Chapter 3

What Makes a Science and How Does Linguistics Fit in?

Introduction
All sciences do not work the same way. How do we recognise a science when we see it? Unfortunately no easy definition or simple characterisation can be given because of the wide variety of inquires that come under science. In this chapter, we try to develop an understanding of science. In the last five or six decades the idea of science has gone through much refinement thanks to philosophical, sociological and historical discussions about topics of science such as nature of data, theory, experiments, falsifiability, unobservables, modelling, historical contexts and social factors have clarified and sharpened questions about the nature and practice of science. Each of these categories has shortcomings and assumptions built into them that often pass unnoticed, but have consequences on what science is. The goal of this chapter is to present an overview of the prevailing discussions of science, paying attention to certain questions that are of relevance to the topic addressed in this dissertation.

This chapter is organised as the following. The first section is about the objects of knowledge of natural and social sciences. It is followed by a section on methods of knowledge of science. The third section brings up the complexities that mar the serene and idealised perceptions about what constitutes scientific knowledge and method. After this, we discuss these issues in relation to linguistics. The last section deals with the sociology and the context of scientific practice.

Objects of Knowledge

Physics
Physics started with studying the objects in the world around us. It studies various properties of objects such as motion, heat, states of matter and so on. The objects can range from the minutest particles we know to the largest galaxies which can be observed using sophisticated telescopes. It studies forms of energy such as sound, light, infra red
and ultra violet. Many more objects and phenomena come under the domain of physics. Some of them are molecules, subatomic particles, condensed matter, motion, natural phenomena such as rainbow, scattering, the red-shift, phenomena such as photoelectric effect, forms of energy such as electricity and magnetism, astronomical objects such as black holes, white dwarfs, the origin of universe and so on.

Right from the beginning of the discipline, a major attempt was also to reduce matter to its minutest component – an attitude known as 'atomism'. Throughout history, different cultures have had their own ways of trying to discover the nature of objects around us. Such attempts from the Greek, Arabic, Indian and Chinese cultures are well-known. Because of the way the story of science is narrated, we usually associate the beginning of modern physics with the beginning of the heliocentric view associated with Copernicus (15th and 16th centuries) and Kepler (16th and 17th centuries). Then came Galileo who is considered the father of modern physics. It was from roughly around his time that the methods of all physical sciences, which included both theorisation and experimental work, came in place. Galileo studied the properties of objects of the world using thought-experiments and mathematical tools. Newton carried this process forward and made several path-breaking discoveries such as gravitation and laws of motion. The centuries that followed Newton saw significant advances in studies of the universe, thermodynamics, electricity, magnetism, small particles of matter such as atoms which are further divided into even smaller particles. Studies of macro-level (of stars, planets and galaxies) and micro-level (of subatomic particles) led to new ways of thinking about the material world. Research aimed at integrating the micro and the macro, as well as attempts to unify various forces brought in new theoretical tools such as string theory and high technology experimental settings such as particle accelerators.

Chemistry

Chemistry's concerns are similar to physics to the extent that it looks at properties of matter, but it focuses on types of matter and their combinations. Such combinations
involve different number of atoms of the elements involved in order to produce a new
substance. Atomism has also been a major concern for chemistry, in the sense of studying
the arrangement of matter in a micro sense. Small units of matter such as molecules and
atoms as well as their properties such as masses were a major concern of pre-twentieth
century chemistry. Chemists those days also tried to isolate basic substances, famously,
gases such as oxygen and hydrogen. Pre-twentieth century chemists also tried to arrange
basic substances or elements in some order, such as increasing atomic mass. There were
attempts by various chemists, but the one that came to be very influential was thought out
by Dmitri Mendeleyev. This came to be known as the periodic table because the chemical
features of elements repeated at regular intervals – in other words, periodically – on the
table.

The periodic table highlights an important feature of science, namely prediction.
Properties of substances recurred in regular intervals when they were arranged according
to atomic masses. This also largely coincided with the arrangement based on atomic
numbers or the number of electrons around the nucleus of an atom, which was a later
discovery. A lot of recent work is about the fine structures of substances such as crystals
and organic compounds. Much attention is also paid to the chemical combinations of
molecules that are essential for life, such as the DNA.

