build equipment that can be used to produce the medicine. Advisory is needed to teach people how to avoid at all getting the virus, and if getting the virus, to avoid spreading it furthering. Of course this is only an example; all three groups of people do a lot more in such a project.

Most research projects are much smaller than the development of use if wireless links or the combat against AIDS. Still they may include for example basic and applied research, or applied research, engineering and advisory; sometimes one single person having all the roles.

Ethical Research?

Above, when applied research was described, one of the examples of outcome of first basic and then applied research was the atom bomb. Probably, most, or all, people agree on that

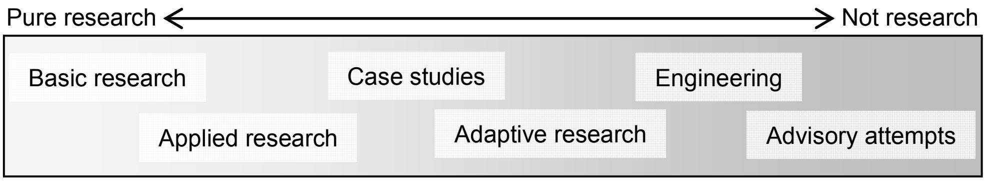

Figure 3. The different major kinds of research and research-related attempts are not distinctly different from each other, but are on the contrary connected along a gradient.

this is not a really nice thing to have. Because of the destructive force of this bomb, it has sometimes been suggested, within different societies, that scientists should be forbidden to perform such research that may lead to such dangerous constructions. However, even if such a regulation is imposed, it is in fact impossible to know what the result from any basic research will be used for. Thus, if a regulation says that specific kinds of research should be forbidden because it will lead to dangerous results, the regulators need to foresee both the actual result of research and the possible applications of the result; which is of course impossible, if it had been possible, no research had been needed. Therefore, the only possible way to forbid research that may lead to findings that can be used destructively in the future is to point out an entire area already known to be dangerous, as to forbid all kinds of research dealing with nuclear power. Such a regulation will lead to a situation when also possible benefits of nuclear power (as new and safe ways to produce electricity) will not be encountered.

Today, there are a lot of discussions about the ethics of gene modified organisms going on such as: shall we, humans, spread genetically modified organisms in the nature (we are already doing, through gene modified crops that can withstand some specific herbicides, and thus are the only survivor in a crop field sprayed with such a substance - very efficient weed combat), do we have the ethical right to produce pigs or other animals with some human genes and use the animals as "spare parts" individuals for humans in need of organs, and shall we modify the genes of a foetus when knowing that it has inherited genes that probably will lead to a serious disease later in life? These questions, and several others, are very important and should be discussed openly in a society. If the society majority regard this as things that not shall be done, and forbid research about genes to make sure it will not happen, also other thing cannot be researched on; like using gene modification to increase the nutritional value in crops that efficiently can be grown in backyard farming by poor people in disfavoured parts of the world.

However, to perform research in order to know about nuclear power or genes, or anything else that can be used in destructively and/or in ethically doubtful ways, is not necessarily the same as taking the action to implement different practises. It is an ethical decision whether or not to use the knowledge; no one suggest that research on AIDS medicines should be forbidden because some of the medicines found are lethal in high doses. The research done does not tell that people should be killed by the medicine; the research gives the knowledge of the effect when it is given in different doses.

Research may itself be regarded as unethical; what is regarded ethical or unethical vary over time and between societies. Generally, research regarded as unethical is a lot of research possible to do, or already done, with human beings. To be ethical acceptable, research that involve humans should not be done without clearly declare to the individuals that they are invited to be involved in a scientific study (thus, no one can be forced to participate), it should be explained to the participants what the research is about (thus, it is not accepted to tell people that they will test a new substance against headache if the substance in reality is assumed to enhance good mood), all possible risks with participation should be clearly explained, the individuals should be allowed to withdraw from the study whenever they like, without having to explain the reason, and all possible actions that can be undertaken to do the investigation in other ways than directly on humans should have been done. There are also ethical decisions, and in most countries regulations, when using animals for research. The animals should not have to suffer more than necessary (and what "necessary" is can be the subject of furious debates between people of different opinions), the smallest possible number of animals should be used, and other ways (like using tissue culture or electronically models) should first be considered. In a lot of countries, there are committees to which the researcher has to submit the plan for any research including living organisms, and the committee decides whether or not to allow it to be realized.

Overall, researchers should make ethical decisions regarding implementation of their research results, and users of outcome of research should make ethical decisions: it is not acceptable to claim "we did it because we could" or "the thing was developed by research" when deliberately causing disasters for others; there is no any exception for researchers or for anyone claiming to use research results - all humans have the same responsibility when it comes to ethics. However, if a society forbids different kinds of research to protect people from the outcome of any possible application, the society may instead destroy possible positive developments. In principle, research should not be hindered because the outcome can be used in unethical ways, but research that itself is unethical cannot be accepted.

Studying Scientific Work

Background

Theory of science is about understanding of scientific work. As long there have been scientist, there have been other scientists (in the field of philosophy) that have attempted to study, and describe, how scientific work is done, both how it practically is done, or should be done, and how it organized, or should be organized, within the scientific society. Different ways to explain and describe scientific work have evolved. These theories do not explicable make differences between basic, applied and adaptive research and case studies, but they may appear to be more or less suitable for different kinds of research; usually the philosopher had basic natural research in mind when developing a theory. As may be evident from below, there is not one single theory of how science should be described agreed on, but several, sometimes conflicting, suggestions and possibilities.

Deduction

In its scientific meaning, deduction means to logically draw conclusions from available information, from premises. Observe, that this imply that *only if the premises involved are true, the conclusion will be true*. Thus, a logically correct conclusion is a false description of the reality if one or several of the premises is/are false, but it is still a proper deduction.

A simple example:
Premises 1 - Silver ions are harmful to living organisms.
Premises 2 - Lettuce is a living organism.
Conclusion - Silver ions are harmful to lettuce.

There are two main problems with this method for its practical use for entire scientific attempts. First, it is rare to have such complete information that is needed to formulate true premises. Second, scientists do in practice seldom work with such problems that can be solved only logically.

In the simple example above, the scientist it probably more interested in how harmful silver ions are to lettuce; how it affects during different part of the life cycle, and what concentrations and/or amounts of silver (which determines the silver ion concentration) that may be tolerable in soil for lettuce growth. To reach conclusions in such cases require a number of detailed information, like:

Required information 1 - The silver ion effect on seed set.
Required information 2 - The silver ion effect on seed germination.
Required information 3 - The silver ion effect on plant growth.
Required information 4 - The silver ion effect on seed set in concentration X.
Required information 5 - The silver ion effect on seed set in concentration X+1.
Required information 6 - The silver ion effect on seed set in concentration X+2.
Required information 7 - The silver/silver ion balance in soil type A.
Required information 8 - The silver/silver ion balance in soil type B.
Required information 9 - The silver/silver ion balance in soil type C.
... and so on. Of course, the list can continue in eternity; involving all combinations of all possible silver ion concentrations, all possible stages of a plant life cycle, and all possible soil types.

Thus, to reach a conclusion of the overall effect on silver ions on lettuce require very complex or very large numbers of premises. From limited premises, deduction will lead to limited conclusions, for example:

Premises 1 - Free silver ions are more common in soil type A than in soil type B.
Premises 2 - Free silver ions affect lettuce growth negatively.
Conclusion - Lettuce growth is more negatively affected by silver supply in soil type A than in soil type B.

This conclusion can be drawn by deduction, without actually growing lettuce, with and without silver supply in soil types A and B. Conclusions through deduction require that information (premises) is available. Conclusions that are true (that are in line with reality) require that the premises are true. In the case with silver and lettuce, it is needed to be sure that the silver/silver ion balance in soil type A and soil type B *always* differ in the described way (for the same silver concentration supplied, there should always be more free ions in soil type A; that principal outcome should not dependent on humidity or temperature or something else, even though these factors may affect the actual amount of free silver ions) and that lettuce growth *always* is negatively affected by silver ions, regardless of other circumstances. The information in the premises must come from somewhere, and to be meaningful for conclusions it should be correct; it should be facts.

The main benefit from deduction is that it allows interpretations of general theories or natural laws: for example, based on the knowledge on gravitation and other natural forces, conclusions can be drawn about how items of different masses perform if thrown in different ways on the moon. It is also suitable when it is impossible to actually study the cause and effect in question, like when aiming at understanding a historical process. However, in the case of lettuce and silver, and other attempts when the goal is to get knowledge about what happen with one specific thing during different circumstances (in the lettuce/silver case: what happen with lettuce along a gradient from no silver to lethal silver dose in different soils?), the research would most probably be done according to induction and probability below.

To benefit from deduction, it is necessary to have proper premises that can lead to novel conclusions about how things are. In obvious cases, like:

Premises 1 - All trees in plantation P are of the species *Eucalyptus globulus*.
Premises 2 - This is a tree from plantation P.
Conclusion - This tree is an individual of the species *Eucalyptus globulus*.

the deduction is not really meaningful; if it is already known that all trees in a group belong a certain species, it is not interesting to tell that every single individual is of that species. But:

Premises 1a - Light can be considered as a wave movement in a medium.

Premises 1b - When light pass from one medium to another, the direction of the movement changes.
Premises 1c - When white light passes a prism, it will be separated in seven different visible colours.
Premises 1d - Rain drops acts as prisms, because light changes angle when passing between the two mediums air and water.
Premises 2 - On a suitable angle between the sun and an observer on earth, the effect of rain drops as prisms can be observed.
Conclusion - When it rains, and the sky is not entirely covered by cloud, white light passes rain drops that function as individual prisms; giving a rainbow when observed from a suitable site.

is a meaningful deduction in order to explain how rainbows arise (this is a very simplified description of the what could be two very complicated premises: the first one describing all facts of light and how it breaks against surfaces of different angles and/or different mediums, the second describing everything about the sun's position in relation to the earth and the observer for the effect of prisms to appear).

Deduction, or deduction-like thinking, is often a part in the process leading to a scientific hypothesis. In such cases, one or more premises are not regarded as facts, but as the best explanation to a phenomenon found so far; thus as scientific theories (more about scientific theories below) that, if they are correct, will lead to the hypothesis being correct during specified circumstances, like:

Existing theory - The majority of couples in a society will reduce the number of children they have to one to three if the risk for infant mortality is low and there is an income guarantee for those who cannot work.
Premises - In country C, in Africa, where the present birth rate is five children per woman, the government has recently increased health care for infants and set a guarantee pension for elderly people and people incapable of work for health reasons through social security laws.
Hypothesis - The birth rate in country C will decrease to on average circa two to three children per woman as soon people start realising the effect of the social security system; possible within ten years.

In this case, there is one theory (that is based on the transformation from high to low birth rates in North America and West Europe) and one premises; the premises is a fact, it is known that this is done. The conclusion is regarded as a hypothesis: the researcher will follow the development in country C and either find support for the original theory (if the hypothesis is correct and thus the number of births are reduced as predicted) or reject it as a general theory (if the birth rate change in response to the actual factors in country C not follow the pattern from North America and West Europe).

The premises used for deduction must come from somewhere; that "somewhere" may be induction or direct observations.

<u>Induction</u>

In its scientific meaning, induction means that a large number of observations, showing the same result, are finally enough for concluding that it is in that way always, also for all coming occasions. Induction leads from a large number of singular observations to a universal conclusion. A simple example:

Observation 1 - Sunrise occurs in the east every day in April.
Observation 2 - Sunrise occurs in the east every day in September.
Observation 3 - Sunrise occurs in the east on Wednesdays.

Observation 4 - Sunrise occurs in the east on Fridays.
Observation 5 - Sunrise occurs in the east on cold days.
Observation 6 - Sunrise occurs in the east on warm days.
Observation 7 - Sunrise occurs in the east on humid days.
Observation 8 - Sunrise occurs in the east every day in Ethiopia.
Observation 9 - Sunrise occurs in the east every day in the Philippines.
Observation 10 - Sunrise occurs in the east every day in Mexico.

After doing these kinds of observations for a large number of occasions; at some point the researcher will draw a general conclusion:

Conclusion: Sunrise occurs in the east every day.

However, if the observer is north of the northern polar circle (the three above mentioned countries are located entirely between the northern and southern polar circle) in the end of December, the observation will be that sunrise not occurs in the east; simple because there is no sunrise. On that latitude on that time of the year, the angle of earth in relation to the sun leads to 24 hours of darkness per day (on the other hand, in the end of June there are 24 hours per day with sunlight there; so there is no sunrise on that time either). Thus, the observer had not covered, for example, all Wednesdays at all places on earth. As far as is known, a true conclusion should be "when sunrise occurs, it is in the east" or "between the northern and southern polar circle, there is sunrise in the east every day".

Thus, conclusions from induction suffer from the uncertainty that an additional observation can be in contradiction to the ones already done. Therefore, induction requires that proper observations are done during all relevant circumstances - conclusions should not be drawn about the outcome in other cases. In the simple example above, the observer made sufficient observations for April, September, Ethiopia, the Philippines and Mexico (wherever one is on earth, there is sunrise to the east in these months, and through the year there is sunrise to the east in these countries), but incomplete for the other (not including, for example, a Wednesday north of the polar circle in January among the studies Wednesdays). The difficulties is of course to know when the amount of observations is enough for a conclusion, and which different external circumstances that are important to have present when doing the observation (in case they influence the outcome).

The problem with amount: Assume that you are studying zebras, and you travel around Africa to observe as many individuals as possible of all different races. You note the colour on each individual, and end up with a protocol like: zebra # 1 - black and white striped, zebra # 2 - black and white striped, zebra # 3 - black and white striped, zebra # 4 - black and white striped, ... zebra # 76,302 - black and white striped, zebra # 76,303 - black and white striped; with anything else than "black and white striped zebras" in between. Are then 76,303 zebras enough for drawing the conclusion that all zebras are black and white striped? It may seems so, but zebra # 76,304 can be an albino, and thus completely white. The conclusion that all zebras are black and white striped would be wrong. Whatever is observed, how many observations are done, it is, of course, not known what the next observation will be. How can anyone know that the there will be sunrise in the east in Ethiopia tomorrow?

The problem with external circumstances: In the case of observing where sunrise occurs, it is irrelevant to include all possible environmental conditions (like: 50 % air humidity and 20° C, 50 % humidity and 13° C, 40 % humidity and 20° C, 60 % humidity and 20° C.... in eternity, because humidity, temperature, cloudiness, wind speed and wind direction are continuous variables - they can be measured with an endless number of decimals). Relevant to include for the sunrise conclusion is the place on earth from which the observation was done. However, we can state what is irrelevant and relevant in this case just because we already know (at least we think we know) the reality ("between the northern and southern polar circle, there is sunrise in the east every day") and the reason for it. When performing research, the outcome is, naturally, not known.

When Hertz made experiments on the electromagnetic theory Maxwell had formulated, on producing and sending radio waves, he could have included an endless number of external circumstances. What factors were relevant to measure and/or include? Air humidity? Time of the day? The size of the laboratory? The size of the researcher? The colour of measurement apparatus? These are only a few suggestions of possible external factor to take into account, and before having knowledge, it is hard to include or exclude any, but "time of the day", "size of the laboratory", "size of the researcher" and "colour of equipment" probably seem to be irrelevant to most people. However, one of them turned out to be relevant: according to Maxwell's theory, radio waves should move in the same speed as light, but even though Hertz could experimentally confirm several of Maxwell's predictions, he found that the speed of the radio waves in his laboratory was, according to his measurements, considerably slower than the speed of light, despite repeating the measurement a lot of times. Later, when Hertz was no longer in life, it was understood that the size of the laboratory had been suitable for radio waves to reflect and continue to move properly; reaching the apparatus used after additional distance to the intended. Therefore, Hertz had measured the travel time for radio waves that had travelled longer distance than he thought they had. Thus, the size of the laboratory was of huge importance in this case. If including laboratories of different sizes, maybe Hertz, who continued to try to find explanations to either why Maxwell's theory failed or if Hertz' own experiment were inadequate, had been able to draw the correct conclusion that the radio waves travel in the speed of light.

Induction has the drawback that one has to assume, at some point, that all relevant observations are done, even though this cannot be known.

When performing research, scientists often use inductive methods without questioning them, or reflecting over that such methods are used. For example: [1] this magnet camera has always been proper for detecting brain tumours, so of course it should has done also this time if there were any, but it is not, [2] this inventory method of animal species has been used for long time, so it must be good, or [3] there is no difference in weight between these two groups of chemical compounds, because we can not measure any difference with the scale we have always used. The reality may be: [1] in this case, the tumour was too small to detect with that camera, or some lens had been damaged (and how could anyone know that the results have always been correct before?) [2] there are some species that are excluded by this method; just because a method has been used for long, and may has become a formal or informal standard, nothing is there to evaluate if it is "good" or accurate (however, if the goal is to compare changes over time, the best way is always to use the same method used before, even if some species may impossible to detect with the present method), or [3] there is a difference, but how small differences one can measure depend on the equipment - better to state that with the accuracy of X g (the size of X depending on the scale) no difference can be detected (assuming the scale has not been damaged). Thus, it is a good advice to *not take methods for suitable just because they have been, or seem to have been, functional before, but to evaluate the suitability of possible methods to use every time planning and performing research*.

Facts and Observations

Observations are considered essential for different theories of science; observations should provide the scientists with facts; with the truth to base conclusions and/or further research on. As obvious from above (regarding deduction and induction), the information used for conclusions most come from somewhere - someone must deliver the knowledge that silver ions are harmful to living organisms to make it possible to draw the logical conclusion that silver ions are harmful to lettuce because lettuce is a living organism. For the conclusion to be meaningful, the knowledge should tell the fact.

Observations are often regarded as being the truth: what we see, feel tactilely, smell, taste or hear must be the truth. Thus, whatever conclusion is done, it should be based on observations, is a common claim.

So, can we uncritically believe what we observe? The simple answer is no. One example: If one takes a stick that is completely straight and put it in water to half of its length (holding the stick so it is neither completely vertical nor completely horizontal), one will make the visual observation that the stick is bent on the middle; where it passes from the air to the water medium. If one slowly lifts it up again, one will observe that the bent part move on the stick, always occurring where air meets water. When the stick is completely up in the air, one will observe that it is again completely straight. Is this observation wrong? No, it is not wrong, but it is wrongly interpreted. The proper interpretation is that it looks like the stick becomes bent and unbent in the described way. The visual observation of the stick that bent at the water surface is an optical illusion, caused by light going through different mediums. Thus, the "instrument" the unaided eye is not a proper tool for observing the effect on water surfaces on items.

Analogous, the equipment, the instruments, used for more complex observations may cause impressions that are illusions. In addition to this, the instrument used must have a resolution that allows observation of the studied phenomenon. When light microscopes were first constructed, during the Renaissance, a lot of interesting, and proper (at least as far as we know) observations were done, but also some that were based on illusions. One example is when seminal fluid from humans was placed in an early microscope, one interpretation was that the sperms were small individuals, with a head (having eyes and mouth) visible. This misinterpretation was caused by unclear views in the microscope (dark patterns, resulting from the optic, on the lighter sperm could be eyes and mouth with some fantasy), too low resolution; the observer was drawing relatively large sketches, but the views in the microscope must have been very small items, and the observer's presumption that the seminal fluid must be involved in pregnancy. Similar misinterpretations have been done with the structure of planets, by interpreting patterns that were caused by the optical equipment used as mountains, floods and seas. Today the light microscopes give very clear views, but optical laws restrict the size of the item that can be observed to minimum 0.2 μm. The smallest bacteria known are a bit smaller than that (about 0.17 μm), so if attempting to study the total number of bacteria in a sample, and be sure bacteria of all sizes are counted, not even a modern light microscope is enough. Always when doing observations that involve any measurement, the conclusion is depending on the scale and accuracy of the used equipment.

An observation the authors to this text have done is that most students that have laboratory lessons are quick to begin asking if there is something wrong with the equipment used when the obtained result is unexpected ("wrong"), but no one question the equipment when the obtained result is as they expected. On the contrary to this, we should all strive toward the questioning attempt, and ask ourselves to what extent we can trust the used equipment/instrument for giving us a true impression regarding the observation done.

Another difficulty with observations is to determine whether or not one has done all observations needed to understand the phenomenon in question. An example: The swallows in northern Europe, that were assumed to hibernate in lakes (before it was understood that they migrate to Africa), is an example on how interpretations from not complete observations can lead to false conclusions. In the autumn in northern Europe, when the swallows that were born that year have learned to fly, one can observe quite large numbers of swallows flying close to the water surface of lakes. They fly there because they are insect eaters, they catch flying insects in the air, and there are a lot of flying insects close to the water surface of lakes. The way swallows were flying was observed, and it was also observed that during a short period of time the number of observed swallows first decreased steeply, and then became zero. The conclusion was that they went down into the lakes (because swallows, even though in a smaller number, came back in the spring, it seemed unlikely that all should be caught by hunting birds or die by any other reason during that time). The possibility that these small birds were able to migrate thousands of kilometres to the south, where they have suitable climate for the time period with harsh winter in northern Europe, was not even thought about.

When the available observations were: "swallows are close to the lake surface in autumn" and "swallows are gone from autumn to spring", the conclusion that they spend that time in the lake maybe not was so very unrealistic? There are other animals, for example frogs, that hibernate under the ice cover in lakes in northern Europe. The missed part of the observations regarding the swallows was that they fly away to the south (they fly quite high over the earth surface, so it is indeed understandable that this was a missed observation).

One more example: when the planet Mars was observed thorough an early telescope, the observation was that is was quadratic - because it looked quadratic because of the quality of the lenses used. Today it is known that all planets are (more or less) spherical; this can be observed with today's lenses.

The examples with sticks and swallows above may seem obvious: no one should be stupid enough to assume a stick will bend and unbend in that way when put in water, and no one should conclude that swallows go down into lakes without seeing any individual actually diving into the water and not finding any individual in the lake. However, this is obvious just because we know how it is (or correctly: because we think that we know how it is). For observations that concern not yet explained phenomena, it is far from obvious if an observation is proper or an illusion; or whether or not the observation is complete regarding the phenomenon concerned. There are also risks with observations when the observer already has an explanation in mind; this may lead to (unconscious) exclusion of part of the observation and/or of some possible explanations to the observation, just because the observer is convinced it is in a certain way. Can we really be sure that the stick does not bend in the water surface? Maybe we are too indoctrinated from attending physics lessons in school to believe the witness of our eyes?

For long, people regarded the earth as flat. They did this even though there were observations available that could not occur if the earth is flat. One observation that require that the earth is not flat is that when a ship is first observed at the horizon, one can only observe the top of it, when it comes closer more and more of the it will be seen (Figure 4). This is indeed not any proof for the earth being a sphere (it could be a cylinder, or bent like a saddle, for example), but it shows it cannot be flat. By being convinced that the earth is flat, a large number of people may have done the observation in Figure 4 without reflecting on its interpretation.

Thus, a scientist has to be aware of that *an observation may be an illusion*, *the observations done may not be enough for a proper conclusion* and *unconscious presumptions may influence the interpretation of the observation*. Observations are not necessarily analogous to facts.

Replication

Replication means making repeated measurement (or sometimes estimations) of the factor of interest during the circumstances of interest. The motivation to this is that an observation should be closer to the truth if the same thing is observed several times; this would make the observation being general. This does not mean to measure the same item again and again, but to measure the same factor again and again. Thus - not to measure the height of the same zebra several times if interested in the height of zebras in a population, but in that case measure the height of different zebras in the population to get an approximation of the general height of them. For several commonly used statistical methods, it is necessary to include replicates of the studied factor(s).

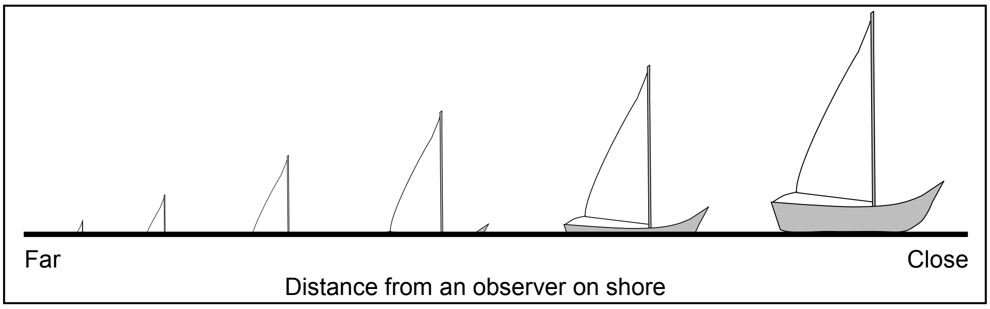

Figure 4. This is what, in principle, is observed from shore from when a boat is fist observed at the horizon, and moves toward the shore where the observer is.

For replication to fulfil the intention to give a stronger support for an observation being correct than if the observation is done only once, first, *it is needed that the repeated observations not suffer from being illusions or a result of the observer's presumption*: despite measuring the travel time of radio waves several times, Hertz could not do the correct observation, because his observation was an artefact of room size interfering with the factor studied. Second, *it is needed that the repeated observations are made on independent items*. If measuring only one zebra, the observation done shows nothing about other zebras, nothing about zebras in general, regardless of how many times the single one is measured.

What is replicated determine what the following estimation of mean or median or minimum or maximum or fraction (or something else) is regarded to represent. Three examples:

1) If taking one litre of water from one spot in one water treatment plant, and then taking ten samples of one millilitre each from that litre and count the number of bacteria in each millilitre (using all proper and relevant methods for mixing the litre and counting bacteria), the resulting result (e.g. average number of bacteria per water volume unit) *does not* show anything about bacteria occurrence in water treatment plants in general, or about bacteria occurrence in water treatment plants in that country, or about bacteria occurrence in water treatment plants in that region, or not even about bacteria occurrence in that specific water treatment plant or in the specific basin from which the litre was taken. It shows the occurrence of bacteria in that litre (as an estimation based on the average of the ten millilitres investigated). The litre initially collected was replicated; nothing else. To replicate the occurrence of bacteria in that basin requires samples from different points in the entire volume (deep, shallow, close to inlet, close to outlet...), to replicate the bacteria occurrence in that specific water treatments plant require replicates from different basins, to replicate the bacteria occurrence in water treatment plants in that region, or in that country, or in the world require samples from different water treatment plants from the area of interest. If interested in whether the bacteria occurrence changes within one basin, replication should be done in different parts of the basin: taking replicated samples from deep parts, from shallow parts, from parts close to inlet, from parts close to outlet... If interested in whether bacteria occurrence changes consequently within water treatment plant basins in general, the procedure has to be replicated with other basins.

2) If aiming at investigating how much iron increase in size when heated to 70°C from 20°C, it is not proper to use the same piece of iron and put it in 20°C and measure it, heat it to 70°C and measure it, cool it to 20°C and measure it, heat it to 70°C and measure it, cool it to 20°C... and so on. This method has replicated the response of that piece of iron when transferred between 20°C and 70°C (and also between 70°C and 20°C); it has not replicated anything about iron in general. To investigate, by using replication, how much iron in general increase in size when heated to 70°C from 20°C requires measurements of different pieces of iron.

3) If aiming at investigating the possible effect on soil quality of having trees in grasslands, it is not regarded as proper replication to go to two different enclosures, one with trees and one without trees, and take soil samples from both (Figure 5A). Regardless of how many samples that are taken from each enclosure, how similar the grasslands are regarding all other factors than the occurrence of trees, and how careful the soil quality is measured, there is no replication for the effect of trees on soil quality in grasslands. To replicate the effect on soil quality of having trees in grasslands, it is necessary to replicate grasslands with trees and grasslands without trees (Figure 5B). Replication of not directly adjacent enclosures is assumed to give a general observation of soil quality in grasslands with trees and a general observation of soil quality in grasslands without trees; these two general observations can then be compared, and if there is any difference, this can be concluded to be correlated to the occurrence of trees. However, any such observations and conclusions are only relevant for the environments from which the samples are taken; if interested in whether there is a worldwide general effect on soil quality of having trees in grassland, the researcher should take samples from different environments, including grasslands both with and without trees from all environments.

The authors of this booklet have the impression that the most common misuse of the theory of replication is to do as described as improper in the three examples above: instead of replicating by using independent items of the factor of interest, the researcher uses one item and take sub-samples from it. If aiming at investigating the effect of ploughing on weed emergence in farmlands in southern highland Ethiopia, it is not proper to take several samples from one field with ploughed and not ploughed parts, or samples from one ploughed and one not ploughed field (compare Figure 5A). Instead, it is necessary to involve several fields in the region, using both ploughed and not ploughed parts in each (compare Figure 5B). Otherwise, the replication and observation done is only about the effect of ploughing on weed emergence in the single field, or a comparison of two fields without knowing anything about the reason for a possible difference. In this context, it shall be underlined that it may well be of interest to investigate the difference between ploughed and not ploughed parts in one single filed, or the difference between two fields of which only one is ploughed, but results from such studies cannot be used for general conclusions of the effect of ploughing practice.

There are several things that may be of interest to study but which cannot be replicated. To this group belongs everything that involves the entire earth. When aiming at predicting future possible climate changes, and the effect of such changes, researchers cannot use full-scale replication, regardless of the amount of resources that are provided, simple because there is only one earth. A solution that is used is to use huge computer resources and modelling an earth and all environmental factors that at all are known, and put in random occurrences of factors, or amount of factors, for which there are not known correlations to other factors. By "copying" that model earth it is possible to repeat a certain scenario, like: what happen if all carbon dioxide emissions can be kept on the present level for the future? Such attempts are, of course, highly dependent on the accuracy of the model - this is an important reason for different scientist coming to different conclusions even though all used repetition on theirs models, and also one important reason to the debate of whether the predictions at all are plausible.