A strong conceptual-level connection between chemistry and linguistics was
attempted by Mark Baker in his 2003 work *The Atoms of Language* where he argues that
the role of atoms in chemistry is analogous to that played by parameters (in the
Chomskyan sense of *Principles and Parameters*) in linguistics. Each language is decided
by a combination of a definite number of parameter settings it chooses.

*Biology*

At a very basic level, it is the study of life. A large field, it covers living things, their
behaviours in the contexts they live in, the fundamental chemical units that largely
determine their appearances and physiological functions and so on. It is important to note
that on the one hand, the discipline studies observable minute entities such as the DNA and the cell, abstract entities such as the gene and at the same time, large-scale historical processes such as evolution. It also studies taxonomic categories into which various living organisms fit.

Historically speaking, it started with classification-based descriptive work or taxonomy. Karl Linnaeus is associated with the major taxonomical project of describing a large number of plants and animals using a range of categories starting from broad ones such as kingdom, phylum, sub-phylum, etc. and coming down to narrow ones like genus and species. The discoveries of evolution by Charles Darwin and foundations of genetics by Gregor Mendel laid the bases for the explanatory science of biology. Later in twentieth century, a number of important discoveries were made in relation to the chemical foundations of genetics, including the very famous discovery of the DNA.

In chapter 1, we had discussed some interesting parallels between linguistics and biology. Studies of entities and behaviours are like synchronic linguistics and the study of large-historical processes are like diachronic linguistics. The ideas of classification or taxonomy and evolution were seen to be common to both the disciplines.

Social Sciences
Social sciences studies societies and units of social life such as family, clan, tribe, caste, race, society, state, nation, and so on. It makes fine distinction between pairs of these categories (for example, nation and society) while also studying the relationships between them. Some branches of it like social psychology studies individuals by placing them in a social context. Some parts of it study consumer behaviour and decision making when it comes to purchasing and so on. Reflecting the diversities of human societies, these disciplines study a range of topics from social mobility, race relations, ethnic nationalism, ethical questions relating to descriptions of victimhood, relationship between social class and romantic partnerships, ethical values concerning collective greed in society, the relationships between NGOs and the development in a nation and several others.
The methods of social science evolved in the nineteenth century. Following the ideas Auguste Comte in his 'A General View of Positivism' (1830–1842), objectivity and establishments of laws became a primary concern for scholars who studied society also. It was modelled after the methods of natural sciences. A discipline such as economics has been using an increasing amount of mathematics of late. Sociology uses significant amount of quantitative methods and statistical analysis. The related discipline of anthropology also studies culture, kinship, social institutions like religions, castes, bonding and relationships among human beings and so on. But different from sociologists, anthropologists pay greater attention to detailed descriptions and narrative styles, what the practitioners call ethnography.

The discipline of history raises very important questions about objectivity and 'point of view'. It is often said that what is presented as history is often the history of the winners in various soft or hard battles. In the last few decades, there has been an emphasis on presenting points of view which were generally ignored by 'mainstream' narratives. The mainstream narratives went about as if they were an objective and chronological presentation of events. In recent times, there has been an increasing awareness of the impossibility of objectivity and much attention is paid to the perspective from which history is written and thus to the process of history-writing itself.

**Linguistics**

Linguistics broadly studies the nature and structure of language. Linguists study units of language such as phonemes, morphemes, words, phrases, sentences, tones and intonations; structures such as clefts, relative clauses and passive constructions; phenomena such as derivations, inflections, pronominal and quantifier references and filler-gap dependencies. As described in chapter 1, the discipline also studies language in relation to the mind, the brain, society, gestures and details of expression of language.

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such as styles of writing and so on.

How do we think of the idea of measurements in linguistics? Consider the question of measuring mental principles. They cannot be easily measured, just like we cannot easily measure the mass of an electron or the sun by weighing it on a scale. There has to be some indirect ways of measuring external things like the mass of an electron as well as internal things like the principles of grammar.

The scientific status of linguistics is the main concern of this dissertation. After presenting conceptual aspects of science, we will be looking more closely at factors that contribute to the status of linguistics as a science. Those factors are theories, laws, methods, knowledge, predictions, the notion of truth, facts, technology and modelling, all of which we discuss in relation to the purported scientific study of language.

Methods of knowledge

In order to arrive at its knowledge, science uses a combination of experiment and theory. This insight is many centuries old, dating back to Francis Bacon. A general view about science is that it collects facts from natural and experimental observations, then hypotheses are made about the pattern underlying the facts and then theories are developed.

Facts and Hypotheses

Science works with facts about nature. Facts are collected by observations and experiments. So facts arise out of unbiased observations of nature and experimental results. Scientists usually work with a hypothesis about a phenomenon. They make a preliminary set of observations and using some already known facts, they would arrive at some working hypothesis. This hypothesis would guide further experiments which usually lead to the formulation of some theory. Only in fields where scientists do not have sufficient number of initial facts to work with do they start making observations and then arrive at post-hoc generalisations. In experimental linguistics, senior researchers often

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2 This example comes from Ray Jackendoff, *Patterns in the Mind: Language and Human Nature*, (New York: Basic Books, 1995)
advise juniors to work with certain hypotheses because the argumentation involving the preliminary hypothesis and its comparison with the results obtained lead to rigour in analysing the new data.

Theory

The conventional understanding of a theory is that we arrive at one from particular observations. From a set of observations, a generalisation is arrived at using logical reasoning. Such generalisations are tested for an extended period and are refined and modified to account for larger sets of data. That is how scientists arrive at a theory.

Complexities of Science

What we saw above was a general and idealised picture of science, endorsed by most scientists and by some of the stalwarts of modern linguistics, as we saw in chapter 2 and will analyse in chapter 4. In this section we discuss some of the complexities of the beast.

For example, there has been a considerable amount of discussion about whether there is a single methodology to the whole of science. Ian Hacking (1983) responds to that by observing that science need not be associated with just one method. Like other activities such as building a house or growing tomatoes, there are multiple methods of doing science also.

Facts

Scientific facts are often considered pure observations about nature. But it is a questionable category. For example, for a long time, it was thought that the number of planets was 9. Later some observations showed that Pluto was too small to be a planet and now the consensus among scientists (and in turn an acceptance among the general public), that the number of planets is 8.

The current understanding seems to be that observations do not have a pure and categorical presence in nature. For example, how do we recognise the existence of something which can be detected only by using a very sophisticated instrument? Or how do we account for concluding that there is a particle on the basis of vapour on a cloud

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chamber, which is an inference based on a theoretical account of how certain particles would behave in a particular context? What seems to be the case is that observations are often accepted as true because of a consensus that the society of experts have arrived at based on certain assumptions and logical inferences. In modern science, many objects that cannot be experienced by the senses in their normal states or do not occupy space are considered real. For example, consider photons and electrons. We cannot see them with our eyes, but many people believe in their existence because they are shown to be present in the world using sophisticated theories and experiments. It is also not clear that these objects take up physical space. Neither is it clear that a photon is a matter in the sense of being an object with mass.

**Logic**

Logic is often spoken of something that underpins science because theories are arrived at using logical reasoning from facts and generalisations. It is of primary importance in arriving at inferences from observations. The three types of inferences – induction, deduction and abduction (also known as inference to the best explanation) – are the result of applying tools of logic on observations and laws.

In linguistics, logic is understood to have another important function – that of arriving at meanings. Sentences have phonetic forms and logical forms. Phonetic forms are the sequences of sounds, which in itself correspond to an acoustic signal mapped on a speech analysing device. But logical forms are an attempt to computationally model and thus scientifically study the meaning part of language. They involve function application of predicates on arguments and logical operations on variables, constants and quantifiers which form parts of a sentence.¹

**Experiments**

Experiments are an important part of the scientific method. Proposing a hypothesis, making a prediction based on the hypothesis and testing the hypothesis are important parts of scientific method. This is the idea that is at the base of the hypothetico-deductive

¹ This is in the technical sense of expressions that make a predicate complete.
method. Gower (1997) writes about the importance of experiments on science, citing Richard Feynman:⁵

...the physicist Richard Feynman said that, in science, we compute consequences of a proposed new law and compare the result with experiment ‘to see if it works’. ‘If,’ he continued, ‘it disagrees with experiment it is wrong. In that simple statement is the key to science’.