There are also a lot of things smaller than the earth that cannot be replicated: a village, a natural reserve, a lake... If someone attempts to investigate "what happen if people in this village get education of the benefit of hand hygiene?" this person cannot use replication, because there is only one of the village. The person may decide to use similar villages (about the same size, about the same environmental circumstances, about the same living standard...); in that case at least four villages are needed, two (two replicates) that are subjected to education on hand hygiene and two (two replicates) that are not subjected to any education regarding hand hygiene. Because of the difficulty of finding similar villages (or natural reserves, or lakes) and the very large size such study attempt soon reach, it is much more common to use a case study attempt than a replication attempt: to carefully investigate the present hand hygiene and health situation before beginning education, then

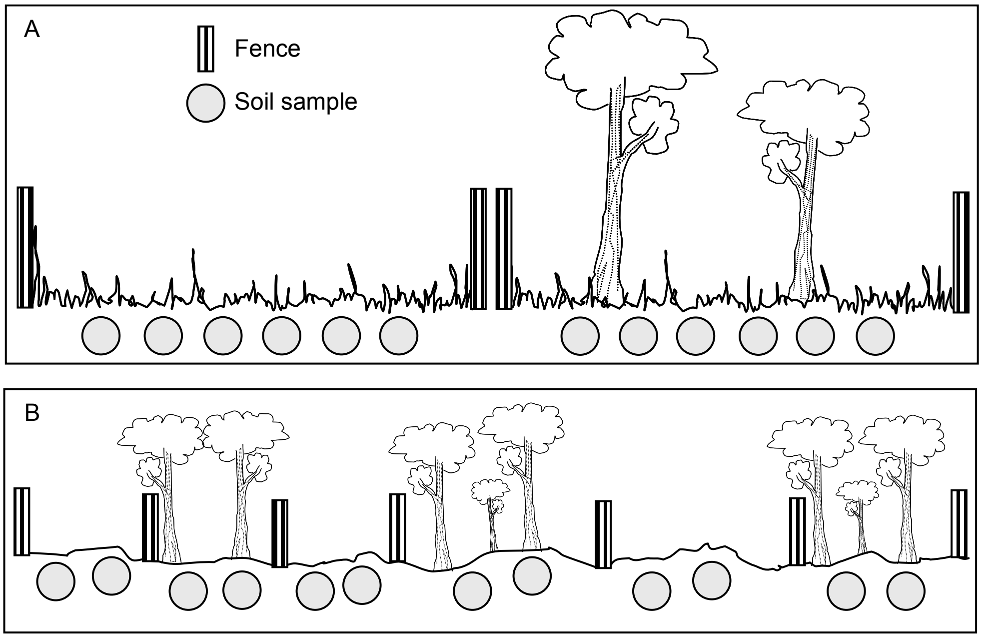

Figure 5. Repeated soil sampling from grasslands; all being in the same environment. Six soil samples from each of two different grazed enclosures; one with and one without trees (A) and two soil samples from each of six different grazed enclosures; three with and three without trees (B). In A, there is replication (six replicates) on the soil quality in each enclosure, but there is no replication of the occurrence of trees in the grassland: there is only one enclosure with and one enclosure without trees. In B, there is replication (two replicates) on the soil quality in each enclosure and there is replication (three replicates) of the occurrence of trees in the grassland: there are three enclosures with and three enclosures without trees. The replication used in B, but not the one used in A, is regarded as acceptable for conclusions about the effect of trees on soil quality in grasslands during such environmental circumstances where the enclosures are.

perform the education, and then investigate the situation again in the same way, maybe several times after different time periods.

Probabilities

One way used to solve the core problem of induction (i.e. that regardless of the number of observations during different circumstances, it is never known if the next observation will contradict, thus; it can never be known if the conclusion is the truth) is to not state a universal conclusion, but to specify with what probability the conclusion is correct.

Spontaneously using probability is, for many people, an appealing way to handle induction: despite the fact that it is impossible to do all possible observations on sunrise or colour of zebras (even if all resources needed should be available, there will always be new days to check sunrises and newborn zebras to check the colour on; the investigations would never be finished) the scientific society needs to be able to draw conclusions, otherwise the work has no meaning. Therefore, it seems like a good idea to use the observations available and determine whether conclusions from them are true with high probability. However, it is impossible to determine the probability for whether something is the absolute truth; if something with guarantee will happen again during specified circumstances.

To some extent, replication is a way to be convinced that an outcome is the one and only result of a specific activity: the first stone thrown up in the air fell down back on earth, the second stone thrown up in the air fell down back on earth, also the third, the forth ... and all other stones, also if trying with billions, thrown up in the air fell back on earth. Thus, it is high probability that also the next stone thrown up in the air will fall back in earth. If we do X, and Y happens every time, and we do this a number of times, we are inclined to regard it as truth that if X is done, Y will happen. However, it is impossible to tell how many times we have to do the same, always getting the same outcome, to be convinced that there is a direct correlation between that activity and the outcome. On an individual level, people have different tendencies to regard an observed pattern as an indicator on correlations: some people think "the two last times I bought a lot from this boy I won, so I will by from him again, and I will win again", while other would regard the seller of lots as a factor not at all involved in whether a bought lot turns out to be a winning one. The same problem is there for more complex possible correlations; if someone tries a certain soil cultivation method for the first time, and get higher yield than usual, and then use the new method also next year, and get higher yield than usual - is this enough for drawing the conclusion that the new method with high probability is generally better than the old method for this farm? Some people should spontaneously say "yes" and motivate with the fact that there had been unusual good harvests when using this method, some should say "no" and motivate that there may have been other, not observed or recorded, factors that led to the unusual good harvests. Thus, we cannot use our own opinion (not within the scientific community, nor in any other part of the worldwide community) to determine the probability for something being the true explanation to a phenomenon, because we have very different such opinions.

There are statistical methods for calculating the probability that something will happen again if doing it again. If someone tests the germination of 50 newly ripe and viable seeds of the species *Heliotropium zeylanicum* in an environment with 25°C daytime, 15°C night time and light present during daytime, and found that all seeds germinated within two weeks, the result is that 100% germinated. From this, it can be calculated that the lower 95% confidence limit[1] is 92.885%. Thus, with 95% probability at least 92.885% of the seeds will germinate each time this test is repeated. The reason for the uncertainty of about 7 percent units, despite that all seeds germinated in the test, depends on only 50 seeds being tested. If 500 seeds were tested, and all germinated, the corresponding figure would be 99.261%, if 5,000 seed were tested and all germinated it would be 99.926%, and if 50,000 seeds were tested and all germinated it would be 99.993%. Thus, the statistical model is based on the assumption that the more occasions the same thing happen, the higher is the probability that it will happen again.

However, statistical models do not allow the outcome to be 100% probability that the same thing will happen again; 100% is the upper asymptote for the lower confidence limit; an asymptote is mathematically a level that a function approaches but never reaches; if using an endless number of *Heliotropium zeylanicum* seeds and test for germination in the environment described above, and all germinate, the statistical outcome will be that the lower 95% confidence limit (or any other lower confidence limit <100%) will approach 100% but never reach it. If using probabilities closer to 100% than the 95% confidence interval used for the calculation in the example, the uncertainty will be larger, and more seeds (that all must germinate) would be needed to reach any certain lower confidence limit. However, as with the lower confidence limit, there is no mathematical way to calculate an outcome with 100% probability. Mathematically, the 100% certainty arises when the eternity is reached, thus; it will never happen, regardless of how many replicates the probability calculation is based on.

[1] Confidence intervals, with lower and upper limits, should be understood as the range within which one can assume the achieved result to be representative for the truth with some probability. In the case of 50 germinated seeds of 50 seeds tested for germination and 95% confidence interval, the outcome could be read "with 95% certainty, the result, if testing the entire *Heliotropium zeylanicum* seed population for germination in the described environment, would be something between 92.885% and 100% germinated". Thus, 92.885% is in this case the lower 95% confidence limit and 100% is the upper (when calculating probability based on fractions, the lower confidence limit is $\leq 0 < 100$, the upper is $< 0 \leq 100$, and the lower < the upper). There is no mathematical possibility to achieve a situation where the lower confidence limit is 100%, or the upper is 0%, or when the two limits are exactly the same. Thus, there is always some uncertainty reaming.

Very often, probabilities are not used to determine strictly if something will or will not happen, but to give an impression of the probability that something specific will happen (or will not happen). This use includes statements like: "a smoker has 75% higher risk to get lung cancer than a non-smoker", "with 65% certainty it will rain in southern Sweden tomorrow" or "the chance to survive a severe car accident increase with 90% if using belt". Such calculation is the result of investigations of what happen in a large number of cases: sometimes non-smokers get lung cancer and sometimes smokers not (even though the opposite is much more common), often when having the weather circumstances present that day it will rain in Sweden the coming day (but quite often it does not), and people killed in car accidents were much more often individuals not using belt than using it (but belt is no guarantee for surviving). Thus, in such cases it is not possible to predict what will happen in any specific case; the probability is general, and may function as advice: do not smoke, bring an umbrella, and use belt in cars.

Using statistics for calculating any probability is automatically use of induction; it is about drawing general conclusions from several single observations; not claiming that the eternal truth is found, but claiming that there is some specific, calculated, probability that the conclusion is correct (and the complementary fraction until 100% probability being the probability for the conclusion being wrong). Thus, using probabilities, and statistics, is not a way to detach from induction; it is a way to soften the conclusion that the truth is found.

Falsification

The principle of falsification sounds logical to most people. A conclusion should be tested again and again, attempting to falsify it. Only if the conclusion withstands the attempts to falsify it, it is regarded as true, or rather as a temporary, tentative truth, until finally falsified by someone in the future. As soon as a conclusion has been falsified, it is absolutely true that it was false. Thus, by using falsification one can not judge that something is a true conclusion, but it is possible, with 100% certainty, to judge a conclusion as false - if it is proven wrong at any single occasion, then it is not generally right. To use falsification, one needs a statement, some conclusion, to test. It is not possible to falsify "it may or it may not lead to better health if people in small villages in Africa are educated about hand hygiene", because whatever happen, this statement is true. In this case, it seems more logical to formulate the statement "it will lead to better health if people in small villages in Africa are educated about hand hygiene" and then attempt to falsify it; thus checking the health of people in a small village in Africa, educate the people about hand hygiene, and check the health again. If health improved in the first village, additional villages should be included to attempt to falsify the statement.

Observe that it is not possible to properly falsify statements that include words like "perhaps" or "maybe" or other words for uncertainty that include different possibilities in the outcome. In all these cases, the outcome of a test will be true whatever happen.

The underlying thought for using falsification is that it is needed to have "working conclusions", it is not possible for the scientific community to wait for all true explanations before using any conclusion for any interpretation or explanation - without allowing conclusions to be regarded as true, or at least true enough to be usable, all scientific work would come to a stand-still. By trial and error (by construction conclusions and try to falsify them) the scientific work should grow; even if a formulated conclusion is not really logical, and easily becomes falsified, it is not wrong to formulate such conclusions - the method with falsification will directly lead to them being discarded, thus no damage done by formulate a wrong conclusion from the beginning. In this way more and more possible statements and conclusions will be tested, some will not be falsified, and these will be regarded as being true for the time being. More and more knowledge will be gained; not only by stating probably true conclusions, but also by knowing clearly what is false. Each new falsification should in this way lead closer to the entirety truth.

From observing a 10,000 zebras, that all are black and white striped, the conclusion that all zebras are black and white striped is regarded as a "temporary truth" until something is observed that prove the conclusion wrong. In this case the attempt to falsify is most probably done by observing more zebras. Still number 76,303 was black and white striped, but zebra number 76,304 happens to be albino. Thus, the first conclusion is regarded wrong and another conclusion, a new "temporary truth" should be drawn, like: "the huge majority of zebras are black and white striped, a few are entirely white". Any additional observation counteracting with that conclusion (for example an entirely black zebra found) falsify that conclusion and require a new one to be formulated. In that way, each falsification done leads to a conclusion that is closer to the truth than any previous conclusion.

The example with the zebras is straight-forward and no one can possible complain about the logic. More complicated issues are, of course, more complicated to handle. Further, not all falsifications lead closer to the truth.

If going back to that statement of education and hand hygiene and health in African villages: if the people in one single village did not get improved health, the statement tested is falsified and thus wrong. Should then all attempts to educate people in African villages be cancelled? It seems not like the best idea, when people i a lot of villages have got improved health by the education. Another attempt, that is not part of falsification, is to think about the reason to the falsification of the statement: maybe the people in that village already had good hand hygiene? If yes, the education could not improve it, and then there could not be any health effect. A more meaningful statement may from the beginning have been "it will lead to better health if people with bad hand hygiene in small villages in Africa are educated about hand hygiene". However, the falsification method does not itself give any guideline for how to formulate statement or how to formulate a new statement when one is proven wrong.

To coming closer to the truth by falsifying an already drawn conclusion from new observations require that all involved observations are true. If the animal that was regarded as a white zebra in reality was a horse, the later conclusion is not proven to be closer to the truth than the first one (even though it is highly probable that there are some white zebras, because most animal species sometimes occur as albinos); the second conclusion is based on a false interpretations of what was observed. Thus, *the accuracy of a falsification is highly dependent on the quality of the observations used to falsify a statement*.

Of course, scientific work is usually more complicated than observing the colour and pattern on zebras, or teaching the benefit of hand hygiene. The statement being subjected to attempts to falsify it may be complex and based on several other conclusions. Statements like "when bacteria are soaked in 100°C water for 10 minutes, they die" are based on other assumptions; as that there are some always present cell functions in living organisms that cannot survive 100°C, and that such cell functions are always present in bacteria. Assume that after such a test, some bacteria survive. Thus, the initial statement was falsified, and proven wrong, which increase the general knowledge; after the test it becomes known that at least some bacteria can survive 100°C water for 10 minutes. It is more complicated to investigate how this can happen. Nowadays we know that some bacteria species can form spores - a kind of resting stage in which they have very little cell activity and are very resistant to environmental circumstances, and that there are other that are adapted to a life in high temperatures, higher than 100°C, which is possible by special cell functions. Falsification itself does not give any guideline for how to reach such conclusions; on the contrary, it requires that the researcher comes up with such statements, which can be subjected to falsification, and if not being falsified they will be regarded as true, until a better explanation may be presented.

A problem with falsification as a way to work that always improve knowledge is that if there is any error in any underlying conclusion that is not subjected to falsification, any conclusion building on this error is also false. If accepting the explanation that the earth is flat, the observation done in Figure 4 may be explained with the boat rising from below water surface, but after a person drawing that conclusion followed out on the sea, the person would observe that this is not the case - the conclusion of boats rising from the water is falsified. The next conclusion may be that what is observed from shore is an optical effect; an illusion. In this case, the second conclusion is not more truth than first; both suffer from being based on a false underlying conclusion of the shape of the earth. The falsification of one conclusion did not lead to a conclusion that is closer to the truth, only to a new false one (even though it may temporary be regarded as correct). No conclusion based on the earth being flat will ever be true; the number of falsifications of conclusions based on this conclusion is irrelevant; the falsification has no meaning. In such cases, falsification does not lead closer to the truth, but from one false conclusion to another false conclusion. *Falsifications done on statements where any underlying assumption is wrong, but not tested and not falsified, do not lead to improved knowledge.*

Organisation

There are two main ways to explain how scientific work is organized within the scientific society. It shall be underlined that the organisation ways alluded at are not formally arranged, but are assumed to arise informally, without anyone involved being aware of it. The two ways are "programs" and "paradigms". Both are supposed to give a framework for handling scientific work and theories, i.e. explanatory models that have arisen from work done by any of the above described ways to work, to enhance the possibility for scientists to put their finding into a bigger whole, and to evaluate the growing sum of knowledge.

Programs are supposed to grow around an important theory, which allows additional research to take place based on it. One such theory, or set of theories, was Newton's explanations to mechanics (in which he explained a lot of how forces work and interact when items move in different ways). Using such a theory complex as basis, other research will grow, using the basis as a fact and drawing conclusions that only allow additional theories as be falsified, the basis should remain constant. If a program is progressive, it explains more and more about observed phenomena. If it degenerates, it fails to lead to additional explanations. It is assumed that scientists decide to either accept such a basis of theories, or reject it. As soon a scientist makes adjustments in the basal theory, he or she is said to reject it; to (attempt to) start a new program. Thus, several programs that attempt to explain the same phenomenon can act at the same time. One well known example is Copernicus' explanation of the planets and the sun and the movements in relation to each other (he regarded the earth as the centre, and the sun and other planets as moving around it) and Tycho Brahe's explanation to the same thing (he did not accept the present basal theory in Copernicus' explanation, but regarded the sun as the centre, with the earth and the other planets moving around it). These two programs were in use at the same time, and it can be regarded as it was competition between them. Finally, Brahe's program came out as the winner, being the program that was the most progressive.

Paradigms are also based on one important theory, or set of theories. The paradigm theory assumes that a scientific field, after some time of research work, becomes entirely steered by one explanatory model - a paradigm. Newton's explanations to mechanics may well be seen as a paradigm instead as of the basis for a program. Under the rules of the paradigm, research is ongoing. On the contrary to programs, paradigms allow adjustments also of the basal theories. The goal is to always compare the theories with the outcome, and adjust the theories if necessary. However, scientist performing such within-paradigm work must be relatively uncritical to the fundamentals of the basis to the paradigm, in order to build further theories and give explanations instead of criticising the paradigm. When a paradigm has been in use for a while, there are most probably a lot of not explained phenomena - the longer the time a paradigm is in use, the more unexplained parts of the scientific field will there probably be. When too many such anomalies are there, the paradigm collapses. After this, a period of chaos characterizes the scientific field. During this period, the scientists have no good basis in the old paradigm, that has been proven wrong on to many points, and they have no good alternative. From this chaos, a revolution will take place. Alternative basal explanations will arise - like Einstein's novel explanation that space can be full of "nothing" and still light and sound can move in it; the previous explanations of the space having to be filled with some substance had became too problematic to use with any meaningful outcome. After the revolution, a new paradigm arises. Scientists have to either switch to follow the new paradigm, or continue without explanations to important phenomena.

<u>In Reality</u>

As the reader may have noted, the described identified ways to search for knowledge: induction, deduction,, observation, replication, probability and falsification are not detached from each other but interwoven: for example, the premises in deduction may come from induction, the induction being based on replicated observations and the conclusions drawn being based on probability, and finally falsification may be used to determine which conclusion that shall be accepted. Also the organisation ways may be interwoven, it seems plausible to interpret the switch from having Copernicus' to Brahe's explanation of the planets and the sun and their movements in relation to each other as a swithch from one paradigm to another, even though there was overlap of them in time and not "chaos and revolution" in between them.

When scientific work and research is undertaken in practice, the researcher often uses a mix of different theories of science (often neither reflecting over what theories of science that are used, nor over that they are mixed). However, it is important that scientists sometimes reflect over their way to work - as human beings, we may otherwise follow the easiest way, and continue as we, or our colleagues, have done before, without noting or understanding possible weak or distorting parts of our way to do research and/or in our way to draw conclusions.

Philosophers will continue to try to understand and explain how scientific work is done, and strive toward finding an ideal model for scientific work; to improve theories of science. Researchers will continue their work in understanding observations done, using theory of science, consciously or unconsciously, as an underlying basis.

How to do Research?

<u>In Principle</u>

It is simple to describe how scientific work within natural sciences is usually assumed to be done: The scientist makes an observation, from which he or she formulate a hypothesis. The hypothesis is then tested in an experiment, and it is either confirmed or rejected. If the hypothesis is confirmed, the scientist has contributed with new knowledge, which either support or reject existing theories, and may lead to the formulation of a new theory (Figure 6). However, the reality tends to be more complex, as described below. The text immediately below aims at giving a general understanding of a usual working process; under "Research Methods" further below you will find advice and examples for direct use when setting up a scientific study.

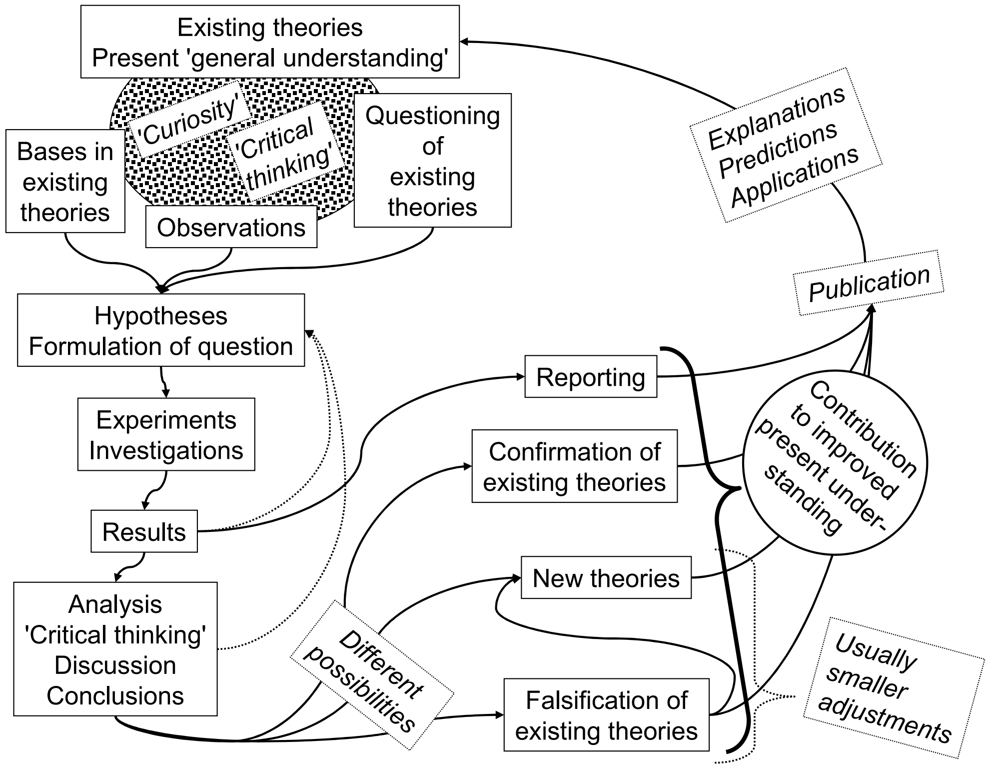

Figure 6. Principal flow scheme of scientific work. A research attempt usually begins in the upper grey area, with a scientist merging the knowledge available with observations done. A hypothesis and/or a scientific question is formulated and investigated, giving some results. The results are discussed within the present frame of knowledge and theories, and the researcher's conclusions are published if being accepted by a number of other scientists within the specific field of science. Sometimes, the result, or the discussion of the results, will lead the researcher to continue the research with a new hypothesis/question before proceeding further (grey arrows). Finally, the new finding can be used to explaining and predicting other results, and can be used in applications; it adds to the general understanding of the subject.

Knowledge

Scientific Theories

To gather knowledge within a scientific field, it is important to know and remember what a theory, in its scientific meaning, is regarded to be. In daily language, it is not rare to hear the word "theory" as a synonym to "guess". However, within science, a theory is built on evidence based scientific conclusions. Thus, theories are what in daily language are frequently referred to as "scientific knowledge". A well known theory is Einstein's theory $E=mc^2$ (energy = mass × velocity^2) that tells, for example, that the unit "mass" is not static but dependent of the velocity and the energy of the observed item; this is frequently referred to as "everything is relative", meaning that even such things that we usually considered as fixed, as the mass of an unit, are not static.

A scientific theory shall be useful for predicting outcome, and for explaining the reason for that outcome. A scientific theory shall not only state how something is: even if such a statement leads to proper predictions, it is not a scientific theory.

Regardless of what definition of "science" each single scientist uses, or which way of work he or she uses, the scientist aims at explaining parts yet not understood within his or hers field of research, and will probably submit the findings to scientific journals for possible publication. The editors of the journal will send the manuscript to referees (scientists working within the specific field that is studied), and if found to be trustable and interesting (the latter means "not inventing the wheel again") the finding will be published. Then, these findings have become a part of the existing laid part of the puzzle, and new research efforts can take place based on a little bit more information than before. Thus, the scientific community works by internal control, by scientists evaluating the results and conclusions of colleagues before publication, as a quality control. This does not mean that everyone agree on published conclusions, it means that the reasoning is regarded as plausible by at least one editor of a scientific journal and the two or three referees to the manuscript. Every other scientist in the field of study have then the possibility to read the article, to agree or disagree with the conclusions drawn, and to test the result by repeating the study or to performing a new study with another experimental design in case he or she doubt a general conclusion drawn to be proper during all circumstances. In this way, scientific theories are tested during different circumstances and by different scientists. The success or failure of theories to properly explain and predict are discussed. When failure occurs, scientists aim at formulating new or adjusted theories. In this way, the scientific society (hopefully) comes closer to the true explanation to phenomena by time.

Science has to be evidence based (otherwise it is not accepted as science by the present worldwide community), and it has also to take into consideration what already have been found and concluded. The latter do absolutely *not* imply that every conclusion published within any scientific field is true; neither should automatically be regarded as truth! It means that new findings should be discussed and explained in the framework of scientific theories, information and knowledge that is present; new results may falsify old theories, resulting in new ways to explain previously done observations. Scientists are *not* supposed to stick to their old opinions forever; on the contrary, they are supposed to handle their own old conclusions as critical as anyone else should have done. Scientific explanations to observed phenomena are "the best possible explanation found so far", not automatically the eternal truth, even though some theories may indeed be the truth.

To be able to do meaningful research, it is necessary to have knowledge about, and understating of, theories within the subject of interest.

Information

Beside scientific theories and conclusions of results, there is also a lot of other information that is communicated within the scientific society. While performing research, a lot of observations are done, and it is important to explain how these observations were done, and what the observation was. Such information can be anything from listing the species encountered in a natural reserve (including how the recording of species was done) to report the result of collisions of protons at a speed close to the speed of light (including descriptions of equipments and methods used). The communication of such information allow other scientists to properly evaluate the conclusion drawn, to draw their own conclusion, and to get the knowledge "at these circumstances, at that occasion, this was the outcome" which can be important for further studies or for interpretations of other results, even if the reader not at all agree on the conclusions drawn from the information gathered. Thus, *it is extremely important that methods used and results are detailed and honestly reported*: cheating is not only a lazy shortcut to give a temporary impression of success to the cheater; it may also be destructive for other research activities. A proper description of actions taken and results observed shall be a part of every scientific report.

Getting Knowledge

The common way to get knowledge within a subject is to have a formal education at a university. During courses, the student will be subjected to a lot of information (facts) that is new knowledge for him or her, but is not at new for the scientific community within that field of study. What occur in course books are a lot of information, and descriptions of scientific theories. In this way, students get the possibility to relatively easily catch up on knowledge that may have taken hundred of years to build up. It is important that students read a lot! A subject should not be studied by using only one book, but by comparing what is written about the subject by different authors. Reading should not be done in order to memorize the text, but to understand the content. The goal for every student should be to be able to interpret the facts from one source into another context, to be able to draw conclusions from facts learnt. It is important for students to train in thinking critically; to not automatically accept what one teacher or one written source claim but to make an evaluation of the information communicated and compare with other sources of information. This is to becoming an independent learner, to have enough knowledge to be able to question information given about the subject, and have the capacity to logically connect information from different sources and analyze where the weak and strong parts are in different sources. This requires, of course, that the students are curious about their subject and actively search for information.

In addition to learning facts and becoming aware of scientific theories, university education also include parts were the students perform research. With the aid of a supervisor, students should plan, conduct and evaluate a scientific study. To succeed with such a work, the student must begin with getting specific knowledge of a narrow study subject; very seldom there is enough information within course literature (that shall address a broader field of study that what a specific practical study can cover). This requires that the student reads not only course literature, but original scientific articles and other specialized literature. The goal is that the student should be aware of what is done before, and be able to performing a study that contributes with novel information.

By working in this way, the students will, by hard work, make the facts delivered from teachers, books, articles in scientific journals and other sources to their own knowledge, become aware of gaps, lack of complete knowledge, in the general web of scientific theories and information available, and get insight in the difficulty with actually performing research to gather new information. Thus, during university education, students will be prepared to take actions in order to contribute with additional knowledge in the future if they decide to continue with research within their field of study.

The search for knowledge will never end. All scientists read a lot about their field of study; any researcher needs to be familiar with present theories, with theories that have been accepted historically but later became discarded, with studies done and outcome from them, and be aware of the ongoing discussion and debate in the scientific field of interest. This does not mean to uncritically accept formulated theories or drawn conclusion, but to be aware of what have been done and how it had been interpreted in order to conduct new, meaningful, research. *It is necessary to keeping ones curiosity - if getting blasé, and thinking that one has already heard of everything, one will never encounter novel and interesting parts of any report.* The most important source for information is original articles published within international scientific journals (primary sources). In such articles, the scientist will find specific descriptions of performed studies. However, because of the very large number of such journals, and each issue containing a number of articles, it is impossible to read everything related to the own field of study. Thus, when not a specific original report is needed, most scientists also read different texts that communicate the results from several original articles, with references that clearly point out from which original article any specific facts is taken; such sources can be review articles or books (secondary sources). For information that will be used as a background to any research to be undertaken, it is necessary that the researcher reads the proper original article; it is always a risk that there is some misinterpretation when someone communicate what someone else have done, and it is important that the researcher gets the information from the original source, thus not relies on someone else's interpretation.

Getting knowledge is never simply or easy: it requires continuous studies of literature, and continuous critical thinking about information communicated and conclusions drawn.