A hypothesis, according to 'the Newtonian method', is arrived inductively from observations or mathematically deduced from mathematical statements of other empirical laws. There are problems with this approach as discussed in the section on scientific method.

*Intervention and Criticism of Experimentation*

Ian Hacking (1983) shows the class and caste difference between a theorist and an experimenter. He illustrates that using the contrast between Robert Boyle, the theorist and Robert Hooke, the experimenter. Boyle was speculative and he advocated the corpuscular theory and the mechanical philosophy.⁶

Sometimes experimental results do not make sense without theory. Hacking gives this example of Becquerel noticing the voltage change when light was shone on one of the two metal plates immersed in a dilute acid solution. It could not be explained until Einstein came on the scene and gave an account of it using the theory of 'photon'.⁷

Hacking gives an interesting example of how some empirical observation fit in neatly with certain theoretical claims. Penzias and Wilson were studying the noise in radio signals. They found that the cause was a small amount of energy that was uniformly distributed across space. This observation fit in neatly with the claim that a uniform temperature, which is originally the residual temperature of the big bang, would be

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⁶ See Ian Hacking, *Representing and Intervening*, (Cambridge: Cambridge University Press, 1983) p 151; an interesting analysis of science in India that is relevant here is R. K. Kochhar's “Science and Domination: India Before and After Independence”, which appeared in *Current Science*, 76 (1999): 596-601. He discusses the Brahminization of Indian science in pre-independence times, the Kshatriya-ization that happened to science post-independence and the *Mandalization* that is yet to happen, which is hoped to energise the artisan class by bringing in the power of modern technology.

⁷ Hacking, *Representing and Intervening*, p 158.
observed all over space. So Penzias and Wilson's observation fit in with what came to be what Hacking calls 'the first compelling reason to believe in that big bang'.

First of all, designing an experiment is a serious and time-taking step. As Sarukkai (2012) notes, the fact that an idea is simple does not imply that the experiment that tests it would be very simple. Sometimes new instruments have to be constructed for a particular experiment. Then the experiment may run for a very long time to make observations. The relevant observations are not often made directly with our senses; they are usually measurements on an apparatus. Making readings using an instrument may not always be an easy or direct process. It is usually a skill that is acquired by the expert as a result of long familiarity with the instrument.

**Explanations**

An explanation can be easily accounted for as a generalisation that captures a number of facts. But it is not as simple as that. As we mentioned earlier, a given set of data can be compatible with more than one explanatory theories. While analysing experimental results, the experimenters bring in their own theoretical positions and biases. They are not just plain numbers or observations any more. Very often, this is where we see the scientists interpreting the data in a theory-laden manner.

All inferences are not based on what are perceived through the senses. The case of unobservables is a case in point. Sometimes, in order to explain a phenomenon, scientists have to make use of unobservable or theoretical entities. For example, consider the idea of a gene. It is unobservable, but it helps us understand the transmission of features from one generation to the next. The proposal of the existence of such a unit of heredity preceded the discovery of its chemical composition.

The theory of evolution also gives another important insight into explanatory accounts. Evolutionary theorists do not give an account of why a particular organism turned out the way it is, in terms of its physical and functional characteristics. They might

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be able to give an account of how the system is structured or how it functions, but an explanation of why it turned out to be so is not possible. This is a problem similar to what happens in linguistics, because it is not within the research domain of a linguist to answer the question of why the arrangements of sounds in the words in a language turned out in a particular way and not in any other. This is a topic which we will discuss in some detail in chapters 4 and 5.