Get Started

Principles

Of course, any research attempt has to start somewhere, and sometimes it seems difficult to at all decide what to investigate; what to do and where to start. Above, the scientist's curiosity has been mentioned as a component involved in performing basic research, and this feature can be said to be involved in finding a starting point for all research. However, far from all questions asked of curiosity are scientific questions. For example, a child will ask a lot out of curiosity, but several such questions do not require research to answer; the parents can answer directly. Also, a lot of more advanced curiosity questions asked during life can be answered in a relatively simple way: a good encyclopaedia contains an enormous amount of information.

Usually, the starting point of research is assumed to be observations. The observations referred to in this content have not to be, but can be, concrete. It may be that the scientist have done some observations while performing another study, it may be that he or she has seen some information, or has combined some information, in literature that seem to be of interest to study further, or it may be that the scientist has begun to question the logics of a theory already present.

The observation is put into its context by the scientist who checks what is already known on the subject (literature studies about existing theories and results from scientific studies, the 'general knowledge' in Figure 6) and thinking critically about the conclusions drawn and theories suggested from previous studies (are they satisfying, or are there better suggestions?). The curiosity of the scientist becomes involved in order to decide whether to regard the observation as meaningful to consider, and to drive the scientist to search for information and go into details about already done studies. The more one reads, and the more one works within a scientific field, the more will one encounter that requires research. After a few years or research, the problem is usually not to find something to study but to be able to conduct all research one regard as meaningful.

In reality, the observation, the curiosity, the literature studies and the critical thinking tend to overlap each other. This part of a scientific study is symbolised by the grey area in the upper part of the flow scheme in Figure 6.

Advice

- Perform studies within subjects where you have proper knowledge; it is hard, or even impossible, to learn a new subject and make research within it simultaneously. Even when conducting scientific studies within the general field of your knowledge, you will have to read a lot of literature to get sufficient knowledge of details.

- Limit your study to a researchable problem. There is no official or formal definition of what a "researchable problem" is, but the term alludes at problems that can be solved by research, that not requires only decision-making. Compare with the example around Figure 2.

- Question your initial observation, the reason for doing the study, already from the beginning! Compare with "Facts and Observations" above; if you have seen something only once, you better think twice before undertaking a time-consuming study. Do not start extensive research attempts on the basis of one single vague observation not supported in the literature if you are not prepared to take the risk of ending up with concluding "aha, I mistook me when I thought I saw that...". If your initial observation is a result from information in different published sources, make sure you do not misinterpret the original texts; if you do it may spoil your study entirely.

- If you are in the beginning of an academic carrier: look for missing pieces in the puzzle that build up your subject of interest, and begin with finding and investigating the smaller and/or easier ones. Maybe some theory should be tested on other facets than already done? Maybe a method should be tested during other circumstances? It is rare that someone report revolutionary finding in his or her final thesis. A well performed and clearly reported smaller, more narrow, study is always much better than a larger and broader study aiming at solving any huge problem of the world but failing to conduct an investigation about the problem and thus failing in clearly report anything.

- When performing literature studies ahead of a possible research attempt, make sure you include theories and scientific studies regarded as important by the scientific community within your subject. That means: read carefully also what authors you do not agree with report; you need to understand their reasoning. Try to achieve a good general knowledge of the subject; not only including parts that are directly related to your observation. This will make you much better off when deciding how to continue. This part of the preparation may well make you revalue or discard your initial idea of what to study - you may find that is already studied, or you may find an explanation you did not think about that well explain the observation as it is.

- Discuss with some person or persons! Preferable people with scientific experience, in the best case within the scientific field where you plan to make research. Such discussions may lead you to revalue your observation or may introduce you to literature and knowledge that are important for your research. You may also get direct suggestions of what to study, and how to do. These is usually good advice, but think critical about it before accepting, and make sure you really understand the research attempt; if you just do as told without understanding and having your own opinions, you are not a researcher but a servant.

Hypothesis or Question

Generally

The next step in the Figure 6 flow scheme is to set up a hypothesis and/or formulate a scientific question. This will be the anchor point for the consecutive steps and is therefore a very important point. When working on this point, the more knowledge the scientist had gain about the subject in general the better the entire study will be. Either if formulating a hypothesis or a scientific question, the goal is to understand the observation leading to the research. Thus, the researcher should try to understand the reason to the observation, in order to make a suitable study about it.

Sometimes, especially when applying for research grants, the term "possible application" is used. In such cases, the scientist should have an idea not only about what is the explanation to the observation leading to the research but also about how new knowledge gained could be directly used in practice. The formulation of the "possible application" is thus very dependent on a clear, and limited, hypotheses or scientific question.

Hypotheses

To formulate and test hypotheses is related to formulate statements and subject them to attempts to falsify (see "Falsification" above); in fact some scientist regard it as the same, but the authors of this booklet have the impression that most scientists that use hypotheses as the way to work regard these as a special kind of statements, not accepting all statements that are possible attempt to falsify as hypotheses. Rather, hypotheses can be regarded as a special, more advanced, case of the general falsification theory. The difference between a hypotheses and whatever statement that can be tested and judged as true or false is that the hypotheses should be based on logical conclusions - there should be reasons for it. The scientist that formulated the hypotheses should have reasons (based on theory and/or observations) for formulating the statement that is the hypotheses.

A hypothesis is a formulation of what the scientist thinks is the explanation to the observation done that was part of the starting point. In the ideal case a hypothesis is very concrete, like "if there is water to the rim of a bucket and more water is added, there will be water overflow". Of course, such a hypothesis is very clear and simple to test, but the challenges encountered in reality are often difficult to describe in such a straight forward way.

If the observation is that an established theory seems unsuitable for explaining some concrete observations (which is of course only of importance if the theory aims at explaining that circumstances), the hypothesis could be formulated as: "The theory X will not succeed in explaining the feature Y as it should", and if the scientist has a better suggestion for a theory already from the beginning he or she can add another hypothesis: "The feature Y will be explained by the new theory Z, which also will explain everything else covered by theory X".

A requirement for a hypothesis for being a hypothesis is that it is testable and possible to evaluate. A statement of the type "there may be a way to cultivate soil that minimize weed occurrence" is not a hypothesis; to be a hypothesis it is necessary to include descriptions of how this possible cultivation method should be performed, and the word "may" should be excluded, because when included it is in fact impossible to ever claim that the so called hypothesis was either right or wrong (compare with "Falsification" above). The cultivation hypothesis could be something like "repeated cultivation of soil between harvest and sowing of annual crops will minimize weed occurrence".

Regarding the water in the bucket and the reduction of weeds by repeated soil cultivation the hypothesis are not really meaningful, even though they fulfil the basal requirements of being possible to test and to judge as true or false. The reason that they are not meaningful is that they are already known; in this case both are true. *A meaningful hypotheses is a statement describing something that is logically true (based on the scientists reasoning) but not yet known, the statement is possible to test to judge it if being true or false.*

Sometimes the hypothesis is confused with the statistical null hypothesis. This shall never be done; there is no excuse available for confusing these. The statistical null hypothesis is a tool in statistics, where it is evaluated if a result differs from the statement in the null hypothesis. Common null hypotheses are "there is no difference between the two groups" and "there is no effect of the treatment".

Scientific Questions

When describing how research work should ideally be done, there is usually a part included pointing out the importance of having a hypotheses. But indeed, a lot of scientific work is ongoing without having base in a formulated hypothesis. If excluding physics and parts of chemistry and biochemistry, a lot of our understanding of nature (in a wide sense, including for example understanding of human social behaviour) is based on characters that are best described on continuous scales. Therefore, the scientist will frequently get results that are only described in a relative way, not as, for example "the results show that environment A is a suitable environment for that species but environment B is not". Instead, the scientist will frequently end up with results like "there is an optimal environment for this species that can be described as C, the species has a range of tolerations that allow it to live and reproduce in a range of other climates, each of them different from C in some way, and even further away from a C climate the species still survive but not reproduce, but climates of the types D, E and F are lethal for the species".

When starting an investigation about the species above, it is quite meaningless to formulate a hypothesis of the type "there will be differences in species X's response to different climates". It is true for all organisms that they respond different in different climates, so that does not make any sense to test. If instead formulating something like "if placing species X in environment B, the reproduction success will be the half of what is the case in environment A", it is not a hypotheses (not based on any logical reasoning) but only a guess (there may of course be a logical basis for drawing that conclusion, but most probably not; the amount is a guess if not the reproduction is not tested in these two climates before, and if it is tested it is not a meaningful hypotheses to formulate). Instead, the attempt can be formulated as a scientific question, like: "how does species X respond to climates within the range A - F?".

A scientific question is thus a question that clearly formulates what is going to be investigated. Sometimes it is not formulated as a question but as an objective:

Scientific question: Which insect species, in what densities, occur in the area?

Objective: To investigate which species, and in what densities, that occur in the area.

However the intention is formulated (as a scientific question or as an objective for the research), it is important to keep it clear and limited, and to not extend it beyond what is possible to answer with research. If comparing the example around Figure 2, the scientific question was "how much, to what cost, can maize harvest in this area increase by fertilization?". The connected non-researchable question was "how much of taxpayers' money shall be used to increase maize harvest in the area?".

Advice

- Think carefully about what the kernel of your starting point, your initial observation, is. Try to formulate all your thoughts from the starting point in one or two sentences. This will help you to clearly state what you are going to investigate.

- Be as clear concrete as possible when formulating a hypotheses or a scientific question. If it seems impossible to formulate a testable hypothesis for the basic research you aiming at, then accept that it is probably impossible and formulate instead a clear scientific question. Hypothesis of the type "We hypothesize that the there may be variance in germination between populations from different altitudinal gradient, and the response of germination to chilling may vary with altitude of seed origins in order to avoid the risk of unfavourable environmental conditions and to maximize probability for seedling establishment" (a true example from a manuscript submitted to a scientific journal) has no meaning. It is much better to clearly formulate that the germination pattern along a specific gradient will be investigated.

- Keep your hypothesis or scientific question within the framework that realistically can be realised at the institution you are at the moment if your goal is to test or investigate it in the near future.

- You may have hypothesis and scientific questions in your mind that cannot be investigated at the institution you are at the moment. Do not forget them; sooner or later you may be in a position to do also that research.

- If being in the beginning of an academic career, focus on smaller adjustments of present general understanding rather than scientific revolutions.

- Ask yourself if your hypothesis/scientific question is in line with the knowledge you have about the subject. If there are disagreements, you may gain from thinking about why they arise: are you aiming at falsify an old theory (which is just fine as long this is your starting point) or have you not formulated your hypothesis/scientific question properly?

- Do not allow your fantasy to carry you too far! Curiosity is one thing, fantasy is another.

- Discuss with others! Discussions with colleagues tend to sharpen ones mind by enforcing one to formulate the problems addressed in a clear way. If it seems difficult for others to understand what you are going to study, you will gain from trying with a new formulation.

Experiments and Investigations

Theory

This point, the one following hypothesis/scientific question in Figure 6, is the point for concrete work. The hypothesis or the scientific question will require work to be done; either theoretical or practical investigations, or both. Not rarely, people not used to scientific work tend to start with practical work when aiming to perform research, which may end up in a situation when a lot of data have been collected, but there is no way to use it for proper interpretation, even less for a scientific publication, just because there is no reason behind. A too common example of this problem is inventories of vegetation: a person mark a number of plots in an area and spend several weeks, and a lot of work, there by listing every plant found. If there is no underlying reason for this work it will not be considered of interest for the scientific community; it is just a snapshot of what was there at the moment. This is not to dismiss all inventories of vegetation; there are good reasons for doing this in several situations!

The experiment and/or other kind of investigations should be designed to test the hypothesis and/or examine the formulated scientific question. The choice of method is often critical - an unsuitable method will spoil the research regardless of how well the problem addressed has been thought through.

Frequently, there are a set of more or less standardized methods present within scientific fields. From the literature studies done when aiming to find a starting point, the researcher is hopefully aware of at least some method that is used in the area. Methods that are used are probably used for some reason, hopefully because they are reliable and repeatable. However, one should always be careful to judge whether or not a method is suitable for the actual scientific study addressed at the moment; one should never use a method without reflecting about its suitableness for the actual case. Compare with "Induction" above.

Methods may be, for example, experiments, inventories, questionnaires or computer modelling. The choice of method is probably quite simple so far - it is dependent of in what way the hypothesis/scientific question is formulated. However, to choose for example, what experimental method to use, or how to formulate the questionnaire, is worse. This requires that the researcher is well aware of difficulties within his or her area of study. When setting up a study one has to think about what the main point of research is - it is impossible to cover everything on earth in one study! Thus, be concrete when setting up an experiment (i.e. do not begin to add more and more factors that you think may possible be of interest - you should have thought through what to study earlier), planning an inventory (i.e. do not include extra areas not having the environment you should study), formulate a questionnaire (i.e. do not bore your respondents with any not absolutely necessary question) or construct a computer model (i.e. do not add as much variables that you run out of capacity before you have included your main point of study).

When planning a study, it is important to keep in mind that combinations of included factors result in large research setups: if aiming to study the effect of sun radiation (S), temperature (T) and precipitation (P) on decomposing of wastes laying in the open air, one has to decide within what ranges each of these factors should be studied and how many different amounts of each factor that should be studied within the chosen limits. Let us assume that we select five amounts (which is not much, considering the factors studied) of each of these three factors. To set up a complete experiment we have to include each sun radiation amount (S1, S2, S3, S4, S5) with all combinations of temperature (T1, T2, T3, T4, T5) and precipitation (P1, P2, P3, P4, P5), thus:
S1-T1-P1
S1-T1-P2
S1-T1-P3
S1-T1-P4
S1-T1-P5
S1-T2-P1
S1-T2-P2
S1-T2-P3..... and so on, until all combinations are included. Because this example includes three characters and five amounts of each there will be 5×5×5=125 unique combinations. Each of these has to be replicated sufficiently (as a rule of thumb; never less than three), so there will be at least 125×3=375 units to handle to perform this experiment.

If there is space, time and labour available (all partly depending on funding) for the research attempt you plan it is just fine, but frequently one has to limit the setup because of some of these factors. If being in the situation that an outline that includes several factors has to be reduced, it is very important to think carefully about how to do that.

It may be appealing to include only the five combinations:
S1-T1-P1
S2-T2-P2
S3-T3-P3
S4-T4-P4
S5-T5-P5, claiming that everything aiming at then will be studied. However, such layout will not allow the researcher to draw conclusions about the reason to the outcomes of the study. To understand this difficulty, assume that the decomposing of wastes was most efficient in the S3-T3-P3 treatment of these five. Because of the experimental layout, one will never know if that is a result of a combination of two or three of the factors, or if it is the specific amount of one of the factors that make the process more efficient. To answer these questions, the full experiment, with the 125 combinations, has to be done. Thus, other ways to think when having to reduce the setup that seems to be the ideal (but happen to be impossible) are needed.

First, question if all the factors included are of similar importance; maybe you just included one of them by chance, because it "seemed to be nice to include"? Or because it just has to be there (like temperature - whatever you do there will be some temperature, but that does not imply that different temperatures always must be included in all studies). If you are convinced that all the included factors are of similar importance and have to be included to test your hypothesis or investigate your scientific question, then the best solution probably is to reduce the numbers of amount of each included. If that is your choice, you have to think carefully about what amount to include. In the example with the waste: will it be better for your study if you include two extremes (yearly min and max, for example) plus one intermediate level, or will it be better if you include three more normal levels, around the intermediate? The answer depends on the research planned and on the reason to perform it, and cannot be generally stated.

Before starting the practical part of the research, it is important to evaluate, as good as possible, whether the results will be achieved in such quality and quantity that it is possible to analyse them properly. For example, it is obvious that it is not enough to ask one citizen in a town whether or not the people of that town thinks the taxes should be raised in order to be able to build better roads. However, it is not that obvious how many persons, and whom, that should be asked for getting a proper estimation of the opinion of the people in the town. Whenever possible, use information from literature to determine the numbers of replicates/repetitions needed for your study. If you are unsure; it is always better with some extra: too few spoil your research, but there cannot be too many (as long as possible to perform). It is always good to make a pilot study (that is, a small study resembling the planned one) when the setup involves methods not used, or not used in that way, before.

Develop a protocol for your study. This will help you to keep on track, and is necessary if including other persons in the work. The protocol should include space for noting everything that should be studied: a unique space should be available for each different part and each replicate/repetition included.

When performing the practical part of the research, it is important to keep to the plans and not change the method during the ongoing study. If the choice of method was wrong (it may for different reasons be impossible to conduct the research) a new attempt has to be regarded as a new study; methods cannot be mixed and then treated as one study in analysis and discussions.

Finally; regardless of how interesting your observations have been, how clearly you have formulated your hypothesis/scientific question and how well you have planned your experiment/investigation - the outcome may be spoiled by a carelessly managed practical work. It is not possible to be too accurate when performing the practical part of the research! If involving other persons for making some parts, make sure they are informed about the need of accuracy and that they have clear instructions. *All scientific work has to be done carefully and accurately*; otherwise it has no meaning.

Advice

- Be sure that you have a clear hypothesis and/or a scientific question to address before thinking of what experimental/investigation method to use.

- Do not use a method just because you have used it before or it has been used by others! The only reason to use a method just because it has been used is when conducting studies that are a continuum of other studies. In such cases the benefit from being able to compare the results will, in most cases, be more important than a smaller drawback of the method per se.

- Make sure your practical attempt will address your hypothesis/scientific question.

- Evaluate the number of replicates/repetitions needed by comparing with published studies and, if necessary, make a pilot study.

- Make a layout of your study before starting it, and make sure you have resources (time, equipment, space, labour...) for performing it. If not, reduce the study if not possible to increase resources.

- Develop a protocol to be followed.
- Keep to your plans when performing the practical work. Any change of the protocol has to be very well questioned before performed; methods cannot be mixed if all results should be used in one single analysis. If you change your way to work during the study time, you may end up with two small studies (one before and one after the change) of which none address your hypothesis/scientific question or contribute with meaningful new knowledge.
- Perform the practical work accurately: there is no excuse for carelessness available.

The Results

Principles

The result is the "simple part" of your research. If everything is well done until this point, it is just to measure (or estimate, or list, depending on the study) and put together the outcome from the practical work. While doing that, it is of course necessary to poof read the computed numbers or the information recorded in the protocol carefully. Always evaluate whether the results are the true outcome of the planned study. Ask: Has everyone involved in the practical work done his/her part carefully? Have there been additional, unwanted, factors involved (like animals eating the experimental crop and then, naturally, reducing the harvest)? If there are problems like these, either repeat the study or discard the suspected part of the result.

Put the results together in a way that makes it easy to interpret what have happened. Usually, the results can be shown clearly by being presented in tables and/or figures. Figures are better than tables to show general results or trends, tables are better than figures to show exact details or for reporting results when there are not pronounced differences between treatments. Note; if you aim at a publication in a scientific journal, you will not be allowed to show the same results in different ways, but you may use tables for some results and figures for other. Figure 7 shows an example of using both Figure 1nd table when presenting results from the same study. In this case, the figure was used to show a change over time at different temperatures tested, and the table was used to list relatively small amounts of germination achieved during different circumstances.

When preparing your data for reporting, be careful to present the data in a way that is meaningful for others. Put together the replicates/repetitions of each treatment so you report just one result per treatment, if possible together with some distribution range (there are numerous different ways to calculate; it is common to show standard deviation, standard error or 95% confidence interval - consult a statistician if you are not used to this), as done in Figure 7. The distribution range is used to show in a standardised way, how large differences there were within each treatment. Do *never* report just everything like "group 1 replicates were: 1.22, 1.30, 1.31, 1.42, 1.45; group 2 replicates were: 1.37, 1.40, 1.44, 1.47, 1.48". You should present the data so they show the outcome, do not leave that work for your potential reader. Make neat figures or tables, and think about people that do not know anything about your study ahead of reading. For example, do not use legends as "treatment 1, treatment 2..." even though this was the way you labelled your study in practice. Instead, use legends that tell the reader a little of what it is, like the legends in Figure 7 that tells what temperature it was.

Sometimes the researcher will observe directly that the result is not at all as he or she expected. This may be very interesting; for example, the result may indicate a new explanation to a phenomenon, or, if using a theory claiming to predict the outcomes of the performed study, the results may falsify the theory. Thus, un-expected results should not automatically be regarded as "wrong", and they should not be discarded. In most cases, it is

This data, and the figure and table, are from: Karlsson LM, Tamado T & Milberg P (2003) Seed dormancy pattern of the annuals *Argemone ochroleuca* and *A. mexicana* (Papaveraceae). Flora 198:329-339.

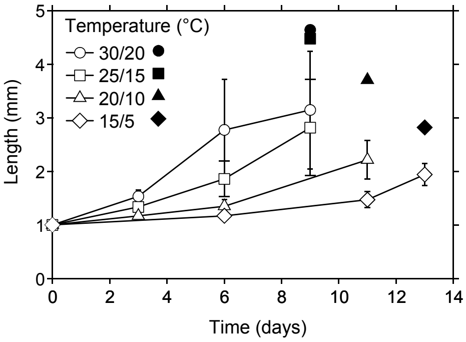

Table X. Germination (%) of *Argemone ochroleuca* and *A. mexicana* after being abraded on the surface when tumbled with sand. The confidence intervals are based on statistics for binomial distributions.

Incubation temperature (day/night °C)	Abraded on surface	*Argemone ochroleuca* Germination (95% C.I.)	*Argemone mexicana* Germination (95% C.I.)
30/20	not at all	2 (0.4 - 5.7)	3 (0.7 - 9.5)
	slight	1 (0.0 - 6.1)	3 (0.7 - 9.5)
	heavy	8 (3.2 - 15.2)	4 (1.2 - 11.0)
25/15	not at all	2 (0.4 - 5.7)	2 (0.3 - 9.5)
	slight	12 (6.2 - 20.9)	1 (0.0 - 6.1)
	heavy	9 (3.2 - 15.2)	2 (0.3 - 7.8)
20/10	not at all	0 (0.0 - 2.4)	1 (0.0 - 6.1)
	slight	0 (0.0 - 4.0)	3 (0.7 - 9.5)
	heavy	1 (0.0 - 6.1)	6 (1.8 - 12.5)
15/5	not at all	0 (0.0 - 2.4)	5 (1.3 - 11.3)
	slight	1 (0.0 - 6.1)	4 (1.2 - 11.0)
	heavy	0 (0.0 - 4.0)	6 (1.8 - 12.5)

Figure 7. Examples of different ways to present data. A Figure is suitable for showing general responses and trends; a table is suitable to show details and small differences. The original text to the figure was "Embryo lengths of *Argemone ochroleuca* after various times of incubation in light at different temperatures. The seed coats were cut off at the opposite end to the embryo, to the extent that a small piece of endosperm was removed, before the start of the experiment. Mean embryo length (open symbols) with 95% confidence interval and estimated critical germination length (filled symbols) are shown."

preferable to continue through the basic research flow scheme (Figure 6) regardless whether the result seems to support the hypothesis/explain the scientific question or not. However, when the results are obviously not the expected, the researcher may choose to continue from a new hypothesis directly, even without making a formal analysis. This attempt is only to recommend when the researcher has a realistic explanation to the achieved outcome. That is, if he or she is able to merge the unexpected outcome with what was known from literature before (at starting point), and formulate a new hypothesis or scientific question. To just continue in a more or less random way, using methods like "ok, let's test sugar - did not work, let's test honey - did not work..." and so on is not science, and will not lead to meaningful conclusions, even though you may finally find something that works.

Advice

- Compute the results from protocol accurately, and proof read.
- Make sure that your results are trustable, and not influenced by unexpected random factors.
- Do not discard your results if they are not in line with what you expected.
- Put together the results from your replicates/repetitions in a way that help your readers to understand and evaluate the outcome. Use distribution ranges whenever possible.
- Express your results by making clear figures and/or tables.
- If intending to directly set up a new hypothesis/scientific question, make sure that you base this attempt on as serious thoughts as you did with the first attempt.

From Analysis to Conclusion

Goal

This point, the one following "results" is a large and important part of the research, and could be separated in four parts: analysis, 'critical thinking', discussion, and conclusion (Figure 6). However, in this text these parts are treated together because they to a high extent are interconnected. The goal is to evaluate the hypothesis or scientific question, to explain the results, put them into their scientific context and draw conclusions from them together with what was the 'general understanding' (Figure 6) when beginning the research.

About Statistics

The analysis does often involve some kind of statistics. Statistics is a large subject that can not to any acceptable extent be covered within this text. The general advice is to always consult a statistician, or a research colleague interested in statistics, if not confident with the own knowledge for the analysis required. It should also be pointed out here that it is always good to discuss statistical issues among colleagues; it is too easy to become customized to a number of methods available that one usually use, and therefore not consider other, maybe more suitable, methods for a specific analysis. When writing a manuscript intended for a scientific journal, the statistical analysis (if any) may be described as one of the methods used, and be a part of the heading "results", there shown only as a plain result (that is, no explanation, just the outcome of the statistics used).

It is of great importance to not focus only on a statistical outcome, and forget everything else. For example, the term "p-value" is an important part of numerous statistical methods. A p-value tells weather or not there are significant differences between analysed items. A "significant difference" means that there to a high probability are differences between the average of included groups, and the p-value is calculated from a number of randomly chosen sub-units (replicates). The smaller the p-value, the higher the probability of difference, and a common limit for regarding a difference as being of importance is $p=0.05$, i.e. $p<0.05$ is regarded as a significant difference. Assume we have the three groups A, B and C, and measure something on five different individuals (the replicates in this case) of each group and get:

A	B	C
1.25	1.62	1.42
1.32	1.78	1.45
1.28	1.65	1.39
1.35	1.70	1.47
1.34	1.59	1.38

On average:

A	B	C
1.31	1.67	1.42

In all possible comparisons of A, B and C (A vs B, A vs C, B vs C), $p<0.05$. Thus, one may just conclude that these are different. However, for the research going on it may be important to rank the groups according to value (A<C<B), and/or to consider the large difference between B and the other (about 0.1 between A and C, nearly 0.3 between B and C, and nearly 0.4 between A and B); these outcomes may be of greater importance than the fact that there are differences between all groups. Thus, the researcher has a great responsibility regarding the interpretation of statistical outcomes. *Never stop thinking after "there is a significant difference", but continue to analyse by critical thinking.*

If your research is regarding for example history or art, your analysis can probably not involve statistics. In these cases, the analysis is performed entirely through critical thinking and discussion, as described below.

Analysis and Discussion

Important analyses are frequently done without, or in addition to, statistical analysis. The intention is to evaluate an outcome through discussion (internal or external). The 'critical thinking' should be included in all parts when evaluating the research attempt and the results. It is hard to define what 'critical thinking' really is, but the idea is to, as far as possible, be objective, and to view the research and its results from different directions. Thus, not being fixed in an opinion and try to fit everything observed into it, but instead trying to find the most logical explanation and interpretation possible. However, in this process one should always be aware of that a completely objective person does not exist. We all have our predilections, and we are not aware of all of our own. It is therefore important to frequently ask oneself "Do I just like it in this way, or is there a logical reason to prefer this way?". In a first step, one can ask "what do I think about this" and formulate the answer in a few sentences. These sentences are intended for yourself. Try then to argument against yourself, finding weak points in your sentences, and, if possible, defend your sentences against these arguments. This process may make you change what your first thought about your research, and will in any case make your better prepared for the continuous work. If you have colleague(s) whom you can have this discussion with, it is even better.

A discussion, in the way the word is used within science, includes a lot of "non-statistical analysis". That means: it is the thoughts of the scientist, frequently expressed in a text or an oral presentation, where the author aims at coming to a conclusion that is logically in line with the results and can be defended against possible argument based on what is known about the subject as a whole. When presenting the discussion for others, the author should be prepared to answer arguments based on other sources than what he/she regards as important - this is one reason why it is necessary with good general knowledge about the subject one is studying.

A good starting point for any such discussion is to say/write something about the results as such, like: "plant embryo length increased faster at higher temperatures, and critical length for germination increased with increasing temperature (Figure 7)". This remains both you and an auditorium/reader about the result, and point out what in the results you regard as important.

Generally, it is a good advice to continue with explaining the results as reflected in the general understanding available at starting point for discussion, for example regarding the results in Figure 7: "It is well known that higher temperature in general increase development rate as long the temperature is within the tolerated range. However, until now, critical embryo length for germination has not been reported as temperature dependent, which is the case for *Argemone ochroleuca* (Figure 7)".

Discuss these findings in relation to your hypothesis/scientific question, like: "Our first hypothesis, i.e. that embryo growth rate of *Argemone ochroleuca* increase with increasing temperature (Figure 7), was confirmed and is in line with earlier studies. In addition, we investigated the critical embryo length for germination at different temperatures, and find that it is temperature-dependent (Figure 7); this is contradictory to the assumption that has been generally accepted until now."

Continue with discussions about how your findings can be interpreted, and what you regard as important with them. Do your findings show that conclusions drawn by others were wrong? If yes, point out that, and explain in what way they were wrong and how your way provides a better explanation. As for example: "The method sometimes used, to include approximate values for critical length at root protrusion regardless of test environment, is not proper, because critical lengths for germination may vary considerably between temperatures, as shown by our results (Figure 7). When using plant embryo lengths as predictor for time to germination, it is thus necessary to investigate embryo growth at different temperatures in advance".

Do not forget to argue against yourself now and then during this process. Do not get stuck into one way of thinking! Try to find the arguments against your reasoning that somebody else would come up with. Is it he/she or you that are right? Maybe all of you are wrong?

Finally, the discussion should arrive at a conclusion; the non-statistical analyses should give an answer. This conclusion should be the result of all your 'critical thinking' and discussion, and it should contain the main finding, with your interpretation explained. In a wider sense, there are three principally final different outcomes (Figure 6), regardless if your hypothesis was confirmed by your study or not, or what the answer to your scientific question was: 1) your research result was in line with existing theories; maybe strengthen them or adjusting them, 2) your research lead directly to a new theory; possible only if you investigated something not yet based on a theory, and 3) your research falsified an existing theory, or part of it. In case 3 you may be able to adjust the old theory or formulate a new theory, which more accurately explains yours and others observations.

It is through discussions and conclusions, not simply by reporting results, that the scientific puzzle grows and changes. It is very seldom an entire theory will be falsified by one study, but each single study is part of the always ongoing process of finding better and better explanations to observation, by strengthen or weaken the theories regarded as the most suitable at the moment.

Advice

- Perform first statistical analyses (if applicable on your results), if needed after contact with a statistician.
- Argue, for yourself, for and against your spontaneous interpretation of your results.
- Point out your main results, the ones you regard as most interesting and important.
- Put your findings into the available scientific context. What confirm old knowledge, what is new?
- Discuss your results, with yourself and if possible with colleagues, in relation to your hypothesis and/or scientific question.
- Always argue against yourself! Assume that someone else argue against you, and figure out what his/her argument should be. You may then argue back successfully, or you may be convinced that you were wrong at the beginning.
- Discuss your research outcome in relation to present theories, do your results strengthen or weaken them, confirming them or falsifying them?
- Discuss the entire work with colleagues! Informal discussions are important; you may encounter new angels of old questions and may get fresh perspectives on your problematic points.
- Concentrate, 'cook down', your results and discussion to conclusion(s). Ask yourselves if this is the one and only logical outcome of your results as reflected in the scientific understanding available.

To publish

Background

As said above, science of today can be regarded as the common result of the work of numerous scientists, and to become a part of such a network your findings need to be available for others. The best existing way is to publish in scientific journals, even if it seems reasonable that there will be more and more publications on the internet in the future (however, there are difficulties with this, because science as we know it require that there is a within-subject control before publishing - today a research result that is only published as a personal file on the internet is not regarded as serious and will not be considered by other scientists). Besides the aim to contribute to science, you have also personal benefits from publishing: the number of papers, and the quality of these papers, are used to evaluate your competence as scientist; that method for evaluation is used around the world. You have also a responsibility to publish, to make your result available for others; even if you do not regard them as important, or the result was not in line with what you assumed it should be; the findings may be important pieces for someone else to draw novel conclusions. This text aim at given some general advice when going to publish in scientific journals, assuming that you have done a study following the principles in the text above under "How to do Research?". Below, under "Research Methods", there is a description about how to write a report intended rather for colleagues performing practical work (implementing the findings) and decision-makers than the scientific community.

You have to decide what journal to send your manuscript to. This is not always simple. You should find one that deals with the (sub-)subject you deal with, and you should find one that is on the right "level", i.e. there is no reason to waste time by sending a manuscript to journals only publishing what can be called "sensations" if your research is not of that kind. The very best advice if being in the beginning of your academic career is to talk to more experienced colleagues within your field of research. Another good advice is to compare with published articles, from different journals, and send your manuscript to a journal that seems to publish about the same kind of research as you have done. It is important to be careful in the selection of journal; the process before your paper is accepted or rejected may take half a year, and according to publishing rules you are absolutely forbidden to send it somewhere else during this period. Thus, in order to not waste time: only send your manuscripts to journals where you think you have a possibility to be published.

The first advice when heading for having a manuscript published is to follow the instructions to authors from the journal aiming at. If you dislike some principle (for example that you dislike giving references as numbers, not names of authors, in your article) you just have to send the manuscript somewhere else. The instructions may tell you how to write different abbreviations, how figures and tables should be prepared and how the reference list should look like. Just do it that way. All scientific journals of any importance receive much more manuscripts than they can publish, so there is no need for them to bother with carelessly prepared manuscripts. In most cases you will have to write with double row space and to use the correct format (as italics when required), but not be allowed to make any page formatting as row and page breaks. *Just follow the instructions*.

The advices below are general, not aiming at any specific journal. However, you will find the parts: title, abstract (summary), introduction, and discussion in most journals, sometimes you will also be asked to have an additional heading: "conclusions". For scientific fields dealing with any kind of concrete investigations you will usually also find: (material) and methods, and results. In the description below the five common main headings are included. Most journals allow you to add suitable sub-headings if your study not is very small. If your study includes entirely literature studies of, for example, the historical development of art in one specific region you have probably nothing to report under "material and methods". In such cases the introduction, results and discussion may be merged to a narrative, for which you make suitable sub-headings. Sometimes there is a possibility to merge the result and discussion part to one; "results and discussion", this is only to recommend if you do not have much to discuss regarding your results, but rather like to report the outcome. The headings below are in the order they will be found in a journal. Advice of writing order is in the end of this text.

Title

Put effort in developing your title. This is the first thing a potential reader sees, and it is frequently the title that makes us decide whether to read more or not. All people working within research have a lot to read, and will seldom take their time to read something that seems not to be of high priority. If you like to spread your results - try to catch interest with your title. It shall be underlined that the way to catch interest in scientific journals is *not* to be "funny" or "entertaining", it is to be clear and informative. For example "proper irrigation timing can increase harvest of potato" is better than "a study of irrigation of potato". Sometimes people not used to scientific publications thinks that the former title tells to much, they think that if they tell the outcome already in the title no one will read the rest. This is however wrong; the clearer you are, the higher the possibility that the people really interested in your work will recognize and read it, because they get the message that this is something of interest.

Abstract

The abstract, which sometimes should be called "summary" (depending on journal), should describe your entire study in short. The number of words allowed in the abstract is always set by the journal, and is normally 200-300. If not stated otherwise, the abstract should be written in one continuous paragraph and not include any references: not to literature, nor to figures and tables in your manuscript.

It is estimated that out of 100 persons who see your title, 10 will read the abstract and 1 will check something from the remaining of the article. Thus, you address the majority of your readers entirely through the abstract, which make it very important. Another reason for the abstract being important is that it is frequently the only part of the paper that is freely and easily available for most people. You can therefore expect to be judged by the scientific society mostly from your abstracts. Thus: write excellent abstracts!

A common error done when writing abstracts is to allocate too much of the allowed space to descriptions of how things were done, some space to background, a little to results, and nearly nothing to interpretations. This is probably a result of the author wanting to describe the study properly, which of course is good to do but not possible to do in detail in such a short text. Write the abstract so there is no need to check anything in the entire paper in order to understand the content of the abstract. Do never use formulation as "...as the results showed, species B is better suited than species A...". Write instead "...species B was larger than species A, and therefore better suited...".

A few journals require that the abstract is parted in "background", "method", "key results" and "conclusions" (or similar), and this is often helpful for making a proper disposition. Even when this is not required, it is helpful to think in that way, i.e. to try to use about the same amount of the text to each main heading of the paper (i.e. "introduction", "material & methods", "results" and "discussion"). When you have written your abstract, imagine that you do not know anything about this study, and read the abstract. Do you understand why this study was important to do? How was it done? What happened? What conclusions were drawn, and is this in line with the outcome presented?

Key Words

Most journals allow you to list a number of key words/terms (five to ten is common). These words do usually appear after the abstract, and are mainly used for putting your research in its right context in data bases. Here you can list such words that you think may be used by people searching databases when they may have an interest in finding your paper. Most journals recommend you to not duplicate the words from the title as key words, because words in titles also can be searched for. You can use words that not appear otherwise in your paper as key words, for example, to give common names of the species you are working with, even if you use only the scientific names in the paper, or to include formerly names on cities and countries being a part of the study.

Introduction

The introduction should allow your readers to follow your thoughts leading to your research. You should give a sufficient background by putting together what you have found in literature, and should allow the readers to understand how this background leads to your hypothesis or scientific question. The introduction is sometimes described as a funnel; it begins quite widely and directs the flow to a specific point; the point is your research. It may in principle be like below (this is without references - for all statements that are not regarded as "general knowledge" a proper reference should be given when writing a manuscript).

1 - wide entry: Sewage sludge contains important nutrients, and is frequently suggested to be used as a soil fertilizer. However, such sludge contains also toxic compounds, for example heavy metals, which may cause problems while spreading on agricultural fields.

2 - narrow a bit: Silver is one of the heavy metals that occur in sludge. The toxicity of silver depends mainly on the concentration of free silver ions. Silver is found mostly as silver sulphide in sludge, which is sparingly soluble and therefore comparatively harmless, but repeated fertilizing with sludge results in an accumulation of silver in soil, giving an increase also of silver ions. Soil microorganisms, and organic matter, are known to bind heavy metals, thus reducing the amount available for accumulation in plants.

3 - narrow more: Plants do not seem to be much affected by low silver levels in the surroundings. On the contrary, to microorganisms silver ions are even more harmful than cadmium ions. Thus, increased use of sludge as fertilizer may lead to lethal conditions for microorganisms, which may lead to higher concentrations of silver ions in soil, which may lead to silver accumulation in crops.

4 - narrow even more, and approach your research: To allow use of sludge as fertilizer it is necessary to investigate the effect of silver on soil microorganisms and possible following consequences on crop during different circumstances.

5 - explain your research attempt (in this case three hypotheses): The first hypothesis is that silver concentration in lettuce would increase, and the yield decrease, with increasing silver amount in soil. The second hypothesis is that the activity of soil microorganisms decreases the negative effect of silver on lettuce. The third hypothesis is that soil with a higher content of organic matter buffer against the effect of silver ions on lettuce, leading the activity of microorganisms to be more crucial in a soil with lower organic content in order to prevent the effect of silver on lettuce.

Do not begin the introduction too far from your research; there is no meaning with beginning the describer introduction above with "the earth is a sphere, and on its surface there are soil on some parts". Give references for everything that can be assumed to be non-familiar to your readers. This means, that if you include the earth sentence about there is no need for reference, but for example the first two sentences in point 3 above could look like:

"Plants do not seem to be much affected by low silver levels in the surroundings (Hirsch 1998). On the contrary, to microorganisms silver ions are even more harmful than cadmium ions (Ratte 1999)."

It is usually a good idea to keep the introduction short (about two pages with 12p font size and double row space) and concrete. When writing your introduction you may find yourself discussing previous work in relation to each other and in relation to your planned research. However, it is better to save these parts to discussion; there you can discuss also in relation to what really happened during your research, and you will avoid repetitions.

Direct the introduction to the proper target group. When aiming at publication in a scientific journal the target group is not first year students, even though they should be introduced to the habit of reading scientific journals, but other scientists. However, you have to think about that these scientists are not always exactly in the same field of research as you, so you have to explain specific issues in short; what is field specific or not depend on the journal: If, using the introduction example above, writing a manuscript intended for a general biology journal you have to explaining more than for a journal dealing with soil quality.

Methods

The actual heading may be "Material and Methods", it depends in the journal. This is the easy-to-write-part. You should report what you did and what equipment you used in such a detail that another scientist could repeat the study. That includes reporting the brand of equipment and the producer of products. You should report everything that may have any influence over the results (but as explained with the help of Hertz in "Induction" above, it may be very difficult to determine what was of importance and what was not). If you use more complicated statistical methods, these methods should be reported here, but not the outcome of them; "normal and basic" statistical methods are not described at all.

Results

Also this part is relatively simple to write. Your figures and/or tables will be a part of this heading (even though most journals require that figures and tables are not put into the text of a manuscript but placed in the end or in a specific document - the layout is later done by the journal). Report as much as possible of your outcome in figures and/or tables, thus, avoiding detailed reporting in running text. This will help your reader to get a clear impression of your study. See "The Results" above in this text for details regarding presenting data in figures and/or tables.

In addition to the figures and/or tables there should be some text under the "Result" heading. You should remember to not have opinions about your data/results here, but only present it. However, you are allowed to point out what you regard as important, thus directing the readers in a proper way to follow your discussion later. For example: "Silver concentration in lettuce increased more when grown in sandy soil than when grown in humus-rich soil when the natural microorganism community was destroyed (Figure 8)".

Under the result heading you should also report the outcome of statistics used. If you have made more complicated analysis you should present the results as tables. For basic statistics the outcome may just be included in figures and/or tables, as the confidence ranges in Figure 7 and Figure 8.

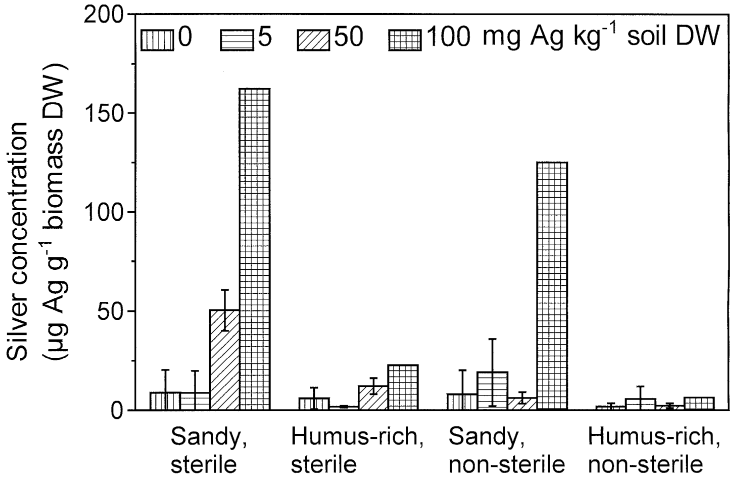

Figure 8. Silver concentration in biomass of lettuce, dry weight (DW), in relation to type of soil, soil sterility, and silver supply to the soil. Mean values with 95 % confidence range (n=4) are shown. Soils used were both brown earth from Sweden. From: Pedersen Brandt A, Karlsson LM & Wennergren U (2005) Lettuce grown in silver laden soil at two different activity levels of soil microorganisms. Journal of Applied Botany and Food Quality 79:33-37.

Discussion

This is the most difficult and the most interesting part to write. The discussion should express "Analysis and Discussion" above in such a way that your readers can follow your thoughts and either agree or disagree with you on a proper basis. There is no use of disagreeing about things that have been misunderstood!

In the discussion, you give your interpretations of your results, and you should aid your readers in understanding these interpretations. Here you clearly point out what you regard as important in the results (including in statistical analyses), and you explain why these points are important, for example: "The general higher concentration of silver in lettuce grown in sandy soil than when grown in humus-rich soil (Figure 8) points towards the importance with site-specific management instructions for use of sewage sludge as a nutrient source in farmlands". Do remember to point out appropriate figures and tables from your results, and using appropriate references to other authors, when discussing - the reader shall not have to just believe in you, but have the possibility to analyse your conclusions in detail.

Continue with discussing your results reflected in what you know from literature and, especially, what you wrote in introduction. Be careful to not "over-interpret" your data or to draw too far-reaching conclusions. However, you should also stand for your interpretations and conclusions; to put in a lot of "may", "maybe" and "perhaps" in the text in order to not risking to be wrong will lead to your text being regarded as uninteresting of most readers, just because it seems so vague. This does not mean that you are forbidden to use these uncertainly-indications words; it just means that they should not appear in each sentence, but only when needed.

Regardless whether the journal you will send your manuscript to require that you end with a "conclusions" heading or not, it is usually a good idea to end the discussion with a conclusion. To come to a conclusion it is often comfortable to briefly repeat your main findings that lead you to the conclusion, this last time without referring to figures and tables. If continue with examples from the study that included Figure 8, such an end may be:

"Living microorganisms and a high organic matter content in the soil protected against a decreased growth of lettuce in the presence of silver. In soil with a low concentration of organic matter, the microorganisms also reduced the silver accumulation in the lettuce. The organic content in silver laden soil was important both to the status of the microorganisms and to how dependent the plants are on the buffering capacity of the microorganisms. Sandy soils are therefore particularly inappropriate for fertilizing with sludge."

A way to work with a discussion can be:

1 - Begin with going through your results again, but on the contrary to in "Results" you interpret and evaluate them. Point especially out the parts that are interesting and parts that are un-expected.

2 - Discuss the results, and your interpretations of them, in relation to what was known ahead of your study, including if your results are in contradiction to specific theories or interpretations.

3 - Do not be afraid of arguing with yourself also in the text ("Analysis and Discussion"). You may present that argumentation as "on one hand......, on the other hand...." and explain to your readers how you thought about this and what you regard as the most plausible interpretation.

4 - Check yourself for not being carried away too far by your thoughts! Your discussion should be possible to follow logically for a scientist within the same field of research. Do not go into discussions that have no relation to your study.

5 - The discussion is allowed to be longer than the introduction in most cases; thus, you can discuss in detail what you mentioned in the introduction. However, no editor of any scientific journal will allow you to repeat the same content in different ways.

6 - Formulate and present your conclusion(s), based on your results and your discussion.

Of course, the points above are a very general description of a how to work with a discussion. To write discussions require training. However, if beginning with points 1-3 you will soon recognize that you quite easily will continue to discuss your results in different respects.

References

Under this heading you should simple list all references (sources) you use in your text. Some journals limit the number of references allowed; to original scientific work it may be 35-50 that is the maximum. In the beginning of a scientific career, that seems to be a lot to most people, but after some years of research work most people quickly reach these numbers when discussion results in relation to other studies done

Regarding what references to use: use as long as possible primary sources, i.e. scientific papers where the issue addressed has been studied in original. Never use information given in the introduction of articles as sources of information (information found there comes from somewhere else, and there should be references that allow you to go to the original source), instead, go to the source. It may be relevant to use secondary sources, i.e. scientific literature reporting from primary sources as review articles and books aiming at clarify any specific subject. In some cases so called "grey" literature (as reports from local authorities that have not been subjected to scientific judgement by referees and theses that are not published in any other form) may be relevant to use, especially if they report about local circumstances that are part of your starting attempt, your initial observation. Never use any kind of "school books" (including books intended entirely for use at university level) as references when writing manuscripts for scientific journals; the information you find in such books is probably well established as "general knowledge", but this is not a reason for not using proper, original, sources as references. The use of "school books" as references will probably lead to your manuscript not being regarded as serious by editors.

Regarding compiling a reference list, the only important thing to say is: *follow the instructions!* If there should be a coma between authors, put a coma there, if "et al." should be in italics write it in italics, and so on. Make sure all references you mention in the text occur in the reference list, and that there not is any reference in the list not used in the text. There are seldom difficulties with writing references to journals or books, but if you have to include references to other sources, as conference papers and various reports, be careful to provide as much information as possible regarding bibliography data, thus aiding for others to find the right publication. If using the internet (only rarely allowed, and never allowed if there is another possibility) as a reference, give the full URL you used, and report which date you visited that site. For some reason, a lot of authors, and nearly all inexperienced authors, make errors in the reference list - simply by not following the instructions carefully. There is no acceptable reason at all to do this, other than if you really want to irritate the editor who is going to decide if your manuscript shall be published.

Acknowledgements

Most journals encourage you to thank people that have aided in your study but not have had such an influence that they should be co-authors. People to thank may be those performing the field work (if not participating in planning and/or evaluation - in this case they should be co-authors), those you borrowed equipment from, and those colleagues you had discussed with (but not to such extent that they should be co-authors). You should also thank any institution that has provided you with funding. Keep the thanking short, write for example: "We thank Nnnn Nnn for advice and Cccccc for financial support", *not*: "We like to very much thank our friend Nnnn Nnn for his outstanding helpful advice, and Cccccc for their kind support to this project by financing the part dealing with Xxxx". Some institutions require that you report the project number (or similar) that you have had funding from when publishing the results. You can do that in acknowledgements if the journal not has any other routine for this.

Appendix

An appendix can sometimes be included. This is a proper way to report huge data-sets that are not really part of the main finding or outcome, but the raw data (the data you actually collected) is still regarded as interesting and important enough to be published as it is. Observe that this is mostly not the case; no journal would allow the results from each single lettuce plant (some hundred) leading to the results in Figure 8 to be listed, for example. Raw data that is sometimes published is lists of species encountered in an area. Other reasons to include an appendix may be to show a questionnaire that was used in facsimile, computer codes used, or technical specifications to equipments used.

Order of writing

There are different advices available regarding in which order the different part of a manuscript should be written. All seem to agree on that "material and methods" should be written before "results", that in turn should be written before "discussion". The "abstract" should be the second last piece, and the "title" the last. The "references" should be written when writing "introduction" and "discussion". The two extreme cases regarding the order of "introduction" and "discussion" are:

a) Write the introduction first, before even beginning the practical part of your study, and do not change anything in the introduction text later (other than formulations in order to increase clearness) - it should from the beginning give the true background to your reason the do this study, and state your hypothesis or scientific question. Regardless of the

outcome, this was the case; you cannot turn back time. Write the discussion after "results", it should reflect your "introduction".
b) Write the discussion after finishing "results" and the introduction after that. In this way, you will be able to write the most interesting discussion possible, without prejudice from what you thought about the issue before performing the practical work. The introduction you write after having put the result together and written the discussion will smoothly lead to the discussion you have found being the most interesting.

In reality, not a, nor b is probably used by many people. A more general, and realistic, advice is to write an introduction draft, based on your literature studies and thoughts that lead you to your starting point, before starting the practical work. This allow you to write an introduction that is understandable to people that have not taken part in your study, and it helps you to structure your thoughts that lead to the practical work you are heading at. Write material and methods while working with the study, and continue with results as soon your practical work is finished. Write a discussion draft after that. Continue the work by alternating between introduction and discussion, thus keeping them in balance and reflecting each other. Check if there have been new contributions to the literature regarding your field of study since you began your work, and include also relevant new publications in your introduction and discussion.

Thus, an order of writing/working could be:

1) Introduction draft (including reference list of used sources)
2) Material and methods
3) Results
4) Discussion draft (including reference list of used sources)
5) Introduction and discussion fulfilment (continue with reference list)
6) Check the reference list
7) Abstract
8) Title

If another order suits you better - used that one! People that have worked within a specific scientific field for some time may find that they usually keep the introduction in their head until the study is finished, and then relatively simple just write it down. Regardless of writing order; remember to keep your manuscript together in one unit! Important circumstances pointed out in the introduction should not be absent from the discussion. If you find that you cannot discuss your study in relation to these circumstances: delete that part from the introduction. If you end up with an interesting discussion regarding issues not mentioned in introduction but involving your results: add information about these issues to introduction.

Before regarding your text as finished, ask some colleague to read it and/or allow the text to "rest" for some time. You will benefit a lot from having comments from others that may find problems you have not thought about, and if that is not possible you will probably yourselves find a number of weak or unclear points in the manuscript when you read it again after some time. Thus, it is much better to allow the manuscript to wait a little before submitting it than to recognise these weak points when it is already published!

Submit

You shall submit to the journal according to instructions by the publisher; nowadays the most common way is to use an upload function on the journals home page on the internet. In such cases, *do not* send the manuscript as an attachment with an email or in any other electronically way not clearly approved by the publisher! Remember that editors are busy people, and you will not gain anything from making their work a mess. You may not even be considered at all if you do not use any approved way of submission. However, for people not having access to the internet, submission of printed copies is still a possibility, to most journals it requires that two or three complete copies of the entire manuscript are be submitted.

After submitting your manuscript, you will soon receive a letter that tells that the publisher has received it. Then you have to wait. If the manuscript comes back relatively soon, within one month or so, you can be quite sure it is rejected for publication in that journal - the subject editor has read it and concluded that it is not meaningful to even send it to referees (see "Scientific Theories" above); it will not be published in that journal. After have waited some two or three months (or longer) you can expect to get the manuscript back after it has been to referees for comments and also being read carefully by the subject editor. At this stage, the manuscript may be accepted (but it is very, very rare that a manuscript is directly accepted), accepted pending revision (most journals specify if they regard the revision required as "minor" or "major"), rejected with the possibility to re-submit, or rejected.

If the manuscript is accepted as it is, you will just have to wait for a proof.

If the manuscript is rejected, you have nothing else to do than to find another journal that may be suitable for publishing it in. You may have to change your manuscript a bit before submitting it to another journal: of course to following the writing instructions in that journal, but also to adjust your manuscript to a slightly different target group. It is important that you try to understand why it was rejected from the first journal. Did you maybe send it to a journal that not at all was suitable? If you regard the journal as suitable, you need to try to understand why the manuscript did not seem interesting to the editor. Maybe the study was too small (compare with what is found in the journal), maybe you were too speculative (which tend to lead to editors not taken you seriously on any point) or maybe it was not interesting because it not seemed to be research at all (if the results seem to be only description of what you did to learn a method, for example)? You may have got the comments from the referees back with your manuscript, read these carefully, and use those suggestions that you regard as good advice.

If the manuscript is accepted pending revision or rejected with the possibility to re-submit, you shall begin work with it immediately. It is important that you read the comments from the editor and the referees carefully. When you do this, do not become insulted or angry. If you get "stupid comments", try to understand why your text did not explain your thoughts properly. Remember that these people are experienced scientists, but they were not around when you did your study, thus, they can impossible interpret your study in the way you want if you did not write clearly and logical thorough the manuscript. Further, the role of the referees is not to be kind to you, but to ensure that what is published reach the minimum quality level set by the journal. You basically have to do as the referees and the editor suggest if you like getting the manuscript published in that journal. Several journals require that you write an additional document, attached to your revised manuscript, in which you explain what you have done to improve the manuscript. Change according to the suggestions you have got as long as you do not really disagree, or as long there is not contradictions in the advice. If you really disagree, and cannot accept your manuscript to be published in the way that is suggested, you have to argue with the editor. In this case, do not try to argue that the text should be as it was when rejected, but suggest other ways to improve what was pointed out as weak parts than the ways suggested in the comments. When a manuscript is accepted pending revision or rejected with the possibility to re-submit, you have of course no obligation to follow the suggestions or advice, you can decide to send it to another journal directly. If your manuscript was accepted pending revision, it is in this case polite to send a letter to the editor to communicate this decision. If following suggestions and submit a revised version, or re-submit a new version, your manuscript will hopefully be accepted, but you may get another revision to do, until the editor is finally satisfied and accept it for publication. Then wait for a proof.

When you proof-read, read very carefully. You shall for example check that every reference to your figures and tables, and to other sources, is still correct. At this stage, you will only be allowed to correct errors that have appeared at the publishers', not errors you had done before submitting. Thus, if you find a not clear, or even bad, formulation which is exactly as you wrote it in the manuscript, you can not expect the publisher to change it - this was what you submitted and what you wanted to publish. Therefore, read always your text carefully *before* submitting!

RESEARCH METHODOLOGIES

Introduction

In this part of the booklet, we try to give some concrete advice about how to think when setting up and performing research; our examples are mostly from the fields of agriculture and ecology, with focus mostly on applied and adaptive research, and on the situation in Ethiopia. We give some advice about how studies can be set up, and how the result can be measured. However, it is impossible to be complete - to give solutions for all possible situations. It is important that any person in the beginning of a research career is curious, is open for discussion, is thinking critically and read a lot - by reading scientific articles published in international journals as well as reports from local research centres the person will gather more and more information about how different studies can be done, and will develop an understanding of when which method is useful.

Statistics is a tool that often is involved when planning research, and very often is a part of the evaluation of results. This text will not focus on statistical analyses, but on the concrete research to be undertaken. However, some general reasoning of statistics is included. For further reading, there are a large number of books written about statistics; at Wolaita Sodo University we recommend especially "Practical Statistics for Field Biology" by Fowler & Cohen as a comprehensive introduction, and "Biostatistical Analysis" by Zar as an in-depth source for wide theoretical understanding for all kinds of biology-related statistical problems. Both books, together with a number of books in general statistics and statistics for certain subjects, are available in library.

Begin

Above, under "Get Started" there is a general description and advice about how to decide what to study scientifically. When going to undertake applied or adaptive research in order to solve problems in the society or to improve living standards, it is often useful to have a systematic way to work, in order to decide what to focus on and to be able to initiate the work. One suggestion:

1. To at all decide what to study, you can begin with a problem analysis. In this, you evaluate major, general problems with respect to their importance. This allows you to focus on the most important, of the initially included, major problem for the society.
2. List problems that are parts of the major problem concerned. If the major problem is "too little food because of too little harvest", list what you know may limit the productivity of the local farming system; it may be diseases occurring, irrigation not used, no suitable varieties to use, or very much weeds that out-compete the crop.
3. Here it may be suitable to make a new problem analysis, aiding you to reduce the number of problems. This may indeed be difficult; it can be impossible to determine the relative severity of different problems before research is done.
4. Identify the causes of each remaining problem as far as possible. Answer questions as: which disease limits the productivity most? Why is irrigation not used (too little water available, or no infrastructure present, or no routine)? Which weed species are there?
5. Identify and analyze intervention points; what are the possible solutions to the problems, what knowledge is lacking to solve the problems? Some solutions may be easily

available; identify these - the conclusion may then be that no research is needed, but it is a case suitable for giving advice to the farmers directly (based on present knowledge, compare with the example around Figure 2). Continue with the points where knowledge is lacking; where research is needed.

6. Again, you may benefit from undertake a new problem analysis, to decide which single point, or a few points, of those that require research to work with first.

In a lot of cases, you will not have, or not have the possibility, to go through all the steps listed above. If you work for a research station, or for the government or a NGO, your employer will often have decided what problem that shall be focused on. Thus, you may start at 2, 4, 5 or 6, depending on the specification in the task. Hopefully, you do not have to do the decision of what to study, of what to investigate, all by yourself, but have colleagues to discuss with. The importance of discussion is huge. When we discuss, we have to specify our arguments in a way to make other understand them, and we will be aware of arguments that we have not thought about. By communicating our arguments, we benefit by making them clear also for ourselves (by getting rid of risk of too much personal preferences that have no basis in logics). Thus, discussions may make you change your mind of what to investigate, and the decision, whatever it will be, will be properly based on critical thinking.

Problem Analysis

<u>Identify</u>

The first step in problem analysis is, of course, to identify the problems. In Ethiopia, like in many other developing countries, the problems affecting the agricultural production are well known: for example natural resource degradation, diseases, insects and low yielding varieties used are problems identified at national level. However, when attempting to seek solutions to these issues through research it is essential to define the problem clearly and to delimit the boundaries. It is important to differentiate the symptom from the cause of the problem. It is common for research efforts to be directed at solving symptoms instead of the cause of the problem. In many causes an inadequate formulation of the research problem is the cause of an ineffective research.