Deductive-Nomological (D-N) Model of Explanation

According to this model, deductions are made from a set of premises, with the condition that one of the premises is a law. D-N models are ideal for working with the criterion of falsification because it tells us that if a universal law is apparently violated, the reason would be that one of the conditions specified by the law was not met in the specific observation that was made. If we can be sure that the initial conditions were indeed met, then we would critically look at the law itself because of falsifiability.

An explanation consists of a set of statements which are together called explanans. The explanans would include statements of particular facts and initial conditions. It would also include a set of general laws (including the laws of mathematics, which cannot be empirically tested) and at least one empirical law which can be tested. A D-N model of explanation also includes the condition that the sentences in the explanans must be true. This last point about truth of the sentences is important in order to keep out false explanations which would give correct results such as Ptolemy's epicycles or phlogiston theory in chemistry.

Theory

A theory consists of generalisations that account for a set of facts. It explains a phenomenon which is understood as a set of individual facts. At the first glance, a theory seems to be a natural progression from facts to a generalisation. But there will always be various explanations for a set of facts. In other words, the observer will never get all the facts necessary to arrive at a theory. That is called the Quine-Duhem hypothesis.
A theory is generally associated with scholars sitting in their offices and working with abstract concepts using their notebooks or computers. This is often contrasted with praxis, which is associated with experiments which have to do with the collection of systematic data, taking measurements and quantitatively analyzing the data. Theoretical science is, alternatively, contrasted with technology, which is associated with the application of science.

A theory is the result of serious engagement with various observations. In an epistemological sense, a theory is often considered to be at a higher level than a detailed description of the phenomenon under consideration, which in other words is called experience. Experience is generally understood as a first-order sensory perception and theory is a second-order understanding of the experience.\footnote{For a longer discussion on this, see Gopal Guru and Sundar Sarukkai, \textit{The Cracked Mirror: An Indian Debate on Experience and Theory}, (New Delhi: Oxford University Press, 2012).
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Based on observations, scientists arrive at a way of understanding a set of data. That is an explanation for a particular phenomenon. A set of explanations that are interlocking or are consistent with each other for related phenomenon forms a theory. A theory is developed by decades – if not centuries – of research. Isaac Newton is said to have remarked that he was able to see as much as he could about nature because he was standing on the “shoulders of giants”, who lived before him.\footnote{Quoted from a 1676 letter from Isaac Newton to Robert Hooke. See the letter in Newton's handwriting on the website of the Historical Society of Pennsylvania: http://digitallibrary.hsp.org/index.php/Detail/Object/Show/object_id/9565, last accessed on 27 October 2014.}

Given that assumptions are important parts of a theory, it is not reasonable to think that a theory accurately and fully explains the object or the phenomenon that is studied? Similarly, if your theoretical goals make you look at your field in a specific manner, how comprehensive can your theory be? The fact seems to be that you never can have a comprehensive theory. You have a number of small theories that deal with parts of your large field. You have to try and fit these different theories and check whether they hold together. A good scientific theory is not merely a positive statement. It explicitly prohibits
the occurrence of certain kinds of data. Popper underscores the features of prohibition and refutability as important to a theory.\textsuperscript{12}

Lipton (1991) notes that underdetermination of theory by evidence is at the core of the Chomskyan idea of language acquisition.\textsuperscript{13} If children learnt only from available data, which are neither complete nor always grammatical, they would not arrive at the knowledge of language they have. What Chomsky concludes from this observation is that people are born with a system that lets them arrive at the grammar of a language using the minimal and imperfect language input they have access to. A theoretically interesting comment made by Lipton is that such an underdetermined knowledge of language arrived at by the human individual is studied by an underdetermined system of inquiry such as generative linguistics, which is typical of the way in which scientific theories work according to Kuhn. A system of scientific enquiry consists of “theories, data, general rules of deduction and induction and any explicit methodological rules,” whose choices are underdetermined by the available evidence.\textsuperscript{14}

A theory that makes use of the least number of assumptions and explanatory categories and steps is considered superior. Elegant theories are also preferred to shoddy theories because of science’s belief in the beauty of nature’s design. Works such as Sarukkai (2004) have explored the relevance of the concept of symmetry as an important component of beauty in scientific theories.\textsuperscript{15} There have been discussions on the importance of beauty in scientific theories in linguistics also.\textsuperscript{16} In addition to logical rigour and empirical strength, there are cases when linguists choose one explanation over another because of elegance of solutions.