Within agriculture, common problems are related to production-limiting factors such as deficiency of nutrients, moisture stress, insect pests and diseases. The problems occur frequently as result of natural phenomena in which man has no direct involvement. Environmental conditions trigger the occurrence of disease and insect out breaks. However, the environmental situation is often a result of human misuse of resources such as over and under application of fertilizers, overuse of irrigation water, improper use of pesticides, too high or low planting density, careless choice of varieties or races, for example. Thus, there may be obvious solutions to the problem: if the problem is serious erosion caused by deforestation, research regarding erosion is probably not the most important. Also forestry research may be wasted as a quick problem-solver; what is needed is research of how to make people stop cutting away more than the forest grows, or how to make them cultivate with terracing, which is proved to be a highly functional way to reduce erosion.

In problem identification it is important to determine the beneficiaries of the research result. The objectives of the clients have to be known to delimit the scope of the research. Further, one has to identify the context or environment within which the problem is to be researched. Researchers often end up formulating research problems outside the limits of available resource (financial, material, and human facilities) or the own institution.

There are some commonly occurring deficiencies in problem analyses:

1. Fixation on a pre-determined solution. That means, the researcher is already from the beginning focused on only one way to solve the problem, for example by aiming at

developing new varieties for all crop-related problems. However, it must also be a balance in relation to you profession: if you are a specialized in genetics focusing on variety development, you probably contribute most by keeping to that area. Thus, be aware of that it is not always suitable to solve a problem with the methods you are experienced in.

2. Failure to distinguish between problems to be solved by the implementing institution and problems better left to other institutions. Thus, attempt to work with research that the person either lacks sufficient knowledge about, and/or which is beyond the scope of his or her present institution.
3. Confusion of cause and effect by failing to push analysis beyond the symptoms of a problem to its root causes. If the animals in a region are too meagre, it is probably not meaningful to do research about the effect of feeding them, nor by investigating the reason for them being meagre (too little fodder because of over-grazed land, will be the probably result). Instead, it may be meaningful to do research on novel grassland management methods, or to investigate the carrying capacity (the amount of grazing animals that can be properly fed by the grassland) of that specific area, in order to be able to give proper advice.

To avoid the problem in 3 above, it is important to be aware of what is meant with "cause". Causes are factors or reasons, which are responsible for the creation of a problem. If there is wilting of sugarcane, the cause may be a clay pan at the depth of 30 cm which the roots cannot penetrate, and the plant can not get enough water. Often there is not one easily to find cause, but a chain of causes. If there is decreasing harvest due to too little nutrients in an area, it may be that because of drought the previous season there were not sufficient fodder to the animals and the farmers removed crop residue to be used as animal fodder. The removal of crop residue caused loss of organic matter, including nutrients. This, in return causes nutrient deficiency in the soil at the moment, which leads to low yield. Thus, the root cause is drought last season. For other problem, there are a number of causes that act simultaneously, if there is stunted growth of coffee can be caused by, it may at the same time be caused by poor soil fertility, little rain, and insect damage.

To not fall in the pit of confusing cause with effect (3 above) you may gain from thinking of what is a declarative statement of what has gone wrong, or just is wrong, or what that is a statement that inquires about the problem itself. The latter should be related to the former, if the former is the general problem that is regarded as the most important to solve at your present institution or position.

Examples of declarative statements of what is wrong: "the forest area of the country is decreasing at an alarming rate", "rural family incomes are very low as compared to urban family incomes", and "Lake Alemaya is drying out at an alarming rate".

Examples of statements that inquire about the problem itself: "What is the existing forest cover?", "What is the rate of decline per year?", "In which part of he country is the problem most serious", "Which species are most endangered?", and "What are the causal agents?".

By asking such questions, the researcher has reduced complex problems to a series of research questions that can be investigated. However, it is important to be aware of that something important may be missing; you may just not think about it when you list your inquire statements.

To as much as possible make sure that you identify all important probably causes to a problem, you should use involve other people, like performing a participatory rural appraisal (which aims at getting knowledge of the stakeholders' knowledge, practices and opinions) and brainstorm with you colleagues. Another way to attempt to identify causes to problems is to construct a problem tree. This is a method highly appreciated by some people, and dismissed by others.

Problem Trees

The goal for a problem tree is to assist in the definition of genuine problems and clarification of the interrelationships between different sub-problems. The way to work is to ask following-up questions to every point of information entered. It may be drawn as a tree (beginning in the bottom with the broad problem, and continue with sub-parts, like a mind-map) but this is not necessary. However, the goal of the problem tree is, of course not a simple task. The limitations of the method are: causes and effects of problems are often not clear-cut, it does not analyze relative importance of problems, and it can get very complex and difficult to interpret.

An example. Suppose someone suggest that you conduct a project on the development of increased protein content in maize in Ethiopia; the problem is: There is too little protein in the maize available for most people in Ethiopia. Each point below is one branch of the tree growing from this point, and each sub-point is a twig from that branch.

- The importance of the problem
    - 90 % of 70 million people live in rural areas in Ethiopia.
    - Per capita income very low, less than 500 Birr per year
    - Maize grown under rain fed conditions important food crop, but yields are low (average of 19 quintals/ha)

- The causes to the problem
    - Yields are well bellow the potential of 80 quintals/ha due to low-yielding varieties, suboptimal agronomic practices, and multiple abiotic and biotic stresses
    - Annual losses due to drought on the order of 25% of total production
    - Losses due to nitrogen deficiency are estimated at around 100 million Birr annually

- What has been done to solve the problem?
    - Ethiopian Agricultural Research Organization (EARO) have worked on drought tolerant varieties, but lacks testing
    - EARO have worked on methods for improving nitrogen content in soil, but only on experimental stations
    - Extension service works in three districts, but not in the remaining seven

Of course, you can continue with more branches, more twigs, and additional smaller twigs. As is probably clear from this example of a tree, you will not get a simple answer about what is the most important problem to solve in order to improve maize protein content. But it may help you to sort out important parts from less important, and if working on it properly, you will get a lot of information of what is already done, and understand why it was done, which will increase the possibility that you contribute with new knowledge rather than invent the wheel again.

Prioritize

When you have identified some problems that require research, you need to set priority. In reality, setting priority of what problem to try to solve (or investigate) first involves, or requires, usually the participation of people from different positions and professions. People involved may be: decision makers (managers, the board of any concerned institution or company, and senior government officials who carry the responsibility for decisions), economists (provide the analytical tools and the data required to execute the priority setting process regarding use of funds) and researchers of different subjects being assumed to be of importance (provide information on the present knowledge and the technical feasibility of any suggested research)

The criteria included can be broad or narrow, depending on the stage in the planning. Early in the process (when deciding what to work with at all), the involved criteria may be factors like: the number of people affected by the problem, the number of people probably affected in the future, and the seriousness of that people are affected in this way. Later on, closer to an actual study (in this example to decide which ruminant species to work with), the factors may be: the maximum growth rate, the meat/bone fraction, the opinion of people regarding the palatability of the meat, and the potential milk yield per fodder energy unit.

There are some established methods for setting priority. These can be grouped as single criterion and multiple criteria methods, depending on if one or more criterion (reason) for the priority is concerned. Of course, any priority decided on can only be based on the criteria underlying the reasoning, regardless of what method is used for the priority setting. Thus, *it is important to think thoroughly about which, and how many, criteria to use for the decision*.

Single Criterion

General

In this case, there is one, and only one, criterion that reflects the objectives of the organization for which the priorities are going to be set. For example, if the objective of the organization is towards increasing the national income, a single criteria method is sufficient; the only thing that matter is how much the national income probably can increase. Related factors, as if the increased income will be evenly distributed among people, or if the gap between the rich and the poor will increase is not taken into account in such a case.

Congruency

This means to calculate the size, the amount, of the criterion for each suggested research attempt regarded. The criterion may be: value of the production concerned, or the number of people earning income from the area. It is basically very simple: if commodity A has double the value (with the value calculated for the criterion regarded only) of commodity B, the amount of research resources allocated to A would be double the amount allocated to B. Congruency analysis is transparent, simple and easy to apply, but its theoretical logic is poor; who knows if the place/area that already is the largest/most productive (or whatever criterion used) is the one where the research will gain most from getting much funding?.

Economic Surplus

This is a way to try to predict the economic benefit of research. For example, if the research is supposed to give a specific increase of the present yield, this should be compared with the cost for performing the research. In this way, the research that gives, relatively, most output for the funding input should be selected as the highest priority. This is a powerful method with strong foundation in economic theory. However, it requires elaborate data (how many scientists can really predict the yield increase as result of any research attempt? As stated above, if this is known, no research is needed). A further problem, but that can be overcame, is that it is not easily understandable for non-economists.

Multiple Criteria

General

In this case, there are two or more criteria concerned. It will thus be possible to pay attention to, for example, both the possible increase of the national income and the distribution among that increased income among people.

Scoring

This method is frequently used for priority setting. A number of criteria are identified and score of each is given. When scores are set for each criterion, a final score can be calculated.

For each criterion concerned, each suggested problem field should get a score. The score used may be 1-5, with 1 meaning very little importance, and 5 meaning very high importance. To get a result that reflect the opinion of the decision-making group, the criteria involved can be weighted. That means, that a criterion that is regarded as having higher general importance than other is given a weight that increase the score used for that criterion by multiplication. From Table 1, where rice turned out to have the highest priority, on can for example observe that if "value of the product" had not had a higher weight than "importance to poor farmers", bean had had higher priority than rice in this case (the products had scored 11 and 10, respectively). Thus, the outcome is highly depending on the weighting (or the absence of weighting). Any weighting used has to be thoroughly thought trough. Of course, it is also necessary to have good information to be able to set the scores for each product and each criterion properly.

Table 1. Example of use of scoring for the decision of which agricultural product to put research effort into. It is scoring for deciding between bean, cassava and rice research by using different criteria. The scores used are here 1-5, where 1 means little and 5 very high. Weighting of criterion is used. The scoring is showed as "criterion score × criterion weight = score" for the products.

Criterion	**Bean**	**Cassava**	**Rice**	**Criterion weight**
Value of product	3 × 2 = 6	2 × 2 = 4	5 × 2 = 10	**2**
Importance to poor farmers	4 × 1 = 4	4 × 1 = 4	2 × 1 = 2	**1**
Nutritional value	4 ×1 = 4	2 × 1 = 2	3 × 1 = 3	**1**
Total weighted score	14	10	15	
Priority	**2**	**3**	**1**	

Ranking

Direct ranking of different problems in different circumstances is another way to reach a conclusion. Table 2 gives an example of what to prioritize when aiming at improve the maize yield. In this case, research on nitrogen deficiency in maize takes the highest priority. However, it is easy to argue that the initial priorities, regarding the different problems' importance in different perspectives, have a very high risk to be subjective. If there is not a proper study recently done, how can you properly evaluate "seriousness of the problem"

(Table 2) ahead of a study? How shall this be known without research? Anyway, this is a method quite often used, and the argument for using it is that if a number of people make such, relatively subjective, evaluations the final result will be useful (assuming that the impression of the majority has something to do with reality). Weighting of perspectives can be used in ranking, as for criteria in scoring (see "Scoring" above).

Table 2. An example of using ranking of different problems regarding their importance in different perspectives to get an overall ranking of which problem to prioritize. The highest priority got 1, and the overall priority was calculated as the sum of ranks divided by the number of perspectives of the problem considered.

Problem	Criterion			**Overall priority level**
	Distribution of the problem	Importance of the problem	Seriousness of the problem	
Nitrogen deficiency in maize	1	1	1	**1.0** (3/3)
Phosphorous deficiency in maize	2	2	3	**2.3** (7/3)
Drought stress in maize at ear filling	3	1	2	**2.0** (6/3)

Plan Investigation

<u>Introduction</u>

To go from the decision of that one specific problem is the problem that needs to be solved first, and by you, to decide what you will actually do, what your actual research attempt shall investigate, is not always easy. To not waste time and other resources, you need to think carefully before taking action; it is rarely meaningful to go out and begin to measure something, or try something, without a careful evaluation of different possibilities. When performing such thinking work, it may be helpful to continue in a systematic way. The list below is a direct continuum on the list under "Begin" above.

7a. Evaluate the possibility to use solutions available elsewhere. The analysis may include the probability that a technology will at all be possible to use at your study local, if the solution can be profitable, if it is compatible with other methods used at present at your study local, if a crop variety will be productive in the climate in your study local, and/or if it is reasonable that the farmers will be able to use the method suggested. Of course, you can not know any of this (that is the reason that research is needed) but you can use your knowledge to make a reasonable probability calculation - if it is obvious that a suggested method will not function, there is little benefit from trying it. If you find possible solutions, which you will try in practice, in this way, your will conduct adaptive research - you will investigate the outcome of using a method that is functional somewhere else.

7b. If there are no solutions possible to use available elsewhere, you need to analyse what is known in general, what basic research results are there that can aid you in solving the problem by applied research, by putting knowledge into practical use? If there are knowledge of the germination requirements of that most occurring weed species, can you figure out some possible combat way in which you disfavour it? This is not easy. You need to have both subject knowledge and a realistic mind to come up with suitable suggestion to test in applied research.

8. Formulate a hypothesis or a scientific question.

9. Determine how an actual study can be done to evaluate your suggested solution (by testing your hypothesis or investigate your scientific question).

10. Write a research proposal.

Decide Investigation

Introduction

After you have decided what problem to target, you need to decide what actually to do. This is very difficult and very important, because it determines what your research will handle; thus it determines what outcome that at all is possible. If you have decided a too broad problem, you will most probably be aware of it now. If the problem you decided to work with was something like "how to solve the present decrease of meat production in Wolaita Sodo", and you do not have any better idea to solution than to make interviews with the farmers (or send questionnaires to them) and talk to the local offices that deals with agriculture, you will recognize that this is not a possible way for solving the problem; you can not assume that the solution to the entire problem lies there and just wait for you among the farmers and the officials, and all that was needed was your magic hand to pick it. Thus, at this stage, if not before, you have to limit your problem. In this case, if the farmers' reasons to reduce the number of animals they keep are not known, this may be your research, and the interviews or the questionnaires will be a suitable method. If the reasons are known (there is no economical gain, or there is not enough grasslands, for example) you have to begin from the beginning; is this a problem that require research, or is it about making decisions in the society, or both? Compare with the examples around Figure 2, and under "Identify" above.

Adaptive Research

Within agriculture, you will gain from paying attention to possible available solutions (machineries, varieties, races, routines) the first thing you do. If a suitable solution is available elsewhere, and you regard it as possible suitable at your study site, you can conduct an adaptive experiment. Thus, to conduct a study to investigate if it is a suitable and economical solution also during the local circumstances you study. The difficulty is; how to evaluate if a solution used elsewhere is meaningful to try; may it at all be suitable at your study site? You have to use your knowledge of the subject to evaluate this - there is no short-cut.

In the case of any mechanical technology, you need to think about the probability that it at all function. For example, for machinery working with soil (as cultivation or potato harvesting) it is important to take into consideration the soil quality; if there are a lot of larger stones on your study site but not on any other site where the machine is used, you will gain from making a pilot study of using the machine in stony soil before investigating the possibility to use it in a full-scale adaptive research project at your site. In all cases, you need to think about if the fuel or power needed is available in sufficient amount and with sufficient reliability; at least if your goal is to provide a useful solution and not only point out a solution that could be useful if there were fuel or power. However, it may be of interest to conduct a study even if there is not fuel or power available as needed at the moment; the research itself is always meaningful by providing new knowledge, and the information that an efficient method (if the method *is* efficient on your site) could be used in case of improved fuel or power availability may lead decision-makers to improve the infrastructure.

In the case of plant varieties or animal races that are successful on another site, it is your subject-knowledge that determines how well you can evaluate its possible success at your study site. There are an endless number of environmental variables, and all can differ more and less between two sites. Thus, it is not meaningful to, for example, begin with measuring temperature during every minute during one year, and calculate the difference, at every minute, between the two sites. First, there is not such detailed knowledge about any living organism that the information gathered will allow you to predict its performance on the new site by comparing with its performance on the site at which it is established, and second you will not know how much of the differences you record that is a result of normal variation between years. What you have to do is to use your knowledge to list the most important factor for the organism concerned; is it known, or approximated, which limits it has for survival regarding some environmental factors (as minimum and maximum temperature)? How much is known, or approximated, regarding its optimum for some environmental factors for different stages in the life cycle (as optimal temperature for reproduction). By gathering information in this way (not only on temperature, but on all environmental factors you regard as crucial for the organism - for some soils quality is of high importance, for other it is air humidity), and compare with was is known about your study site, you can be able to conclude directly that this organism will not be suitable, or that this organism seemingly has a high probability to succeed.

When you want to introduce something new (but used elsewhere) on a local, and if you want it to have any possibility to be functional, you have to involve the stakeholders. This is especially important if you like to introduce a routine, because around the world people tend to be conservative regarding their practice; if someone has done in a specific way all life, and the parents and grandparents and all other known relatives and ancestors have done in this way, the person may not switch method regardless of how energetic you tell how much the gain could be. Thus, the possibility to implement the suggested solution in the culture has to be taken into consideration.

An example of insufficient evaluations of possible solutions can be given from Bolivia, the poorest country in South America. In Bolivia, people in general get too little protein, and several organisational and research attempts have been done to improve the situation. Once, there were researchers that calculated that dairy cows should be a marvellous good solution; it would be economical enough to be possible to fund, and it would provide people with much more protein than what was available to them before. In a number of villages, they constructed cow-houses and dairies, in order to investigate the effect of this solution, with the goal to then apply it in the entire country. There was just one thing they had not thought about - the Bolivians do not drink milk, and the researchers had not even thought about discussing the possibility to consume milk to get additional protein with people. Thus, it was just a huge waste of resources.

Whenever planning a research work that has the goal to solve a problem, and the suggested solution at all includes the behaviour of the stakeholders: do not only evaluate the technical and environmental aspects that may influence the possibility for success, but inform and include the stakeholders before initiating the study.

Applied Research

If it is difficult to recommend what to take into consideration when planning to perform adaptive research, it is close to impossible to suggest what to study if there is not direct possible useful solution available and applied research is needed to develop methods or technologies to use. To decide what exactly to study will always be dependent on your own creativity, competence and subject knowledge.

When deciding, you should take into consideration both the goal of the research and the present general knowledge of the subject - as pointed out above, there is no gain from thinking like "I shall solve the problem with weeds" and then conduct a study of the presence of weed in one field, for example. However, if there are complains about weeds among farmers in an area, it may be reasonable to begin with investigating the weeds in that area, and in some other area where the farmers not complain that much, and record what methods farmers on the different places use to combat weed. This can be important knowledge for subsequent studies, but it is not a solution.

If the problem concerned is huge numbers of weeds in crop fields, and available combat methods are not enough, you may begin (of course in addition to review the knowledge you already have) with reading the latest articles, from basic research, on ecology of the weedy species that are most problematic in your area. Is there anything there that gives you a novel idea about how the species can be combated? Maybe one of the problematic weed species has been shown to suffer, more than most other plants, from bad development if it not has plenty of light available during its early development? Think about if there could be some way to use this. In crop fields, there is usually a lot of light present during the early development of weedy species, because it is when the field is cleaned from crop and crop residues, and the next crop is sown. Could you figure out some way to shade it for a period after the weedy species have emerged? Of course, it must be some method that not hurt the crop too much (at least the overall result must be higher yield with than without your method for it to be regarded as useful).

If the problem concerned is unexpected bad growth among chicken in a poultry farms (they show less growth than what free-running chicken in backyard farming have, when given equivalent of fodder, nutrients and water), you may (of course in addition to review the knowledge you already have) with reading the latest articles, from basic research, on ethology of red junglefowl (*Gallus gallus*); the wild ancestor to all poultry used today. Is there anything there that gives you a novel idea about the reason to the problem? Maybe there is some specific behaviour that the animals perform in the wild, which they can do properly in backyards but not in poultry farms? Maybe this enforced change of behaviour cause the restriction of the growth? Maybe there is some way to construct poultry farms so they can perform that behaviour also there?

You have to think of all possible obstacles you can imagine with your suggestion before trying it, in order to increase your possibility to be successful.

Formulate Hypothesis or Question

When you have decided what you will study, you shall formulate it clearly. This is important both for you and for others. It is important for you, because it will help to keep you focused, and it is important for others (for example for people that shall decide if you get funding for conducting this study) because they can easily understand what actually is going to be investigated. As described in "Hypothesis or Question" above, you are not assumed to just guess something and call it a hypothesis; you are assumed to give a proper motivation to any hypothesis, like "because the weed X has recently been showed to suffer from bad early development if not getting a lot of light, and crop Y is relatively shade-tolerant during this development stage, I hypothesize that mulching during early development will increase the crop yield of Y in the area A, where the two species have similar germination timing", where the concrete hypothesis is "mulching of crop fields in area A will reduce the amount of weed X, and as a result give a higher yield of crop Y". Within agriculture, especially in adaptive research, it is very common that it is much more proper to formulate a scientific question than a hypothesis. Regarding the chicken described in "Applied Research" above, you can probably not formulate a hypothesis, but you can ask a scientific question: "Will the possibility for chickens to perform behaviour B in poultry farms influence their growth?".

You shall remember that formulation like "How can the health situation for cattle be improved in Wolaita Sodo?" or "By, combating weeds, the production of maize can increase in eastern Ethiopia" *are not* scientific questions, nor hypotheses. You have to be specific; which specific effect or effects of which possible treatments will you investigate regarding the cattle, and which weed combat method or methods will you use in the maize fields?

Plan a Study

Introduction

A properly planned study is said to be half executed. The importance of have identified what to study and make sure the studied factor can be identified cannot be overestimated. When planning a study, it is necessary to make sure that the outcome is in line with the intention - it is, of course, not possible to predict the result (in that case there is no meaning to do research) but it is important to make sure that the proposed issue is studied; this make the difference between proper research and plan-less trial and error testing. This sounds simple - of course one decides to study what the issue is about, but it is often a problematic point in reality.

An example: A person has noted that the calves in a certain region grow too slow to give the expected amount of meat within a season. The person decides to try to change this, and collect a number of calves and beginning trying. He/she give them more milk (they may eat too little), force them to not move around (they may use their energy for moving instead of growing) and read tales for them in evening (they may be sleepless and lose growth potential during night). The person succeeded; these calves grew faster than the un-treated. And all farmers got the advice to add more milk, to tie the calves, and read for them in evenings. And all calves grow better. However successful in achieving the wished outcome, this is not research. First, the person should have read the literature better, and thus been able to conclude that the reading part cannot contribute (even though the calves are not hurt, it takes unnecessary time from the farmer). Second, a study should have been planned in order to investigate the effect of extra milk and of tie the animals separately, and of the combination of the two treatments. Thus, a proper attempt could have been to subjecting a number of calves to an gradient of extra milk (from no extra to a lot extra), by tie some and not other calves, and by both giving extra milk and tie additional calves. By knowing the effect of the different investigated factors, separately and in combination, advice could be given to farmers about how to, most efficiently, achieve different growth rates for the calves in that region.

Another example: When working in nature, there are always a lot of factors influencing the outcome. To be able to study, and draw conclusions, of one factor of interest require that all involved units (replicates and treatments) are subjected to the same circumstances, except the studied factor. If investigating the effect of a new fertilizer on teff, the result become useless if there is differences in the water supply in the field, and the different amount of fertilizers included are applied on areas with different soil humidity (one fertilizer level on each humidity level only). There are different ways in which such studies can be replicated, but if the environmental differences are too large it is not possible. If aiming at investigating both the effect of the fertilizer and the effect of water supply, the study must involve all combinations, as described with the calves above.

Design

When the word "design" is used in a context of science and research, it alludes at how the actual sampling (i.e. to pick the individuals, or the items, or the areas, or whatever you will study), and the experiment or the non-experimental study is planned to be performed. There is not any possibility to describe one single "right" or "perfect" design in every specific case. On the contrary, there are often several acceptable designs, but often there are also some drawbacks with each different suggestion. Thus, the researcher's understanding and knowledge is important for making conscious decisions; weighing the advantages against the disadvantages for different possible designs in order to use a method that fulfil the requirements as much as possible, while being aware of the drawbacks. As researcher, it is important to not getting trapped in habit: one should not just follow the design usually used, but think critically in every specific case.

When designing a study, one basal point is to decide if it shall be an experimental study or a non-experimental study. In general, experiments give clearer and more specific results than non-experimental studies, but in a lot of cases it is impossible to conduct experiments.

- An experiment is to investigate the effect of one factor, or several factors (i.e. the independent variable), on some other factor or factors (i.e. the dependent variable, the factor that is assumed to depend on the independent variable; the factor that is measured as "result" and never is allowed to be manipulated). In an experiment, you decide which interdependent variable or variables to include, and you decide also how much of these there shall be. It may be to investigate the effect on silver concentration on lettuce in different soil types, as the study underlying the results shown in Figure 8. For getting these results, different amount of silver was added to soil. The silver amount, an independent factor, was manipulated by the researchers. The soil quality was another independent variable, and it was manipulated (sandy or humus-rich, sterile or not) by the researcher. The dependent variable was amount of silver taken up per mass unit of lettuce (the y-axis in Figure 8). *Experiments require that it is possible to manipulate the independent variable of interest, and to measure the dependent variable of interest in response to the independent variable*.

- A non-experimental study is a study in which there is no manipulation or control possibility of the independent variable, or when there is no independent variable involved at all.

  - With independent variable: When using a factor that occur in nature, and measure it, and measure the response of a dependent variable to it, it is not an experiment, but a non-experimental study with an independent variable. It may be to measure the wheat harvest from plants grown in soils with different (measured) sand/clay fractions: the sand-clay fraction is the independent variable; the wheat harvest is the dependent variable. Or it can be to measure the amount of internal parasites in sheep in areas with different (recorded) annual mean temperature and different (recorded) annual air humidity: the temperature and humidity are independent variables; the amount of parasites is the dependent variable. Both studies, as all non-experimental studies with independent variable, are theoretically possible to perform as experiments, but are often impossible to perform as experiments in reality. *Non-experimental studies with independent variable require that there is a large numbers of measured points,* if there are only two wheat fields or sheep on three sites measured, it is impossible to determine if a difference that occur is the result of the independent variables measured, or if it depends on something that was not measured at all.

  - Without independent variable: This is when investigating how the situation is with something, without aiming at connect the situation with any specific factor. Still, a large number of factors that may be the cause for the outcome can be measured. Typical examples when working in nature and agriculture are inventories of occurrence and densities of species, and surveys aiming at getting knowledge of peoples opinions on situations and/or the methods they use in their production. When in addition measure environmental factors (as soil type, elevation, precipitation, and temperature in the inventory) the result may be possible to correlate with different amounts and combinations of these factors.

Sampling

Definition

Sampling is about collecting items to include in a study. Sampling should not be confused with data collection: data collection is measuring or estimating to get some value or description on studied items. To get the items is sampling, and sampling design is how to decide which items to include. You may do sampling first in your study (to get items or individuals to study) and you can do it in the end (if you for example have applied a treatment on a large number of animals or plants, you may not be able to measure them all, but sample from the groups), and you may also sample both in the beginning and in the end, perhaps in different ways and probably for different reasons. You need to have decided what kind of study (experimental or non-experimental, and the design of the study) before deciding how to sample, but you will often have to sample before beginning the actual study.

Random Sampling

Random sampling may sound as something very simple, but it is important to differentiate it from hap-hazard sampling (see below). Random sampling is when all individual items of the entire study population (that may be some very large groups as all grain fields in Africa, or a much smaller group as all chickens hatched a certain day at a specific poultry farm) has exactly the same probability to be sampled, and which that actually are sampled depend only on randomness. Thus, the researcher should strive toward being as detached as possible from the actual selection.

The most commonly recommended method to achieve true random sampling is to number all the items included in the study population, and then use random number to select the ones to include. Random numbers can be obtained from a random number table, random number selection in computer programs, or by using a stop-watch with 1/10 or 1/100 second precision. In the latter case: start it, do not look at it, stop it after some seconds and use *only* the last figure. This Figure 9s your random number; if you need more, do it again until you have as many figures that you need. The method with the stop-watch has been shown to give completely random numbers; not differing from random tables or random number sequences obtained thorough algorithms in computers.

In a lot of cases numbering all and select numbers randomly is a proper and functional method; if one is going to compare the weed flora in two wheat fields or the egg production from poultry of two different breeds, it is possible to part each field in grids and get quadrates that can be numbered, and the hens are individuals and can be numbered as they are. In other cases it is more problematic; either because of an overwhelmingly large number of items in the population, or by difficulty to actually put the number on each single item, or both. If you are going to investigate the grain size and quality of sorghum in an area, you may regard it as impossible to number several million seeds, and if you are going to study the fat content of fishes in a lake you may not be willing to first take up them all to number them and then only use a small part. In the cases when one for some reason not uses randomness by numbers, it is important to as much as possible detach from the own (unconscious) personal preference and use tools for getting randomness, like tossing a coin to include or not if there is relatively few and large items to select between, throw a marker over ones back and use the item it come closest to, and in the case of a lot of small items (like thousands of seeds or bacteria): make sure to mix them properly, and pick up a number of items at once, without looking.

Proper random sampling gives a result that is interpretable for the entire population; averages and ranges of variation (as standard deviations) refer to the entire group.

Hap-Hazard Sampling

This way to sample shall *not* be confused with random sampling. Hap-hazard sampling is when the researcher or assistants select by choosing. The problem with that is that human beings are selective, also when trying not to be it. Unconsciously, people will select for example the larger (or smaller) or lighter (or darker), and will make some system in the sampling, like never taking two adjacent (or too often taking two adjacent, if being aware of that people normally do not pick two adjacent when trying to select randomly).

Systematic Sampling

This is to take every X^{th} item from the entire study population. This is often quite appealing: if there are 100 cows, and you shall use 20 for your study, it is practical to select the first one randomly and then pick every 5^{th} as they stay in a cow-house or as they pass through a gate. However, there is a risk with systematic sampling, and this risk is that there is some (unknown) periodicity in the population to be sampled from. Assume that some of these cows are competing about being leaders, and when they line up in the cow-house they place themselves in a way so they avoid conflict; thus ending up with not-involved cows in between them. Assume now that there are 20 competing cows, and the first you pick (randomly) happen to be one of them: then get only the 20 competing ones (that well may be the 20 strongest and/or largest) by taking every 5^{th} (because you avoid the four placed in between each competing one with the systematic sampling design). Indeed this is not much likely, but still there is a risk. The risk is there also with plants; if collecting plants from a field in a systematic way, you may get only usually large (or small) by accidentally using a periodicity that is correlated to a natural occurring periodicity of for example competition of space.

Stratified Sampling

This method is often used when there are, known, different groups within the study population. Such different groups can be male and females, or different age or size groups. The reason to use this method, and not sampling randomly, is to be sure to achieve a representative group of items regarding the known characters.

If you are going to make a questionnaire about the opinion on day-care for children among farm owners, you may regard it as important to include a fraction of female owners that is in proportion to the total number of female farm owners in relation to male farm owners. To achieve this: count the total number of each group and calculate the fraction of each. After deciding the total number to include in the actual study, the number to use from each group is calculated. After this, the proper number of each female and the male farm owners are randomly selected. For example: assume there are 1762 farm owners in the study area; 1211 (69 %) males and 551 (31 %) females. You will distribute the questionnaire to 400 people. Thus, you send it to 276 (400×0.69) randomly selected males and 124 (400×0.31) randomly selected females.

In a lot of cases, the groups that are regarded as different are not discrete variables (as gender - one is either female or male, nothing in between) but continuous variables (as age - for human beings it is possible to be of any age: 1.38, 1.2, 3, 7, 7.0001, 15, 23, 42, 42.2, 42.3279.... years and everything else above 0 and below about 100, with an endless number of decimals for each possible year). For continuous variables the population has to be parted in classes. In what way the classes are constructed, depend entirely on the reason to form them. If investigating the effect of a medicine on cattle, you may classify them according to their weight, for example: up to 50, >50-100, >100-150, >150-200... and so on. The classes have not necessarily to be of equal size; you may be interested in the effect of the medicine on cattle of different ages, and suspect that the young ones would be extra sensible and classify them as: up to 0.5, >0.5-1, >1-2, >2-4, >4 years. Each such class is sometimes called a "strata", therefore the term "stratified sampling".

A lot of different things can be used for parting a population in classes (milk production from cows, egg production from hens, seed size of grains, fruit size or number of fruits from trees...). It is important to remember that there may be other differences between these groups than what they are classified from. Thus, if there are differences between the different groups one cannot automatically conclude that the reason for that difference is the factor they are sorted according to. If large grains germinate to a higher extent that small grains, the reason may be that the larger ones are from mother plants that got more nutrients then the other, and thus not being an effect of the size itself (to investigate whether the size matters, seeds from mother plants that all were grown in the same environment have to be used). Do never part any population in strata without thinking carefully about it; ask yourself: is there a reason to sample relatively to the factor you have in mind?

Area Sampling

Very often when investigating something on farms or within nature, one is bound to the areas where the phenomenon to be investigated occur, and one is bound to areas where one is allowed to be (by the owner and/or the government). Further, for practical and economical reasons it is impossible to, for example, distribute 100 randomly selected 1 m^2 quadrates among all Woalita/Sodo wheat fields.

Thus, one begins with selecting the places where it at all is possible to be, and then the actual investigation is done there, by using random sampling locally. The first part, to select the area or areas to be at, is often not random but just opportunistic. However, area sampling is often the only possible way to at all perform on-farm studies. If the study shall include 100 1 m^2 quadrates in wheat fields, maybe you can use five fields (because of time and money). Hopefully, there are more fields than the number that you actually can use to select from, and in that case you select randomly among them. However, you may also have to use just the fields that you are allowed to. After this selection, you distribute 20 randomly placed 1 m^2 quadrates in each field. The fields in this example are the "areas" referred to in the name of the sampling type.

Sampling According to Need

Sometimes an experiment requires something special, as animals with a certain disease (to investigate the effect of a treatment) or plants of different specific sizes. In the case all possible individuals in an area can be identified, these individuals should be handled as an population, and sampled as above. However, there may be a need to look for usable individuals, and use all encountered. In that case, it is important to not be selective, but use all encountered without restrictions. In the case of need for different age classes (or other certain character) the researcher may regard it as more important to sample all individuals from one environment than to sample random among classes, and thus decide to search for one place with a proper natural mix of classes.

Entire-Population Sampling

Sometimes the entire population is sampled, especially when it is not very large. It may be to use an entirely wheat field, or all cows at a farm for an investigation. The sampling itself if of course very simple, and is a kind of area sampling (i.e. a population one happens to be allowed to use is used, and is the only population included). It is important to remember that such a study will not lead to knowledge of the entire site (one field in Wolaita/Sodo cannot be regarded as representative of the site Woalita/Sodo), but is still useful for getting knowledge of different specific treatments.

Experiments

Replicates

An important part of experimental studies is replicates (see "Replication" and Figure 5 above). The replication will determine whish extent of generalization that is possible from the results, and it is crucial for statistics - the more replicates, the higher is the possibility that you will detect a significant difference, even if it is small.

Very often, there is a limitation of how many measured items one can include in a study (depending on time, labour and equipment; which all to a high extent depend on funds). Thus, you may know from the beginning that you will be able to include at a maximum 100 samples of 10 mL milk each to analyse, or 200 dishes with 50 seeds each to test for germination, or 500 hens for egg production, or two plots of each 400 m^2 for a crop harvest study. From this knowledge, you have to calculate and decide for a balance between treatments and replicates.

If that study with the seeds is about investigation on getting knowledge of germination in different environments, you may first decide to have one treatment with light during daytimes and darkness during nighttimes (simulating seeds laying on soil) and one with continuous darkness (simulating seeds buried in soil); thus you have 100 dishes to each treatment (the dishes regarded as replicates, see "Binomial Items" below). Then you may regard it as important to investigate the response to different temperatures; and of course each included temperature should include both the light situations. If you decide to use five temperature levels, then you have now 20 dishes to each treatment (combination of light situation and temperature level), then you regard the extent of fluctuation between day and night as important, and include four different such extents. Now you have 5 dishes to each treatment. Thus, *the more details you include in the investigation, the fewer replicates per treatment will you have*, assuming there is a limitation in the total number of included items. Compare with Figure 5. As a rule of thumb: *use at least three replicates*; and whenever possible rather five to ten. Thus, take one more soil sample from each enclosure in Figure 5B if you like to replicate in the individual enclosures properly; you can also take only one sample from each, and add six enclosures to the study (keeping the present number of soil samples), and thus get more replicates regarding with/without threes, but with no possibility to determine how large the natural variation within an enclosure is.

Binomial Items

In the example above, the seeds under "Replicates" it was stated that there were 200 dishes with 50 seeds each to use in the germination study. In such cases, were the involved items can respond only in one of two ways (in this case either germinate or not germinate), it is possible to use statistics for binomial data to use every included item in these cases. However, it is very common to put a group of items together, and use the fraction of the two possible responses as the result. In such cases, it is necessary to not have too few in each group, because then the measured fraction will have low resolution; if you have two seeds, the result can be that both germinate, one germinate and one stay ungerminated, or both stay ungerminated, giving the possible results 100% or 50% or 0% germinated. If you use 100 in each group, the resolution is 1 percent unit (0, 1, 2, ... 98, 99 100% germinated), and if you have 200, the resolution is 0.5 percent units, and so on.

Control

Whatever experimental design that is used, it is important, to be sure that the result (what is measured or estimated) is really the result of the factor or factors investigated. The commonly recommended way to achieve this is to have a control. A control is a part of the experiments where the treatment is "nothing", that means, to have an experimental unit (properly replicated as all other included treatments) that is not affected by the factor or factors studied, but otherwise encounter exactly the same circumstances as the experimental units treated with the investigated factor(s).

If you are going to investigate the effect of two different substances, separately and in combination, on any living matter, you will get three treatments (compare with the calves in "Plan a Study", Introduction" above). In such a case, the control should be to handle the control units of the experiment in the same way as the treated, except to give the actual substances. When investigating the effect of an insecticide (let's assume it is sprayed on the plants), the control plants should also be sprayed, but not with a solution including the insecticide but with a solution including what there are in the insecticide solution (probably water and a detergent) in addition to the active substance. When investigating the effect of a medicine (let's assume it is given as injection) the animal being in the control should also be given injections in the same way as the ones treated with the medicine, but with a solution not including the medicine but everything else that there is in the solution in the injection (probably water and a detergent also in this case). The reason for this way to work is to make sure that it is *only* the effect of the substance of interest that is investigated. Otherwise, it may not be possible to draw conclusions of the reason(s) to the outcome of the experiment:

- If not spraying the control plants, and the ones sprayed with the insecticide grew less than the non-sprayed, how shall one know if the sprayed ones grew less because of the insecticide, or because of the spraying machine disturbing the roots' efficiency in nutrient uptake?
- If not giving the control animals injections, and the ones given medicine decreased egg production compared with the ones not given medicine, how shall one know if the ones treated with medicine decreased egg production because of the medicine, or because they were stressed by being pricked?

As the controls are described above, one will get knowledge about the effect of the substances in question. In both the cases, it may be needed to include different levels of controls. If wanting to know if the spraying machine disturbs root function, or if pricking hens decrease egg production, it is necessary to have additional controls (i.e. not use the spraying machine, not prick).

However, in a lot of cases, there is no possibility to have a control that represents "nothing"; one that is not is treated at all. Assume you like to investigate the effect both of two temperatures and of presence/absence of light on something. Then you have a factorial design with eight different treatments: Temp 1, Temp 2, Light, Darkness, Temp 1+Light, Temp 1+Darkness, Temp 2+Light, and Temp 2+Darkness. In this case, it is absolutely impossible to have a "nothing" control; there will always be some temperature present (zero degrees is not "absence of temperature" in any temperature scale; it is a temperature), and if there is not light, there is darkness (even though light can occur in different amounts).

Thus, it is necessary to be aware of what is studied and what the control is. If investigating the effect of increased (and/or decreased) temperature or light, then the normal temperature or light, respectively, should be the control. In other cases, there is no control, but a comparison of different treatments can be done. This means, the result should be expressed like: the difference between temperature 1 and temperature 2 was X (thus not claiming that the effect of temperature 2 was X). Within agriculture, it is common with investigations that not include a control in the strict meaning, but aim at investigating the effect between different treatments, like the differences between cows given different kinds of concentrate fodder, or plants given different kinds of fertilizer. There is little use to have a control that is "no fodder" or "no nutrients" (the organisms would just die), but it may be meaningful to have a control that include the fodder/nutrient used locally.

Completely Randomized Design

This is straightforward: sample the items randomly, and distribute them randomly to each treatment (including control, see above) included in the experiment. Treat all replicates in the same environment (except for the treatment studied, of course).

Usually, the distribution of replicates to the different treatments is even, for example if there are 10 cows for testing the effect on milk production of new concentrate fodder, there are 10 cows fed with a well-known concentrate and 10 cows getting only hay. However, the random design allows some unevenness; if one cow dies or escapes it is not a big problem; for example ANOVA can be used to analyze the result, without reducing the data more. In fact, as long there are two or more replicates left of every treatment at the end of the study, the result can be used (but of course the possibility to find differences that are statistically significant decrease with decreasing number of replicates).

The drawback is that "the same environment" for the different replicates may be difficult, or impossible, to achieve, especially within agricultural-related research.

Randomized Block Design

This design, also called "completely randomized block design" is very often used within agriculture-related research. It is useful when experiment has to be repeated in space or in time; i.e. when it is not possible to treat all replicates with their respectively treatment at one occasion within the same environment. In randomized block design, a number of blocks are randomly distributed over an area or over time. Each block has as many places as there are treatments, and the number of blocks is equal to the number of replicates of each treatment. Thus, there must be the same number of replicates to each treatment (Figure 9). Within each block, the different treatments are randomly allocated to one place each, with the restriction that each treatment shall occur once in each block. Thus, the average environment for treatments are supposed to be reasonable similar. If one treatment in one block is lost for some reason, the entire block, i.e. all the treatments there, has to be discarded from the results (i.e. reducing the number of replicates with one for all treatments).

The space case:
Often there is some gradient in nature, like more dry to more wet from one edge to the other on a field. This is just fine if you measure this factor and study the effect of it on something, but problematic is you use the field for studying something else. If the replicates of different treatments are distributed randomly, there is a risk that the gradient influences the result. In the randomized design in Figure 9, treatment B is absent from the wettest part, and treatment C is absent from the driest. Thus, a difference between the results of the treatments A, B and C may be biased because the treatments were not given the same circumstances: if for example investigating the effect of two different amounts (A and B) of a new fertilizer (using the recommended amount of an established fertilizer as control, C), the actual result may be more an effect of the dry-wet gradient than of the application of fertilizers.

The time case:
Often there are practical circumstances that restrict how many items that can be treated at once. There may be only personnel and/or space allowing five cows at a moment to be handled. There is a risk that animals will be treated different at different occasions during

the study period (the people giving the treatment may be tired and irritated toward the end of the day, for example, and may influence the behaviour of the animals negatively) and such differences should be equally distributed among the included treatments. Thus, the cows can be parted in blocks (if assuming there are three treatments, there should be three cows in each block, compare Figure 1) that can be handled as one block at a moment. If there are additional places available, they are not used if it is not possible to treat two (or more) blocks at each time (if six cows can be treated at each moment, two block with three cows can be treated simultaneously, but if five cows can be treated at each moment, only one block with three cows can be treated each time). As in the space case, the number of blocks must be equal to the number of replicates required.

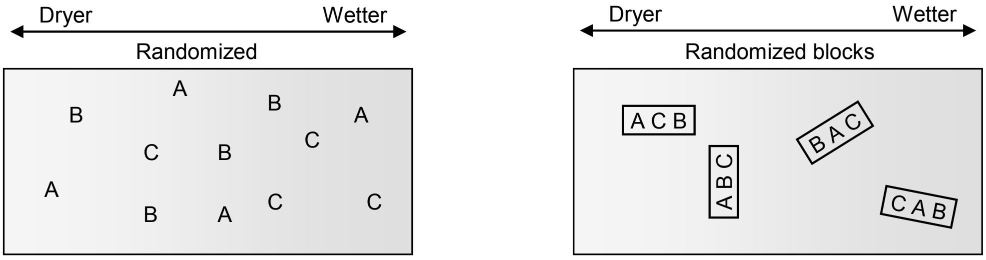

Figure 9. Completely randomized and randomized block designs when three different treatment (A, B, C), including one as control, with four replicates, are laid out on a field with a soil humidity gradient.

Latin Square Design

This is a kind of block design suitable when there are, or is suspected to be, two gradients, in different directions, that may interfere with the study. One of the gradients may be time (for example if space is limited and the space used has an environmental gradient). In this design, n treatments are allocated into one n×n square, and the number of replicates can only be multiples of n (i.e. n, 2n, 3n...). In each square, each treatment occurs exactly once in each row and each column (Figure 10). Thus, there must be place for n×n treatments as once at each place used. If one single replicate is lost within one square, all the results from the entire square have to be discarded.

B	A	C
A	C	B
C	B	A

Figure 10. Principal layout of the Latin square experimental design. In this example, there are three treatments: A, B, C. Each treatment occurs exactly once in each row and in each column. If having one square, the number of replicates = the number of treatments. If adding one square, the number of replicates would become 2 × the number of treatments.

Other Block Designs

In reality within agriculture, blocks used are often not entirely random but are selected based on occurring conditions, like rows/areas that are already present in a plant cultivation or including animals belonging to different small-scale farmers. In these situations, the rows/areas with plants are commonly parted systematically in blocks (each existing row/area is parted in a fixed number of blocks, or the entire row/area is considered one block). In the case with the farmer, the animals from each farmer may be considered one block. In cases like these, the included treatments should still be allocated randomly to the different experimental units within each block.

Combinations of Treatments

As soon as one wants to investigate the effect of the two or more independent factors, and want to know both the effect of each factor and the combined effect of the factors, the design becomes factorial. Sometimes this is called "factorial design", but this is a bit misleading, because the different experimental designs above can be used, and there is no specific way to design these kinds of experiment, other than the fact that they are factorial (i.e. including all possible combinations of factors to be investigated).

Assume you will investigate the effect of two different substances on any living matter (for example one fertilizer [A] and one insecticide [B] on barley growth, or one vitamin [A] and one medicine [B] on poultry egg productivity). You will investigate the effect of these factors separately, and also the effect when they are combined. This is result in a design that is factorial; you get four different treatments:

1) Control (neither factor [A], nor factor [B] present, see above)
2) Only factor [A]
3) Only factor [B]
4) Both factor [A] and factor [B]

If you include different amounts/concentrations of factor [A] and/or factor [B], the number of treatments will increase exponentially (by including all possible combinations); assume two amounts (a and b) of each:

1) Control (neither factor [A], nor factor [B] present, see above)
2) Only factor [A], amount "a"
3) Only factor [A], amount "b"
4) Only factor [B], amount "a"
5) Only factor [B], amount "b"
6) Factor [A], amount "a" and factor [B], amount "a"
7) Factor [A], amount "a" and factor [B], amount "b"
8) Factor [A], amount "b" and factor [B], amount "a"
9) Factor [A], amount "b" and factor [B], amount "b"

Of course the treatments in any factorial study should be replicated, so the design tend to be large; in the last example above, a block design will require that it is possible to have as many blocks as there should be replicates, and each block must include the nine different treatments.

The drawback with factorial studies is that they are large (which tend to mean expensive, time-consuming and space-requiring), the benefit is that a lot of knowledge is achieved in the same experiment, and especially that possible combination effects of the included factors can be identified. This is important, because very often the effect of two factors together is not equal to the effect of the sum of the effect of each of them when applied separately. If factor [A] in concentration "b" gives a result that is +10 when applied separately, and factor [B] in concentration "b" gives a result that is −2 when applied separately, the result when applying [A] "b" and [B] "b" simultaneously may not be +8, but may be +5, +9, +12, or something else. Such a result (that not is just the sum of result from separate treatments with respectively factor) occurs if the factors interact with each other in some way (not only adding to each other). Interactions are only possible to detect if the experiment involve both the effect of the factors separately and the effect of them combined.

There is no theoretical upper limit for how may factor or how many levels of each factor that can be included; it is just to include all combinations of factors (if there are three factors, one gets basically A, B, C, A+B, A+C, B+C, A+B+C, control [eight treatments if having one level of each]; if there are four factors: A, B, C, D, A+B, A+C, A+D, B+C, B+D, C+D, A+B+C, A+B+D, A+C+D, B+C+D, A+B+C+D, control [sixteen treatments if having one level of each]) and levels of each factor. However, practical circumstances tend to set the limit for how may different treatments that can be included; thus, in reality, there is usually a compromise between how many factors and how many levels of each that are included in a study.

Non-Experimental Studies

Surveys

It is often necessary to get information about what people do or what people think to be able to perform experiments within agriculture that are meaningful. A common way to get such knowledge is to distribute questionnaires or doing interviews. When doing this, the sampling design is often stratified sampling (according to gender and/or age, for example, depending on the subject of question). Other ways are participatory attempts or focus groups: the researcher discuss with a smaller number of people. *Always* when asking questions to people, be careful to think of the importance of every included question before beginning. It is too common that the researcher add a number of questions "that may be nice to know" the answer to, but are not crucial for the reason for doing the study. It is important the researcher respect the people concerned, that he or she do not see the respondents time as a free resource. In addition to this, it is known that the quality in the answers decrease if there are too much question - people simple get bored by answering questions and just answer quickly (without thinking carefully) to get rid of the task, or quit answering at all after a number of questions.

Practical Studies

To know what is occurring (which and how much of weed species, which insect pests, how much rodents...) in addition to the target species for agriculture, inventories are done. Samplings of places to invest are sampled by random, stratified, systematic, or area sampling design. Within the selected places, inventories are done according to the precision needed (estimate the fraction of the area covered by a certain weed species or carefully count all weed individuals and not the species of each, are two extremes). The result of inventories may give a lot of information, and may lead to new research attempts, in which the researcher investigates correlation between factors in more detail. For example, if investigating the amount of rodents in different farms, the researcher may observe that there are more rodents if there are apple trees in the surrounding, and decide to study whether this is a true correlation or if it just was randomly occurring on the investigated sites. Other attempts similar to inventories regarding occurrence of species or other groups, is inventories regarding different characters of a species, like investigating avocado qualities occurring in Ethiopia, in order to find parental material to use for breeding programs.

There are non-experimental studies that investigate the effect of presence/absence of a factor, or the amount of a factor, without being experimental (i.e. without manipulating these independent factors). In these cases, the amount of the independent factor to be studied is measured, and the response of the dependent variable of interest is measured. This is a method often used within agriculture; as inventorying the soil quality on a large numbers of fields, and then measure the wheat gain on each. It is important to not draw far-reaching conclusions from too small samples with this method: if there are two fields included (one sandy and one clayey), and there is more gain on the sandy, there are no evidence whatsoever for drawing the conclusion that the gain is because of the soil type. As a rule of thumb, at least ten sites (not just close to each other) should be included to be able to regard a gain (or any result) being dependent on the investigated gradient.

There are also studies that mix experimental and non-experimental attempts. If having a gradient (as in Figure 9) one can decide to use it. In the study design in Figure 11, the effect of the gradient is (not experimentally) investigated together with an (experimental) investigation of the four treatments A, B, C and D that are in (not completely random) blocks.

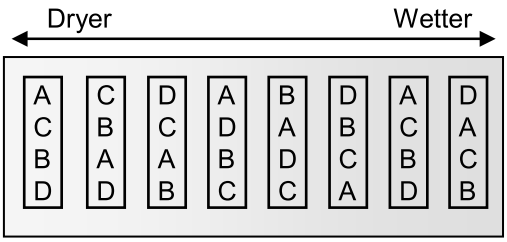

Figure 11. Example of a study design that include both experimental and non-experimental parts.

To Measure

Regardless what you study and how you do it, you will most probably measure or estimate something. It is important that you include in your plan how this shall be done. Do not think something like "and then I measure milk quality". You need to decide what you should measure to evaluate the milk quality; fat content? Vitamin content? If yes, which vitamins? Will you focus on the harvest or on the yield if you study crops? Per area unit, or per labour hour, or both? When you have decided what to measure, you need to think carefully about if this is possible, and if the required equipment is available for you (or if it can be borrowed or bought). If you will work with estimations, decide how this will be done. It may be with discrete categories, like "little, intermediate, much problem with animal health" or it can be on a continuous scale "estimation of weed/crop fraction from 0-100% weed". In the latter case, we tend to make categories anyway; it is impossible to properly determine if it is 35% or 40% weed, and we have a general tendency to not guess on 36.28, but rather on 35 or 40. Thus, it is better that from the beginning decide how large steps that shall be used; to increase the possibility that the estimation will be done in a consequent way. Regardless of how you will measure, *develop a protocol in which you easily can fill in each unique measured unit separately*.

Proposal

Introduction

When you have decided what you are going to study and how that study should be done, it is often time to write a research proposal. That is a document that is submitted to the organisation that is going to decide whether or not you will get the resources for actually conducting your study. It may be you employer at the research station, your faculty at a university, or a national or international institute for research grants. If your planned study will be a part of your education or is a task that your employer ask you to do, you will not have to write a full proposal, but it is common that you have to write a shorter document, which aim is that you shall show that you have a clear picture of what to do, that you know why you do it, that you are aware of which resources you need, and that you have a realistic apprehension of the expected outcome.

Most students and beginning researchers do not fully understand what a research proposal means, nor do they understand its importance. To put it directly, one's research is only as good as one's proposal. An ill-conceived proposal ends the project. A high quality proposal, on the other hand, not only promises success for the project, but also impresses the reviewers.

A research proposal is intended to convince others that you have a worthwhile research project and that you have the competence and the work-plan to complete it. Generally, a research proposal should contain all the key elements involved in the research process and include sufficient information for the readers to evaluate the proposed study. Regardless of your research area and the methodology you choose, all research proposals must address the following questions: What you plan to accomplish? Why you want to do it? and How you are going to do it? The proposal should have sufficient information to convince your readers that you have an important research idea, that you have a good grasp of the relevant literature and the major issues, and that your methodology is sound.

The quality of your research proposal depends not only on the quality of your proposed project, but also on the quality of your proposal writing. A good research project may run the risk of rejection simply because the proposal is poorly written. Therefore, it pays if your writing is logical, clear and convincing. The problem of interest has to be defined and the procedure for solving it developed along with specifying the appropriate objectives and activities to be undertaken. In this regard, a proposal then is a plan employed to solve a given problem. It is a strategy used by researcher in search of a solution to given problem.

Conducting research entails use of resources, which are in general not abundant. This means that many researches will compete for limited resources. These limited resources are appropriated by governments, private groups or are obtained from donor agencies. Whichever source is tapped, the applicant will have to meet the requirements of the funding agencies to obtain the necessary funds. This is generally done by writing or preparing a proposal following accepted standards. Funding agencies review proposals submitted by researchers and release funds only if the proposals meet their standards of practice. In this regard, a proposal is a communication instrument used to communicate to reviewers of proposals, the intention of the researcher. As such it is a promotional document intended to convince the reviewers of the proposal about the capability of the researcher in brining in about an impact on the target group, or the beneficiaries, or broadening the horizon of scientific knowledge.

There are many steps that the researcher must follow to accomplish the objectives of interest. Those steps, which lead to the final results, should be clearly spelt out in a working document. A proposal is then a plan, which contains steps of what must be done in the areas of problem identification, specification of methods of data collection and analysis, interpretation of results and reporting.

Quality

The research proposal should not be too long, nor should it be crowded with too many technical terms, or scientific jargons. If it is any, or both, of these, the reviewer may lose sight of what the developer of the proposal intends to do. This would have a negative effect on the decision of the reviewers. Hence, clarity, simplicity and carefulness should be the principle of the researcher when preparing a proposal. Brief and clearly written proposals are more impressive than voluminous ones, which are full of descriptive and sloppy phrases.

The writer of a proposal should include as much detail as is necessary to convince the reviewers about the significance of the problem, soundness of the methodology to be adopted and reasonableness of the financial outlay. No assumptions should be left as self-evident. Those who read or review the proposal should not be expected to know what the researcher intends unless he explicitly shows it in his proposal. That is, proposal reviewers should not be expected to read the mind of the researcher.

A proposal has to be technically sound, and financially and economically feasible. By technical soundness it is meant that the problem can be solved with the proposed method. It should not be one, which is beyond the technical capability of the researcher. The proposed budget must be reasonable. It must neither be too ambitious to result in wastage of resources, not too low to affect the proposed program.

The researcher should also give a serious thought to the style and language of the proposal. Commonly accepted standards of proposal preparation should be employed. Since the document is generally submitted for financing or approval, the author will not be at liberty to adopt any style. Adherence to established norms should not be overlooked. It must also be prepared in such a way that grammatically correct sentences are used. The proposal must be edited for style and language. No matter how important it is in terms of soundness of methodology and financial feasibility, a proposal with grammatical errors would have unavoidable effect on the decisions made by reviewers.

Components

Overview

Research proposals may differ in style of presentation depending up on the financing agencies; however, all share some common features as regarding their contents. Usual main parts to include are: project title, project overview (or summary or abstract), introduction, literature review, objectives, material and methods, work plan, expected output, dissemination of results, personnel, curriculum vitae, budget, evaluation plan, and appendices.

Project Title

The title is the part that will be read much more times than any other part of the proposal. Thus, the title should be clear and unambiguous. The words you use in your title should clearly reflect the focus of your proposal. The most important words should come first, then the less important words. Try to remove words from your title that really are not necessary for understanding. Example: Title #1 has too many words. Title #2 is just as clear but with fewer words.

Title #1 - The Systematic Development of a Local Initiative to Create a Learning Centre for Community Education

Title #2 - Development of a Local Learning Centre for Community Education

Try and use only a single sentence for your title. If the sentence is getting too long try removing some words. When all else fails try using a two-part title separated by a colon (use only as a last resort!). Do not attempt to use the title as an abstract of your entire proposal. A good title:
- Contain as few words as possible
- Describe the contents of the paper accurately
- Describe the subject as specifically as possible
- Easy to understand
- Does not promise more than what is in the paper
- Does not contain waste words such as Study on the effect of ...., Assessment of the impact of........, Investigation on the influence of.............

Overview

The project overview (sometimes called summary or abstract) is mainly designed for the busy executive probably only has enough time to read a short text and not the entire proposal. Be specific and concise. Do not go into detail on aspects of your proposal that are further clarified at a later point in your proposal. The overview should "paint a picture" of your proposal in the mind of the reader. It should establish the framework so that the rest of the proposal has a frame of reference. Use the overview to begin to show your knowledge of the organization from which you are requesting funds. Key concerns of the funding organization can be briefly identified in relation to your proposed project.

If you will be collaborating with other organizations make sure some of their interests are also highlighted in the overview. This can assist in strengthening the collaboration by recognizing them at the very beginning of your proposal.

The best time to prepare the overview is after you have completed the entire proposal (and you understand all aspects of your proposal very well). Let the overview be your last piece of writing and then insert it at the beginning of your proposal. Try to keep in mind that someone will be reviewing your proposal and you would like to have this person be very positive about what you have written. The overview will probably form a strong impression in the mind of the reviewer. Thus, work on your overview so that you can avoid giving this person the opportunity to say things like:

- Not an original idea
- Rationale is weak
- Writing is vague
- Uncertain outcomes
- Does not have relevant experience
- Problem is not important
- Proposal is unfocused
- Project is too large.

Introduction

The main purpose of the introduction is to provide the necessary background or context for your research problem. How to frame the research problem is perhaps the biggest problem in proposal writing. If the research problem is framed in the context of a general, confusing literature review, then the research question may appear trivial and uninteresting. However, if the same question is placed in the context of a very focused and current research area, its significance will become evident.

Unfortunately, there are no hard and fast rules on how to frame your research question just as there is no prescription on how to write an interesting and informative opening paragraph. A lot depends on your creativity, your ability to think clearly and the depth of your understanding of problem areas. If you have carefully have thought through what to study, you will find this part easier than if you have to figure out a reason for what you like to do. It may be fruitful to place your research question in the context of either a current "hot" area, or an older area that remains viable, but do not be unrealistic; do not mention genetics if you suggest an investigation of grazing pressure in Ethiopia. You should provide a brief but appropriate historical backdrop and explain in which context your proposed research question occupies the central stage. Finally, identify "key players" and refer to the most relevant and representative publications.

The introduction typically begins with a general statement of the problem area, with a focus on a specific research problem, to be followed by the rational or justification for the proposed study. The introduction generally covers the following elements:

i. State what the underlying problem is, what the reason to work with this is, which main problem are you trying to contribute to a solution to?
ii. Provide the context and set the stage for your research question, your identified sub-problem that you actually will solve if you succeed. It should be described in such a way as to show its necessity and importance.
iii. Present the rationale of your proposed study and clearly indicate why it is worth doing.
iv. Briefly describe the major issues and sub-problems to be addressed by your research.
v. Identify the key independent and dependent variables of your experiment. Alternatively, specify the phenomenon you want to study.
vi. State your hypothesis or scientific question (see "Hypothesis or Question" and "Formulate Hypothesis or Question" above)
vii. Set the delimitation or boundaries of your proposed research in order to provide a clear focus.
viii. Provide definitions of key concepts. (This is optional.)

The theoretical background should cover the importance or significance of the study, its rationale or justification. In order to generate this information questions such as what is known, what the current state of affairs regarding the issue of interest is, the possible benefits of the study, the likely beneficiaries or persons to be interested in the outcome, relevance of the study in contributing towards the overall development of the country, should be addressed.

A statement should be made that will justify resource expenditures, both financial and human, for the research. A typical justification would include a brief introduction, a general statement concerning the historical basis for this research, a statement of its feasibility, and what impact the information generated by the research will have say on, related larger fields of interest, as forest science, forest practices, the farmers in particular and the country in general

The background statement must be short, exact and must be devoid of technical details and confusing arguments. For quantitative research, it should include the major variables or concepts that constitute the study and the hypothesis to be tested. For qualitative studies, the background section should spell out the initial feelings that inspired the investigation.

If suitable justification cannot be written then it is doubtful that the project should be approved. Hence, the preparation of a research proposal a very important quality control of a research project.

You should cite previous projects and studies that are similar to what you are proposing. Show the funding agency that you know what you are proposing because you are familiar with what has preceded you. Position your project in relation to other efforts and show how your project:

- will extend the work that has been previously done
- will avoid the mistakes and/or errors that have been previously made,
- will serve to develop stronger collaboration between existing initiatives, or
- is unique since it does not follow the same path as previously followed.
- use the statement of the problem to show that your proposed project is definitely needed and should be funded.

It is essential to include a well documented statement of the need/problem that is the basis for your project. What are the pressing problems that you want to address? How do you know these problems are important? What other sources/programs similarly support these needs as major needs?

Check to see that the potential funding agency is committed to the same needs/problems that your proposal addresses. Clearly indicate how the problems that will be addressed in your project will help the potential funding agency in fulfilling their own goals and objectives. As you write, keep the funding agency in your mind as a "cooperating partner" committed to the same concerns that you are. Is there a special reason why you and/or your organization are uniquely suited to conduct the project? (Geographic location, language expertise, prior involvements in this area, close relationship to the project clientele, etc.) It can really help gain funding support for your project if you have already taken some small steps to begin your project. An excellent small step that can occur prior to requesting funding is a need assessment that you conduct (survey, interviews, focus groups, etc.). Write up your need assessment as a short report, cite the report in your proposal, and include a copy with the proposal.

Review of Literature

Sometimes the literature review is incorporated into the introduction section. However, it is common that the instructions to the proposal require a separate section, which allows a more thorough review of the literature. If there is no specific guidelines for how to write the proposal for your target organization, it may still be good to keep an extensive literature review separately, to keep the actual project description focused.

The literature review serves several important functions:
i. Ensures that you are not "reinventing the wheel".
ii. Gives credits to those who have laid the groundwork for your research.
iii. Demonstrates your knowledge of the research problem.
iv. Demonstrates your understanding of the theoretical and research issues related to your research question.
v. Shows your ability to critically evaluate relevant literature information.
vi. Indicates your ability to integrate and synthesize the existing literature.
vii. Provides new theoretical insights or develops a new model as the conceptual framework for your research.
viii. Convinces your reader that your proposed research will make a significant and substantial contribution to the literature (i.e., resolving an important theoretical issue or filling a major gap in the literature).

Common errors and problems in literature reviews:
- Lacking organization and structure
- Lacking focus, unity and coherence
- Being repetitive and wordy
- Failing to cite influential papers
- Failing to keep up with recent developments
- Failing to critically evaluate cited papers
- Citing irrelevant or trivial references
- Depending too much on secondary and tertiary sources (not original research)

There are different ways to organize your literature review, it there are instruction, follow them! Make use of subheadings to bring order and coherence to your review. For example, having established the importance of your research area and its current state of development, you may devote several subsections on related issues as: theoretical models, measuring instruments, cross-cultural and gender differences. It is helpful to keep in mind that you are telling a story to an audience. , do not bore the readers.

There are three schools of thought as regards literature review. The first group contends that the review should show that the researcher is an expert in his area of endeavour by demonstrating mastery of relevant literature. The second group advocates that the review should function simply to identify relevant previous work to find out where there are gaps of knowledge, which call for research intervention. The third group, though less vocal than the previous two, believes that there is no need to spend time and energy in reviewing the work of others unless it is meant to sharpen ones method or approach to a problem.

Whatever school of thought is hold, there is no denying the fact that there is a need for some literature review. Depending upon the nature of the research, this will be the first major activity of the research projects. Not all projects will require a systematic literature search. For example, much evaluation research is carried out not to advance knowledge but to determine the effect of a certain program such as a new training method. In such a case, background reading on relevant approaches and similar research is all that is normally required, just to check on methods and effects of similar training. A project aimed at testing a new hypothesis of say, the influence of economic conditions on managerial effectiveness, will need to be grounded in the findings and context of other research.

Although most of the time spent searching the literate will occur near the beginning of the project, time should regularly be devoted to it until the very end. This will enable to draw upon significant current other research. In many cases, a thorough background reading is important in order to get a good grip of the situation and justify the research.

Many researchers find it difficult to resist the urge to rush out and start measuring things, designing questionnaires or interviewing people. If such temptation is not overcome, serious problems might occur later on. If time is not spent on reading some of the key, relevant literature, important insights available from other research, guidance on the best use of particular methods, drawbacks that should be avoided, concepts that have special or relevance.

A thorough literature search is not always needed at early stages. However, researchers must be aware of the major research work that has been done in and around their own areas of interest, if only to avoid repeating what has already been done.

In the case of quantitative research, the review may be useful to identify variables and their relationships so as to formulate the right hypothesis to be tested. For qualitative research, the review should serve a more restrictive purpose. It should enable the researcher to be enlightened in fields, which are closely related to his field of research, and also to be theoretically sensitive. That is, a result of the review, the researcher should develop an intellectual power of insight, ability to understand and give meaning to data and interpret results. In this case, the review is expected to broaden the researcher's horizon of knowledge, which would enable him to undertake research and obtain meaningful results.

It is not uncommon for beginning researchers to write pages after pages of literature review just to show that they are well read and have sufficient background to carry out the proposed research. Confusing the review with presentation of who says what and when paragraph after paragraph, or pages after pages, would only bore the reviewers of the proposal itself. For this reason, literature review should provide only relevant information to proposal reviewers, which are enough to convince them that the researcher is sufficiently knowledgeable and capable of undertaking the proposed research to its logical conclusion.

The section should be concerned with literature that is specific to the topic of the research proposal. Only pertinent information should be included in the review. It should be complete enough that the reader can be convinced that the research proposal being presented is building up on a sound information base, and is going to contribute something new to specific field of science.

Any relevant local information obtained from formal literature and personal communications should be included as long as – the researcher feels that it would have a positive contribution towards the overall development of the proposal.

It is very important that the researcher refer all citations in the reference section. Otherwise, if he uses somebody's work without acknowledgment, he would be accused for plagiarism or intellectual piracy. Moreover, any person who wants to read and know more about the quoted idea can do so if the source is properly indicated.

Planning the literature search is important. One should not go into it haphazardly. It will pay to work back through past issues of relevant journals and also to look out for major review articles. They can save a lot of time and effort. If one is recent, only a small amount of updating will be required. Notes should be made of the material read, keeping an accurate record of the references.

Objectives

This shall be a brief but convincing statement why it is important for the organization or individual to undertake the research project, followed by a clear precise statement of the ambitions of the project in such a way as to reveal to the reader the exact boundaries.

The statement of objectives specifies exactly what the researcher intends to do. In actuality, it is the desired end result of the proposed research. It must clearly show that the problem under consideration is researchable and that the objectives themselves are attainable. They must further specify clearly the research question in terms of the expected output.

It is important to classify research objectives. It quite often happens that those who carry out the research may not necessarily be the same people who set the initial research objectives. It is also frequently the case that, even where the staff involved did set the objectives, the passage of time will have rendered them less clear. In either case, it is important to review and classify the objectives. The staff should know what they are trying to achieve. They should check once more whether the objective could be met in practice. The objectives may be too broad or too narrow for the intended purpose. Revisiting the objectives of the project before the research starts may well prevent frustration, anger and depression at a later stage.

A statement of a research objective or purpose generally takes the form “the purpose of this research is to identify, find out, describe, explain, etc.

Two types of objectives can be identified. The first one is general objectives and the second specific objectives. The general objective specifies the overall aim of the project while specific objectives list the detailed aim of the project. Specific objectives can be considered as subdivisions of the general objectives. For example the general objective of the research can be states as “Reduction of the hardships of rural women in Ethiopia". The specific objectives of the research problem can be listed as:

- Provision of improved farm implements to woman farmers.
- Provision of portable water for rural communities
- Establishment of village wood lots
- Establishment of flour mills at appropriate location,

It is common to confuse goals and objectives. Goals are much broader than objectives and are not researchable within the confines of the research plan. An example of research goal can be "The Economic Development of Wolaita Zone". When we are talking of economic development we are talking about the overall improvement in health, education, agriculture, industry, communication, etc. Theoretically it is possible to design a research project, which could encompass all these aspects, but such a plan would be unmanageable to carryout to its logical end.

Under these issues such as improving agricultural production, reduction of death rate, increasing communication networks can be objectives and they are researchable within a given time frame.

Goals are the large statements of what you hope to accomplish but usually aren't measurable. They create the setting for what you are proposing. Objectives are operational, tell specific things you will be accomplishing in your project, and are measurable. Your objectives will form the basis for the activities of your project and will also serve as the basis for the evaluation of your project.

Try to insure that there is considerable overlap between the goals and objectives for your proposal and the goals and objectives of the funding organization. If there is not a strong overlap of goals and objectives then it might be best to identify a different funding organization.

Present measurable objectives for your project. If you are dealing with "things" it is easier for them to be measured than if you are dealing with abstract ideas. Your proposal is easier for a prospective funding organization to understand (and the outcomes are much more clear) if you describe your objectives in measurable ways.

Materials and Methods

This is a relatively detailed project description, on what activities the study will undertake and how these activities will accomplish the objectives. Furthermore, it allows a detailed summary of how these activities will flow from one event to another and how they are interrelated. It shall answer how, when, why, where, and who of the activities of the project. How refers to the implementation of activities that will take place throughout the entire project. When is in reference to the time frame of when these activities will take place. Why is the justification of the chosen method to conduct the activities? Where is the actual location of the activities? It may be useful to mention the institutions that are interested in conducting the study.

Purpose of Materials and methods:
- To describe project activities
- How objectives will be accomplished
- Describe the sequences, flow, and interrelationship of activities

The materials and methods section of a proposal can consist of sub-sections on descriptions of experimental site or arena, experimental design and management, sampling and data collection, instrumentation and data analysis. The site (field, laboratory, greenhouse, district, zone, catchments, etc.,) should be properly described. Similarly the experimental materials (e.g., varieties, fungicides, soil types, and animals), equipment and tools should be described and indicated as how it will be used.

In order for the research project to be successful, one needs to realize that there are limits, both physically and ethically, that needs to be considered. The first limit is the amount of resource that is available. The project must also consider ethical issues in research. Will this project lead to harming the natural surroundings of the experimental area or is a group of people who needs this service being excluded.
Methodological limits may be:
- Level of resources
- Ethical considerations
- Access and cooperation to other institutions
- Time available

Sampling, sample size, sampling unit, and sampling method should be described. It is essential to determine the generality (its occurrence or application in a population, representatives) of the findings. It is also important to know as much information about the sample in order to know if the sample will be significant. Significance depends on the preciseness of the estimate, the difference between the sample and the certainty required. You may be able to describe:
- Clues to the generality of the supposed findings
- Sample size - statistically significant

- Preciseness of estimates
- How different are the individuals

The guiding principle for writing the Method section is that it should contain sufficient information for the reader to determine whether methodology is sound. Some even argue that a good proposal should contain sufficient details for another qualified researcher to implement the study. You need to demonstrate your knowledge of alternative methods and make the case that your approach is the most appropriate and most valid way to address your research question.

Note that your research question may be best answered by qualitative research. Since there are no well-established and widely accepted standards in qualitative analysis, your method section needs to be more elaborate than what is required for traditional quantitative research. More importantly, the data collection process in qualitative research has a far greater impact on the results as compared to quantitative research. That is another reason for greater care in describing how you will collect and analyze your data. Enough detail should be given so that the reader can evaluate whether the methods are feasible, most practical, and will achieve the objectives of the proposal. The following parts should be included in the methodology section:

The study design should give description of the experiment or other kind or study you plan to perform. This section should illustrate the research project in such a way that no alternative explanation can result in the project. The study design section shall address which variables are manipulated or controlled and why and how this is done.

An error that commonly exists in experimental designs is lack of a control group (see "Control" above). Without a control group the researchers are not fully certain the final results are a result of some other outside source. The research expectancy effect is a source of error (contamination) by the researcher and/or field workers, who unintentionally influence the respondents (experimental units) answers.

Is it a questionnaire study or a laboratory experiment? What kind of design do you choose? It is desirable to make a clear statement of the type of experimental design to be used. Choice of design should be made before laying out the experiment. As much as possible a simple design in terms of layout and analysis should be adopted.

Describe all treatments included (for example spacing, irrigation frequency, nitrogen rates) and all variables (as temperature, precipitation, light intensity, grain yield, light intensity, weight gain of animals) that will be included. Tell how many experimental units you will use ion total, and how many replication to each treatment.

Describe the planned work procedure; who will take part? Which instrument and other equipment will you use? What activities are involved? How long does it take? Use of proper research methodology is of paramount importance for success of research undertaking. The research method used must lead to the fulfilment of the set objectives. It should allow the researcher to be able to collect the required data to be used to find a solution to the problem at hand. It is possible that more than one method could exist which would lead to a solution of specific problem. Hence, ease of application, economics, and the degree of certainty in meeting the objectives of the project should dictate the choice of a method.

There should be a very clear link between the methods you describe and the objectives you have defined. Be explicit in your writing and state exactly how the methods you have chosen will fulfil your project's objectives and help deal with the needs/problems on which your proposal is focused. The prospective funding agency will be looking at your methods to see what it is that you are proposing that will be new, unique or innovative. Make sure you clearly present the innovative aspects of your idea.

The researcher should describe how the data will be collected and how the selected variables are appropriate to the study. When collecting data it is essential that the methods of data collection are comparable across the field workers who are collecting the data.
In selecting variables a researcher is required to choose a variable that most reflects the problem under investigation. This process will force the researcher to choose between similar variables but it will also focus the researcher's understanding of the problem. However, sometimes the selection of appropriate variables is not easy because the definition of the problem that the research will address does not match a pre-existing measure. If this is the case, first describe the problem that does not have a variable to represent it. Then the researcher can either create a new instrument or justify the closest measurement. If the researcher creates a new instrument, he/she needs to reassure the reviewer that he/she can construct this new instrument even when other researchers were unable to accomplish this task.

Objectivity is essential when performing surveys through observation. In order to generate objectivity all field workers should be constantly tested as to their reaction in observing an action or materials until each field worker responds in the same fashion.

In preparing a questionnaire, a participatory approach with an enumerator should be incorporated into the design process. Once the questionnaire is complete, it should be pre-tested for logical flow and best method of asking questions. Then the enumerators need to be trained to collect data. After the questionnaire is prepared and the enumerators are trained, then data collection should begin. To ensure proper data collection techniques are being used, a supervisor should make surprise visits to the enumerators as well as require the enumerator to recall the questionnaire. After the data has been inputted into a database, it needs to be cleaned. Finally, to gain the most value from the data, it needs to be made available for other researchers and donors to use.
Questionnaire Preparation:

- Participatory approach
- Pre-test the questionnaire
- Train enumerators
- Supervision of data collection
- Data cleaning
- Data sharing

Describe possible wsys in which the data you suppose you will get can be analyzed. In selecting the method of analysis, be sure that the method is consistent with the objectives. Furthermore, the statistical assumptions of the method must fit the data. If they are not consistent, explain how these inconsistencies will be corrected among the data.

If a new statistical technique, computer program, or analytical tools is to be used in a study, the researcher needs to describe this new approach. The researcher also needs to illuminate how this product is better than the already existing resources. Since these items are new, the researcher should also provide suggestions of what one would do if there are difficulties in using the equipment. This paragraph will illustrate that amount of knowledge about the possible problems that can be anticipated.

Work Plan

A work plan is basically a time schedule of activities. A reviewer may first look at the work plan to gain an overview of the entire project so it is important to graphically interpret this plan so it easier for the reviewer to see the layout of the study. A flow chart or diagram can be used to illustrate the time schedule.

A workload analysis provides a week-by-week view of the demand for personnel; however, it does not compare personnel demands with available staff.

Expected Output

This section describes the end products of the research. The end product can be a concrete product, or a method that solves some problem, or an explanation of what the gain for the stakeholders and the society of getting the knowledge you will get is. Also, you will want to provide monthly and quarterly reports to the donor's in order to inform the donor's of the progress of the project and to constantly keep in touch with them.

In addition to describing the end products, the researcher will also want to discuss copyright policy in this section. This discussion is important because some agency that funds the project will claim the output. Also intellectual property rights associated with the outputs of the project should be made clear. Researchers should always reserve the rights to publish the results of the research.

Dissemination of Results

When discussing the end products, the researcher should also discuss how the results will be disseminated. Provide anticipated titles of journal articles, monographs, conferences and workshop presentations along with expected target dates. In addition to informing the sponsor how you plan to disseminate the results, it is important to explain why it is important to disseminate the results and how you will reach a variety of audiences. It is also essential to consider the impact that these results will have on the general public and how these results will be used.

Personnel

It is very important to include a section on the personnel who will be involved in the project, if any. This section should also describe the qualifications of each key staff members and one-page curriculum vitae for each key staff member should be included in the appendix. Along with stating the qualification of the key staff members, the responsibilities that each member will be in charge of should be described. Finally, each individual's summary should detail how the researcher's expertise fits this particular project.

Staff members with minor roles should be mention along with their responsibilities, assignment, and relevant background. When describing the research teams assignments make sure they are clear and relevant to the objectives. Furthermore, only list names of people that have agreed to be on the research team. If your institution is collaborating with another institution it is helpful to have a letter of collaboration to put in the appendix.

Curriculum Vitae

The curriculum vitae are simple way to list your experience and expertise on the research topic. The curriculum vitae will list your educational background and professional experience along with any unique qualifications.

In addition to work experience, any relevant projects should be mentioned along with dates and activities. It is also useful to mention awards that you have received. If the project will take place in a different country it will be beneficial to mention any relevant international travel. The main purpose of the curriculum vitae is to focus on your research capabilities.

The purpose is to communicate your education and professional experiences and to highlight unique background and qualifications.

Budget

For the budget to be considered reasonable, you need to communicate the purpose of the facilities and equipment you need. This section allows you to elaborate on the generosity of your own institution in supporting this research. Furthermore, you should inform the donor of relevant laboratories, field sites, service facilities, equipment, computer facilities, library facilities, etc. that will be available for your use. In addition to mentioning your own institution's facilities, inform the donor of the in-kind resources of the collaborators.

A budget describes the monetary support that will be needed to accomplish the objectives of the research project. The budget should reflect the research plan; therefore, an entry in the budget that is not included in the activities should be eliminated from the budget. A budget also needs to be credible and realistic.

There are two types of costs: direct and indirect, Direct costs include personnel, subcontracts and services, materials and supplies, communications, reports and publication, travel, equipment rental and purchase.

Indirect cost is basically the overhead cost. It can include the cost of space, heat/air conditioning, institutional administration, accounting, library resources and basic communication service. The indirect cost is usually calculated as a percentage of the direct cost.

Whenever there is a research project, there will be delays in one area or another; therefore, you need to have a contingency plan for your budget. You cannot explicitly state a contingency allowance in your budget, but you can implicitly include a contingency allowance in the personnel cost. However, before adding additional funds to a category you need to find out if funds can be transferred from one category to another. Sometimes funds can be transferred from one category to another, but funds from the latter category cannot be transferred to the former category.

The key questions in budget are: Will the budget
- Provide sufficient resource to carry out the project?
- Include a narrative that justifies the major items of the budget?
- Be in the format required by the sponsor
- Provide enough detail that the reviewer can easily see the way the items were calculated?
- Show a clear relationship between the budget items and research activities?
- Include any attachment or appendices to justify unusual requests?
- Identify evaluation and dissemination costs?

Purpose of the budgete
- Statements of proposed support and expenditure
- What it should do (mirror research plan, credible, realistic)

Types of costs that may be inculded in a budget:

Direct costs:
- Personnel

- Subcontract and services
- Materials and supplies
- Communications
- Report and publications
- Travel
- Equipment rental and purchase

Indirect cost (overhead costs)

- Cost of space
- Heat/ air-conditioning
- Institutional administration
- Accounting
- Library
- Basic phone service/fax/email

Before you include "everything you want" in the budget, check carefully if there are any, and if there are - which, restrictions of what can at all be funded from the organisation you will send the proposal to. Maybe no salary att all will be covered, maybe no office over head costs, maybe none of the inderect costs listed above, or maybe no travelling costs, and so on.

Evaluation Plan

It is important to describe in your proposal exactly how you will decide whether or not your project has been successful, achieved its objectives (had tested the hypothesis, had answered the scientific question). The evaluation plan will tell the prospective funding agency how you will be going about showing them at the end of the project that their investment in you was a good one.

If you plan to use a survey or questionnaire to help in evaluating the success of your project you may want to include in the appendices a draft of what you are considering for the questionnaire/survey.

Your evaluation plan does not have to be elaborate but it is important to indicate to the prospective funding agency that you have not forgotten this important step. Try to include both a concern for formative evaluation/process evaluation (ways to gain feedback on the project while it is being conducted) and summative evaluation/product evaluation (ways to show that the project fulfilled that which was originally proposed). Another way of conceptualizing this is that formative evaluation/process evaluation is concerned with the activities of the project. On the other hand, summative evaluation/product evaluation is concerned with the stated objectives of the project. It is easy to create a summative evaluation/product evaluation plan if you have done a good job of clearly stating your project objectives or expected outcomes.

Make direct reference to your objectives in your evaluation plan. This creates a strong sense of integration/consistency within your proposal. The reader of your proposal will now be hearing the same message repeated in different sections of your proposal. Try creating two separate evaluation plans - one for formative evaluation and the other for summative evaluation.

A good evaluation plan should include some sense of concern for what goes on following the conclusion of the funding period. How will the initiatives that have been started under the project be sustained? Have new things occurred that will be continued in the future? How will other cooperating agencies assist in continuing the project after the conclusion of the funding period? These and other areas should be included in a viable evaluation plan.

Appendices

An appendix is used to attach relevant information that is not required but is pertinent to the study. The content of an appendix can include cooperation letter from administrators, sample items of new or unfamiliar tests and technical information on their validity, description of unfamiliar statistical or research procedures, sample of intended products, reprints of your articles, definition of terms, and subcontract data. Appendices should be devoted to those aspects of your project that are of secondary interest to the reader. Begin by assuming that the reader will only have a short time to read your proposal and it will only be the main body of your proposal (not the appendices). Then, assume that you have got the attention of the reader who would now like some additional information.

Here are some possible sections to include in the appendices:

- Dissemination Plan - An important aspect of your proposal will be the plan for disseminating information of/from the project to other audiences. Most funding agencies are interested in seeing how their financial support of your project will extend to other audiences. This may include newsletters, workshops, radio broadcasts, presentations, printed handouts, slide shows, training programs, etc. If you have an advisory group involved with your project they can be very helpful in disseminating project information to other audiences.

- Time Line - A clear indication of the time frame for the project and the times when each aspect of the project will be implemented. Try creating the time line as a graphic representation (not too many words). If done well, it will help demonstrate the feasibility of the project in a very visible way.

- Letters of Support - Funding agencies would like to know that others feel strongly enough about your project that they are willing to write a letter in support of the project. Talk through with the potential letter writers the sort of focus that you think will be important for their letter. (Try and draw on the reputation of the letter writing group.) Do not get pushed into writing the letters for the agencies - they will all sound alike and will probably defeat your purpose of using them. The letters must be substantive. If not, do not use them! Have the letters addressed directly to the funding agency. (Do not use a general "To Whom It May Concern" letter - it makes it appear that you are applying to many different potential funding agencies and are using the same letter for each. This may really be the case, so make sure you personalize each letter to the specific potential funding agency.)

- Cooperating Agency Descriptions - If you have referenced in your proposal different cooperating agencies that you will be working with, it is a good idea to provide a more detailed description of each of these agencies in the Appendices. Rather than include large descriptions of each cooperating agency, a single page that gives the name/address of the agency, names of key personnel, and brief descriptions of the major services provided is sufficient. Try and prepare each of these single page descriptions so they follow a similar outline/presentation of information.

- Evaluation Instrument - Include a draft copy of the actual evaluation instrument you plan to use (survey, questionnaire, interview guide, etc.). This will let your prospective funding agency know that you are serious about making evaluation an integral part of your project - and funding agencies like to hear this! Indicate DRAFT at the top of the instrument and then make it look as real as possible. Never say things like, "I think I may have a question that deals with...", or "Four or five questions will be included that examine the concern of...". If you will use an interview procedure or a focus group discussion, include a draft copy of the specific questions that will actually be used for the interview.

Why Proposals Fail?

Several studies have been performed to determine the most common reasons as to why proposals fail. The three components that rank the highest for proposal failure are in the materials and methods component, problem section, and personnel sections. The materials and methods component is the most common area for why proposal failed amongst the studies that were consulted. The three key problems that existed in this section are (1) insufficient, vague, or unclear description; (2) discrepancies between the objectives and methods; and (3) design flaws. The five areas that cause proposals to fail in the problem statement are: (1) limited significance, (2) local significance, (3) statements were diffuse or unclear (4) insufficiently limited studies, and (5) lack of theoretical base.

There are six areas that cause proposals to fail in the personnel area. They are: (1) lack of training or experience; (2) unfamiliarity with the literature or methods; (3) poor prior research record; (4) heavy alliance on inexperienced associates; (5) low investment of researchers' time; and (6) insufficient information on personnel and their duties.

The Logical Framework Approach

Introduction

The Logical Framework Approach (LFA) was described by its developers as "a set of interlocking concepts which must be used together in a dynamic fashion to permit the elaboration of a well-designed objectively described and evaluable project". What the LFA seeks to do is provide a structure, which will allow project planners and evaluators to specify the components of their activities and identify the logical linkages between a set of means and a set of ends. Thus, the LFA is an aid to logical thinking and a means by which a project may be structured and described for analytical purposes.

The term Logical Framework Approach is used both to denominate the log frame matrix and different extended approaches, which also includes analysis of context, problems, strategies and organizational issues. This document is limited to discussing the matrix, but many good extended approaches exist and it is advisable to be familiar with different ones in order to be able to select a process that suits the requirements of the individual project. No matter which process you choose, the outcome of the process should be the information required for a well-documented project proposal, and writing this is the focus of this document. Before we move on to the project document we need to look at the log frame matrix.

The structure of the Log frame is deceptively simple: It consists of a 4 x 4 matrix in which the rows represent the levels of project objectives, including the means required to achieve them (the vertical logic), and the columns indicate how the achievement of these objectives can be verified (the horizontal logic). Table 3 represents a slightly modified version of the original log frame.

The first column, the narrative summary, records the hierarchy of objectives. At the top is the Goal, the ultimate objective of the program to which the specific project will contribute. The Goal may not necessarily be reached until well after the end of project implementation. Indeed, successful completion of the project may be a necessary, but not sufficient, condition for attaining the Goal.

The next step down the hierarchy, Purpose, presents more precise and immediate objectives; recording what the project is expected to achieve upon, or shortly after, its completion. The third step, Outputs, registers the specific results arising during the project

Table 3. A slightly modified version of the original log frame.

		Narrative summary	Objective and verifiable indicators	Means of verification	Assumptions
Development hypothesis	If the project purpose is achieved then a contribution is made towards the overall goal	Goal (Development Objective) What are the wider objectives or problems, which the project will help to solve?	What are the quantitative ways of measuring or qualitative ways of judging, whether the goal has been achieved?	What sources of information exist or can be provided cost-effectively?	*For sustaining objectives in the long term* Which external factors will have to occur in order to assure sustained continuity of the achieved contribution to the goal in the longer term?
		Project purpose (Immediate objective) What are the intended immediate effects on the project area or larger group? What are the expected benefits and to whom will they go?	What are the quantitative measures or qualitative evidence, by which achievement and distribution of effects and benefits will be judged?	What sources of information exist or can be provided cost-effectively? Does provision for collection need to be made under results – activities?	*For achieving the overall goal* Which external factors will have to occur for the anticipated contribution to the overall goal to actually take place?
Implementation hypothesis	If these results are obtained then the project purpose is achieved	*Results (outputs)* What outputs (kind, quantity and by when) are to be produced by the project in order to achieve the project purpose?	What are the quantitative measures or qualitative evidence, by which achievement of the results will be judged?	What are the sources of information?	*For achieving the project purpose* Which important assumptions in relation to the results 1 – X that cannot be influenced by the project or have been consciously defined as external factors, must occur in order for the project purpose to be achieved?
	If these activities are carried out then the results are obtained	**Activities** Which activities will the project have to tackle and implement in order for the results 1 - X to be obtained?	**Inputs** (resources) What materials/equipment or services are to be provided?	**Budget** What is the cost of the inputs over what period, and who is to pay?	***For achieving the results*** Which important assumptions in relation to the activities 1 – X that cannot be influenced by the project or have been consciously defined as external factors, must occur in order for the results to be obtained?

life from successful implementation. Finally, the Activities to be undertaken in order to achieve each output, and next to them the Inputs describe the resources needed to carry out the activities. The hierarchy of objectives imagines that if the means are provided, then the ends will be achieved. Hence, working back up the hierarchy, there are a series of implied causal links, thus: if inputs and activities then outputs, if outputs, then purpose; if purpose, then goal. The links have been described as 'hypotheses, and the two upper links are called development hypotheses, and the lower one is the implementation hypothesis.

These linkages, however, only function if sets of conditions apply. These are made explicit in the fourth column, 'Assumptions', They include both premises about how other actors, beyond the control of project managers or owners, are expected to behave, as well as risks in the project environment, which, if they materialized, would render the logic invalid and undermine the project. The 'if then' links in the vertical logic are thus expanded to become, 'if, and assuming that, then' hypotheses. For example if the activities for an output are carried out, and the assumptions related to it hold, then the result is achieved. In this way the logic of the planned project is made explicit.

The other two columns of the matrix establish the basis for monitoring and evaluation. In the column marked 'objectively and verifiable indicators (OVI)' are entered measures to show the achievement of the objectives applying at each level of the hierarchy. The OVIs should be important, plausible, sufficient, independent, verifiable, and precisely defined in terms of the nature, quality, quantity, and timing – familiar criteria when specifying monitoring indicators. The counterpart column 'Means of verification (MOV)' records the sources of information and the methods of data collection and analysis used to check on the achievement of the OVIs.

The framework thus allows the feasibility of projects to be checked, by explicitly setting out the internal coherence (via the narrative summary) and the external plausibility (by considering the important assumptions) of what is planned. It requires planners to openly state just what they assume, thereby making it more likely that improbable premises of high risks will be properly considered and appraised before funds are unwittingly committed to inherently flawed or unduly risky projects.

For management and supervision of projects, it helps define the tasks and accountability of management, and establishes clearly and fairly the indicators against which project progress will be monitored and evaluated from the outset of the project. A final strength of the tool is for communication: it conveys the essence of the project in a single diagram, a useful at-a-glance summary for those interested.

Pros and Cons of LFA

The advantages of using LFA are the following:

- It ensures that fundamental questions are asked and weaknesses are analyzed, in order to provide decision-makers with better and more relevant information.
- It guides systematic and logical analysis of the interrelated key elements, which constitute a well-designed project.
- It improves planning by highlighting linkages between project elements and external factors.
- It provides a better basis for systematic monitoring and analysis of the effects of projects.
- It facilitates common understanding and better communication between decision-makers, managers and other parties involved in the project.
- Management and administration benefit from standardized procedures for collecting and assessing information.
- The use of LFA and systematic monitoring ensures continuity of approach when original project staffs are replaced.
- As more institutions adopt the LFA concept, it may facilitate communication between governments and donor agencies.
- Widespread use of the LFA format makes it easier to undertake both sectoral studies and comparative studies in general.

The limitations of LFA are the following:

- LFA is a general analytical tool. It is policy-neutral on questions of income distribution, employment opportunities, access to resources, local participation, cost and feasibility of strategies and technology, or effects on the environment. The LFA does not identify projects, nor does it help select the best projects. It does not optimize project content, nor make judgments about the value of what is being done, or about the relation between the benefits and costs. LFA is therefore only one of several tools to be used during project preparation, implementation and evaluation, and it does not replace target-group analysis, cost-benefit analysis, time planning, impact analysis, etc.

- Rigidity in project administration may arise when objectives and external factors specified at the outset are over-emphasized. This can be avoided by regular project reviews when the key elements can be re-evaluated and adjusted.

- The LFA appears very simple, but the full benefits of utilizing LFA can be achieved only through systematic training of all parties involved and methodological follow up.

Narrative Summary of LFA

The narrative summary presents the vertical logic in the logical framework. Initially it is often confusing how to phrase the different elements and how to organize it. The following presents some considerations, which hopefully should help you to elaborate the narrative part of the log frame.

Goal or Development Objective.

The goal or development objective should be related to an institutional or a program goal, and it should justify the existence of the project or program component. It is a statement of the overall aim to which the project or program is contributing. It should be clearly connected to the results of the project and should not be stated at such a high level as to make this linkage meaningless. In defining a development objective, make sure that:
- It provides adequate justification for the project;
- Its progress can be verified either quantitatively or qualitatively;
- It is single-purpose, or has multiple purposes, which are compatible.

Occasionally, a project may contribute positively to more than one goal, however, it is important to explicitly identify what the primary goal of the project is. The possible impact on other goals should either be considered positive side effects or constraints. One example of the latter is a goal toward increasing the productivity of a crop and protecting natural resources. This reflects a goal that in reality is made up of two goals: increased productivity and protection of natural resources. These two goals are often at equal chances with each other. It is important to clearly state which one is the principal goal, and which one is considered a constraint or positive side effect. A production project with a natural resources constraint is clearly not the same as a conservation project with a production constraint.

Common problems:
- Definition of a goal toward which the project will only make an insignificant contribution.
- Phrasing the objective in general terms, which makes it impossible to determine if the goal has been achieved.

Bad example of Goal
Improve the livelihood of the people in the southeastern provinces by increasing the agricultural production and protecting the natural resources
- Project will only make an insignificant contribution
- Phrased in general terms, which makes it impossible to determine if the goal has been achieved

Good example of goal
The income from maize of 2000 farmers in the southeastern provinces increased by 25% by year 2010, compared with their year 2000 income of US $ 300 per year from the same source
- A statement of the desired state after the change
- A statement of quantity, that is the magnitude of the change
- A timescale
- A statement of the location of the change

Project Purpose or Immediate Objective

An immediate objective is a statement of effects to be achieved in the short-term as a result of the project outputs. The successful achievement of the immediate objective contributes to the achievement of the development objective. The immediate objective should specify the changes or improvements that could be expected in the target group, organization or region, if the project is completed successfully and on time. It should also state the magnitude of such changes and the time span in which they will be brought about.

Formulation of the project purpose is very important in the design and subsequently in the implementation of a project. Purpose defines what the project can be expected to work towards, but not what it will itself produce (these are the outputs). Many projects only have one purpose and there should not normally be more than two or three.

An immediate objective is on top of a pyramid followed by the results and activities. To facilitate the presentation of the rest of the logical framework it is useful to define immediate objectives that are complementary and as far as possible avoid overlaps where e.g., one result contributes towards two immediate objectives. If more than one institution is participating, it may be useful to define one immediate objective for each area where an institution has the lead. This could be one for CIMMYT, a second for the national research institution and a third for the extension service.

In defining an immediate objective, make sure that:
- It states clearly the desired change or improvement;
- It specifies the magnitude of the change or improvement to be achieved;
- It indicates the timescale for the change or improvement;
- Its progress can be verified quantitatively and/or qualitatively;
- If it conflicts with another immediate objective, priorities are indicated.

Common problems in identifying immediate objectives:
- Confusion between what is a result and what is an immediate objective. A result is, by definition, within the scope of the project. Where as, the immediate objective also includes external factors. For example a project can produce a new variety (a result), but it cannot guarantee farmer adoption (an objective);
- Definition of immediate objectives, which are much larger than the sum of the results proposed to achieve it.

Examples of purpose:

i. Ethiopian Agricultural Research Organization (EARO) by 2009 has developed five locally adapted cultivars of maize with an increased productivity of 15% under conditions of low soil nitrogen, and with 10 % higher protein content as compared to the five most common maize cultivars in year 2000 in the southeastern provinces.
- Assumption: CIMMYT will collaborate with germplasm and technical backstopping

ii. By the year 2010, four extension organizations with a total of 50 extension agents are visiting 5000 farmers and promoting the 5 improved cultivars of maize generated in the project
- Assumption: Agreement on collaboration with 4 extension organizations established
- Assumption: Government support to extension organizations continue on at least year 2000 level

Outputs/results

An output is produced as the result of a series of activities. Usually, a number of outputs must be produced and utilized in order to achieve an immediate objective. If an immediate objective is “improved capacity of the Department of Plant Breeding to manage information related to maize breeding” then outputs might include “X plant breeders trained in database management” and “Y computers with search facilities installed”. The outputs are the actual direct result of the project and their production is the contractual responsibility of the executors of the project.

Most immediate objectives require more than one output, and their sequential ordering is essential, because the output of one activity is likely to be required for the production of another output. The sequential ordering of outputs also facilitates an understanding of the development of the project over time, and it is preferable to have outputs that are produced at different stages in the project rather than a series of outputs at the very end of the project.

Outputs need to be stated in such a way that:
- Their realization can be identified, in terms of quantity, quality, time and place;
- As for objectives, a target is specified for the magnitude of output to be produced and the timescale for this;
- It is clear if a certain output is a prerequisite for other outputs;
- All outputs necessary for achieving the immediate objective are listed and all outputs clearly relate to the immediate objective;
- They are feasible within the resources available.

Common problems in defining results/outputs:
- It is common to confuse the immediate objectives and the results. However, these are, by definition, quite different in the sense that the first is outside the scope of the project whereas the results are within the scope of the project.

- Outputs are also commonly confused with activities. Remember that an output is the result of an action or activity. Research conducted on the impact of striga on maize production is an activity, whereas the research findings are an output.

- Often the expected results of a project are presented in a long list, with no clear indication of how each result relate to immediate objectives and activities. This makes it very difficult for the reviewer to understand the relevance of the proposed outputs and activities, and also difficult to judge the feasibility of the project. A simple system of numeration can solve this, e.g. objective 1, result 1.1, 1.2 and activity 1.1.1, 1.1.2 etc.

Activities

An activity is the action necessary to transform given inputs into planned outputs over a specified period of time. The production of each output usually requires a number of activities, and it is custom to list these activities in the chronological order they are supposed to be implemented.

Activities need to be stated in such a way that:
- Their implementation can be verified in terms of quantity, time and place;
- They are stated in terms of actions being undertaken rather than as completed outputs;
- All key activities necessary for achieving the outputs are listed;
- There are no activities listed whose outcome cannot be traced upwards to the output level;
- It is clear who is responsible for doing the work.

Often the activity list is complemented by a work plan, e.g. called chronogram that summarizes the timing of inputs, activities and outputs. You may choose to indicate the timing of the activities etc. this way rather than directly in the logical framework.

Common problems on defining activities:
- If several institutions are participating in the project it is not made sufficiently clear who is responsible for doing what.

Outputs versus activities:
- The output of a training activity is trained people
- The output of a research activity is the research result
- Research conducted on inter-cropping is an activity
- Research findings on inter-cropping are an output

Inputs and budget

Inputs are the human, physical, material and institutional resources that are required to undertake a program or project. The inputs must be quantified and coated in a budget.

The listing of inputs and/or budget should specify:
- Type of input (of experts, equipment, vehicles, fellowships, etc.);
- The required quantity (i.e., number or amount);
- Duration of assignment or use;
- Cost per unit and in total;
- Timings for delivery or commencement and location (if critical);
- Purpose or activity for which provided.

All personnel should be listed according to their required field of specialization and qualifications, together with a job description or basic function at least. The basis on which personnel needs have been calculated should be set out.

Often a lot of time is spent on costing the inputs. This can be avoided by using a table of costing for indirect costs, personnel costs, accommodation and travel expenses, rental of conference rooms, airfares, publication, and inflation. The table should be based on experiences from previous projects. Project officers review a large number of budgets, and they know the prices of all the most common inputs. You must therefore ensure that your costing are within a normal range or justify why they are not.

The proportion of your own contribution is a strong indicator of commitment towards the project, and a large commitment is highly valued by the donor. It is therefore important to indicate all in-kind and financial contributions of the project collaborators towards the project.

Assumptions

The assumptions concern conditions which could affect the progress or success of the project, but over which the project manager has no control. In the log frame assumptions are phrased as positive statements of what is expected to happen, but in reality each assumption is also implicitly a risk, i.e. some external factor may not act as expected and this can cause a negative impact. In the design phase it is important to analyze the possible external factors that may affect the project. Once a factor has been identified, the possible magnitude of the impact on the project and the chance of occurring should be assessed. If the chance of impact and or the magnitude of the impact are significant then the design of the project should be changed in order to diminish the risk.

As risks or assumptions influences the strategy and design of the project, it is important to include these factors in the analysis from an early stage in the process. The assumptions column should be used interactively in the design process in order to reduce the risks involved in the project. This also implies that at the end of the design process risks should be more or less eliminated through design changes, and it should be very likely that the remaining assumptions will come true.

In summary, the external factors upon which the success of the project depends should be identified during the formulation process and their articulation:
- Makes risks explicit;

- Facilitates the assessment of risk;
- Leads to rejection of nonviable projects or redesign in order to eliminate the risk.

In the log frame, risks are presented as assumptions, which means they should be turned into statements of what should happen in order for the project to succeed, e.g.:

- The Government will provide buildings and staff for the project;
- The extension agencies will cooperate in on-farm trials and carry research results to farmers.

Indicators

The objectively verifiable indicators (OVI) represent a set of criteria, which indicate in concrete terms that expected results or objectives have been achieved. Their content adds precision to the statement of intent given in the narrative summary. For each of the first three levels in the log frame there should be a set of OVI, which are appropriate to the objectives at that level and which constitute proof of achievement at that level. To be valid and useful the OVI must have the following qualities:

- They must clearly indicate the criteria for the success of the project;
- They must focus on what is important in the objective for project purposes;
- They must be plausible and clearly related to the objective with which they are associated (this is especially important if indirect indicators are used);
- There must be a sufficient number of indicators of sufficient detail to allow adequate measurement of achievement of objectives;
- They must be independent, i.e. a given indicator cannot signal achievement at two distinct levels of the hierarchy of objectives, nor should one indicator simply be a different way of expressing another indicator;
- They must be objectively verifiable, i.e. two independent observers would come to the same conclusion regarding the status of the objective;
- They must also be defined precisely in terms of targets to be attained. This implies the need to specify the nature of the OVI, its quantity, its quality and the time required for the objective to be achieved.

In the LFA, the means of verification (MOV) ensure that the previously defined OVI can be measured effectively. The MOV have two roles:

- They confirm that the indicators chosen are realistic, since they specify how the indicators can be verified;
- They facilitate the project evaluation by establishing, in advance, how the criteria for success should be verified.

The MOV can be classified according to the types of data gathered, the sources of information consulted, and the data collection technique used. The types of data to be gathered refer to the information required to measure each OVI. For many OVI the data requirement will be clear from the nature of the objective at that level and the OVI, which derives from it. However, there may still be a need to specify the exact nature of the data to be gathered, since resources may permit only the gathering of proxy data, e.g. wealth indicators.

The MOV's should also identify the sources from which the desired information can be obtained. This helps to keep the system realistic, i.e. it helps to avoid the specification of data, which is very difficult, expensive or time-consuming to collect. The sources may be grouped into three categories:

- Physical location that can be check in the field;
- People, e.g. farmers or experts which can be interviewed;
- Documents, e.g. public statistics or reports.

The choice of information source depends on various criteria, one of the most important of which is validity. However, in choosing sources, account must also be taken of other criteria, notably the cost of data collection and the ease of access to information.

Lastly, the means of verification must identify how the desired information will be gathered. The detail required depends to a large degree of the availability of the information. If it is a publicly available report little specification is needed, but if the data is to be collected via a sample survey then much greater detail will be appropriate concerning for example: suggested sample size, stratification criteria, etc. Simply putting sample survey or case studies is inadequate.

Conduct the Study

Practically

After you have got your proposal approved, or have been told that you can begin by your supervisor or employer if you do the study as a part of your education or as a task for your employer, you shall actually conduct it. Now you will recognize the benefit of a careful and detailed plan. With a proper plan, you basically just follow it.

However, you can be sure that something unexpected will happen. In this case, do not panic, but continue as proper as it is possible with your plan. If you loose one replicate, it is no catastrophe (as long you had more than two from the beginning). If there are more serious disasters, contact your supervisor, employer or donor immediately. If you do that, you may get resources to start again, or to complement a partly destroyed study. Of course, the odds that you get such extra resources are much higher if the disaster was something beyond your control ("a small aircraft landed on my study plot") than if you caused it by being careless ("I forgot to feed the beetles supposed to act as biological control agents, and they all died").

All you do should be done careful and according to plan. This is one reason why it is important to be realistic when developing the plan; if you plan overwhelmingly large works, you will simply not be able to conduct them properly but will probably either do your task more careless by time, or skip part of the planned study.

When you collect your result, fill neatly in your protocol. Do *never* calculate an average and enter only that in your protocol, but track every unit, every replicate, involved in your study. This is needed to benefit from the use of replicates, and to perform all the most commonly used statistical analyses.

Warning

Finally, a word of warning: when you are performing a non-experimental (descriptive) or experimental study, and have an unpleasant feeling that the outcome will not be what you expected, *do not*, never, never, begin with adding additional treatment(s) to what you state in your hypothesis or your scientific question. Assume that you perform the fertilizer on teff study, and after two weeks you cannot see any difference between the parts that get maximal fertilizer and those that get nothing extra. At this stage, it is common that inexperienced persons begin to add some treatment (decided based the underlying reason for the study, in this case to increase the teff harvest in the area) - as beginning irrigation or adding an additional fertilizer. However, whatever the outcome of such action is, it has no scientific meaning. It will not be possible to judge if the result depend the initial studied fertilizer, or the additional treatment, or a combination of them. Thus, the result, even if happen to be successful, cannot be used for advice or any implementation. Therefore - *keep* *to your formulated hypothesis or your scientific question*. *Follow your plan*. If you make new observations during the study, investigate them in an additional study (that well can be done parallel to the original, if practically possible).

Analyse

As mentioned above, statistical analyses are beyond the scoop of this booklet. Let us instead repeat the advice to contact a statistician or a colleague, friend or supervisor interested in statistics if you feel uncertainty of what to do. Be careful that you analyse proper date, i.e. proof read carefully any re-typing you do of your protocol. When you have a statistical analyse, continue with a critical-thinking-analyse; thus evaluating the importance of the findings in the perspective of your study. Observe that not all statistically significant differences are of importance in practice; if there is a statistically significant difference between the average weight of two cattle races, it is possible not of any practical importance if the difference is two gram. Thus, you have to use your subject knowledge and your critical thinking when valuing outcome from statistical analyses.

Report

In a lot of cases, you will not write an article for a scientific journal (see "To Publish" above) but rather, or first, write a report about your study and the results. It is very common that donors require that a report should be delivered soon after you have finished the study - long before it is possible to get it published in a scientific journal. It is also common that companies and institutions require reports on studies done. For bachelor and master exams at universities, several subjects require a report from a practically conducted research study. Such a report does not undergo the evaluations of peers, still it shall be carefully prepared, and has a scientific value. Normally your employer or supervisor is the one that decide if it is acceptable; if it is for an exam it is the evaluation committee. You are much freer to write as you like in a report than in an article for a scientific journal. However, if there are any writing instructions: follow them in detail. A report consists of different components. Use heading and sub-headings to break up the text and to guide the reader. They should be based on the logical sequence, which you identified at the planning stage but with enough sub-headings to break up the material into manageable size.

<u>Generally</u>

- *Write in clear language*. A grammatically correct report is desirable but first and foremost, the meaning needs to be clear to the marker. Pay attention to spelling, punctuation and grammar. Write complete, grammatical sentences; do not use note form or bullet points. Avoid abbreviations and contractions except in citations and references.
- In report writing concentrate on *quality, not on quantity*. Readers of your report give attention to quality, conciseness and clarity.
- Make sure that material in the report is directly relevant to the topic of your report. ‘Padding’ the report with material of marginal relevance, is to be avoided.
- Make sure that you *proof-read* and *spell-check* your final copy. You are responsible for the final document. Correct all typographic and other errors as neatly as you can.
- Make sure that the report uses your own words. Try to avoid extensive quoting and reproduction of material of others.
- If you do use material of others, then you must explicitly acknowledge each use. Not to do so is a serious offence (plagiarism). The practice of taking the ideas or words of other writers and trying to pass them off as your own is plagiarism. To avoid a charge of plagiarism, you must be careful to acknowledge the source of any material that is not your own. This applies not only when you are quoting the actual words of other

writers but also when you are paraphrasing (putting into your own words) the thoughts of other writers, or relying on the research findings or theories of others.

There must be a logical progression from step to step of your arguments, from paragraph to paragraph, *etc.* which is in line with the conclusions of your research. That is, you should 1) tell the reader what you are going to say or argue (introduction); 2) say it in sufficient detail to justify it convincingly to the reader (main body); and 3) remind the reader of what you have just said or argued (conclusion). There is no one format that a report should take. There are many possible components within a report. You will not always be expected to include all of them: it will of course depend on the type of report you are writing and the length.

Components

The following are the most commonly observed components of scientific reports.

Title Page

Always included. This should normally include the title or the report, your name, date of submission.

Content Page

Always included unless very short report. List of all your chapters/sections/headings/sub headings, appendices and illustrations, if applicable. Don't forget to put the relevant page number and to set everything out as clearly as possible.

Summary

Usually included. The summary should indicate the scope of the report and give the main results and conclusions. It must be intelligible without the rest of the report. Many people may read, and refer to, a report summary but only a few may read the full report, as often happens in a professional organization.

- Purpose - a short version of the report and a guide to the report.
- Length - short, typically not more than 100-300 words
- Content - provide information, not just a description of the report.
- Complete in itself: should contain parts of objectives, methods, results & major conclusion
- Should not contain: discussion, references, abbreviations, information not in the paper
- Written in past sentences

The summary usually comes immediately after the title and might also be called a *synopsis* or *abstract.* Like the contents page, it should be written when the report has been completed.

Introduction

Always included. Your report should begin with an introduction that foreshadows the questions to be answered and shapes the substance of your argument. It is often easier to leave writing the introductory paragraph(s) until the end, when you have fully developed your arguments and have a final structure for your essay.

Remember, the introduction is *not* a summary. The function of the introduction is to provide your reader with the necessary background for what is to follow. So give a clear, concise statement of the problem you are going to investigate; define the limits or the scope of your investigation; and if you are dealing with terms that are ambiguous, define them clearly and concisely. The introduction should also include a plan of the way you intend to develop your answer; that is, a list of the main sections or steps in your argument.

The essential components of the introduction are:
- Background of the topic
- Differing views of the topic.
- Definitions

If a controversy exists in the literature concerning the meaning of certain terms in the question, mention this and state the way in which you will be using the term(s). This allows the reader to know what your frame of reference and understand your argument(s) better.

- Make your assertion
- It must be clear and to the point.
- Map your arguments

A statement of how the rest of your essay will be laid out; guides the reader through your arguments; and shows up front what you will be discussing in your essay.

Materials and Methods

Always included. Should allow another researcher to judge your study and repeat your experiment. Include: treatments, design of the experiment and replications, materials used and the procedures and statistical analysis.

Main Body

Always included. This is the substance of your report. The structure will vary according to the nature of the kind of report and the subject matter studied. The body of the essay should contain a logical development of the argument. It is useful to think in terms of subsections. Sub-section by sub-section, point by point, you present and asses the evidence, demolish the fake and grasp the real; and gradually build your case. Be critical and analytical in your approach. It is not sufficient to simply describe a situation experienced readers will be looking for *analysis* and for a *critical approach*.

One important sub-section of the main body is the results of the study. This section records your observations (in the past tense) and would normally include statistics, tables or graphs. This is simply a factual section of your work and should be presented in a clear, logical order. In results:

- Report important and representative data in the text
- Prepare your results in the form of table or figure
- Reduce large masses of data to means with standard errors
- Include only relevant tables or figures, but not both for the same data
- Refer to every table and Figure 2y number

Another important sub-section is the discussion of results. This is where you consider your results and this discussion should lead naturally to your conclusions. You will probably refer back to problems or points raised in your introduction. Again, *use the past tense when referring to what you did/found*. Charts, diagrams and tables can be used to reinforce your arguments, although sometimes it may be more appropriate to include these as an appendix (particularly if they are long or complicated).

Keep your focus on the problem and do not get sidetracked by irrelevant detail and padding. On the other hand, do not make the mistake of regarding all counter-arguments as "irrelevant". Important alternative views must be met. Refute them if possible. If not, take them into consideration in your final assessment and meanwhile give your reasons for having doubts about their validity. Similarly, do not ignore evidence that does not support your case. Examine the evidence. If you can find no fault and if you do not have any counter evidence, then maybe something is wrong with your case — do a bit more research. In discussion:

- Do not repeat what has already been said in the review of literature
- Relate the results to the questions that were set in the introduction
- Show as how the results and interpretations agree or disagree with previously published work
- Discuss theoretical implications of the work
- Avoid extrapolating (speculating) the results too much
- Indicate the significance of the results.

Conclusions

Always included. The conclusion should logically flow from your main body, summarizing what you have shown by analysis and application to the problem and answer the question. The concluding viewpoint should also address if the issues have been fully/completely or superficially resolved and if it was not resolved then recommendations for further action or problems that need to be addressed. If you have reservations about any points, make them. If points are left open, indicate the need for further research. Remember *not* to include any new material here: if it's important enough to include, put it into your main body.

Acknowledgements

Sometimes included. A list of people and organizations that you would like to thank for assistance, advice or information.
You should acknowledge any significant technical help that you received from any individual, whether in your laboratory or elsewhere. You should also acknowledge the source of special equipment, cultures, or other materials. You might, for example, say something like "Thanks are due to J. Jones for assistance with the experiments and to R. Smith for valuable discussion.". You should acknowledge any outside financial assistance, such as grants, contracts, or fellowships.

Reference List

Always included. This part of your report is a list of all and only the references cited in the text of your report. This should be titled "References" or "Literature Cited", not Bibliography". A bibliography usually includes other relevant sources not mentioned in the text and is thus unacceptable for academic essays. You should list only significant, published references. References to unpublished data, abstracts, theses, and other secondary materials should be avoided. Use such references only if absolutely essential. A paper that has been accepted for publication can be listed by using "In press" instead of year of publication.

Check all parts of every reference against the original publication before the manuscript is submitted and perhaps again at the proof stage. There are far more mistakes in the References section of a paper than anywhere else. Make sure that all references cited in the text are indeed listed, and that all references that are listed are indeed cited somewhere in the text.

Appendices

Included if needed. An appendix (plural=appendices) is detailed documentation of points you outline in your findings, for example, technical data, questionnaires, letters sent, tables, sketches, charts, leaflets etc. It is supplementary information, which you consider to be too long or complicated, or not quite relevant enough to include in your main body, but which still should be of interest to your reader. Each appendix should be referred to in your text. You should not include something as an appendix if it is not discussed in the main body.

Writing Order

This is just a suggestion; see also "Order of Writing" regarding articles in scientific journals above.

- begin writing with the main text
- write the Conclusion next
- followed by the Introduction

write the summary at last

Proofreading

This refers to the checking of every aspect of a piece of written work from the content to the layout and is an absolutely necessary part of the writing process. You must note that it is not possible for you, as the author of the report to proofread accurately yourself; you are too familiar with what you have written and will not spot all the mistakes. Therefore, it is recommended that you give it to someone else, as one of your colleagues, to read carefully and check for any errors in content, style, structure and layout

Final Words

After conducting your study, you are hopefully inspired to continue with the next! If you are in the beginning of a research career, you shall be aware of that it is absolutely normal to not save the world for the future with the first study one performs independently from supervisors. On the contrary, to at all be able to investigate what one is attempting at, and to contribute to solve the problem one is concerned of, require a lot of training; training that can only be received by working with research. You have probably observed a number of mistakes you did, and thought "oh, if I only had done in that way from the beginning, it had been much better". This is just fine - you will do it even better next time. For every study you conduct, you will be more experienced.

Good luck with your research.
Remember that the only
way to succeed is
to try!