A logical point about scientific theories is that one can never be sure about whether a theory is true or not because one never has all the necessary data to state a

\begin{itemize}
\item \textsuperscript{13} Peter Lipton, \textit{Inference to the Best Explanation}, (London: Routledge, 1991), p 6.
\item \textsuperscript{14} Lipton, \textit{Inference to the Best Explanation}.
\item \textsuperscript{15} Sundar Sarukkai, \textit{Philosophy of Symmetry}, (Shimla: Indian Institute of Advanced Study, 2004).
\item \textsuperscript{16} See, for example, Cedric Boeckx, \textit{Linguistic Minimalism: Origins, Concepts, Methods and Aims}. (Oxford: Oxford University Press, 2006).
\end{itemize}
theory with 100% confidence. According to van Fraassen (1980), the question of the truth or falsity of a scientific theory is not really important. What is really crucial is whether it explains the relevant empirical data.

A theory is not a mere progression from observations to explanations and schemes of explanations. Popper notes that even the very act of observation “presupposes interests, points of view and problems.” In that sense, it is neither innocent nor unbiased. It is in this sense that we say that observations are theory-laden. A similar issue concerning scientific theories is that scientists often work with knowledge filters. They tend to accept information that is consistent with their belief-systems and reject those with are not. Generative linguists are also prone to the effects of knowledge filter.

Theory in linguistics

A theory is central to any academic discipline because it consists of deep accounts of the facts it deals with. What one means by deep accounts is that they involve putting forward insights that cannot be arrived at by mere observations.

From the perspective of history of science, they arise out of an interaction between observations and generalisations collected and examined over centuries about the subject. For example, the theory of generative grammar has made use of rule systems of language from Pāṇinian traditions of grammar (ca 4th century BCE), Cartesian ideas about objects (16th Century CE), Port Royal grammar (17th Century CE) and European and American structuralist traditions of early twentieth century and ideas from logic and mathematics.

Fitting together various explanations is sometimes a problem that theories in linguistics face. It occurs within the field of linguistics as well as between certain parts of linguistics and fields such as philosophy, psychology and biology. For example, suppose psycholinguists, through a large number of careful experimental studies, have arrived at a theory of sentence processing. Then if we want to work towards a larger theory of

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17 Popper, Conjectures and Refutations, p 46.
language which also seeks to explain the use of language in a communicative sense, we have to place it beside theories of pragmatics and sociolinguistics and see how neatly they fit into each other. But is it necessary for all these to fit in with each other?

Similarly, if generative grammar has a goal of integrating with the natural sciences, we have to see the biological and physical reality of the computational rules proposed by the linguists. We will see later how it becomes a philosophical problem to juxtapose biological objects and real/platonic objects. Also it is a big challenge to understand how a formal science like generative linguistics can merge with biology.

An interesting question thrown open by the multiple dimensions of language – such as biological, social, semiotic, computational – is to what extent can one treat each of these inquiries as independent of the others. In the spirit of Quine's work on analytic and synthetic statements, such an inquiry is impossible.\(^{20}\) Quine (1951) wrote: "The unit of empirical significance is the whole of science." If we go by that, one cannot have a purely linguistic inquiry, independent of psychology, sociology, neurology and computer science. It would also be impossible to have independent inquiries of each of the sub-concerns within linguistics. If that dictum is adhered to verbatim, one would wonder about the validity of the enterprise of generative linguistics with its narrow focus on the syntactic computational system. However, if we function with such an assumption, no research could be done or no understanding arrived at. So for the practical functioning of epistemological enterprises, linguists accept the view of Gillies (1998) that 'a group of (scientific) statements' which is much smaller than the 'whole of science' is sufficient for arriving at significant additions to our understanding of language.\(^{21}\)

The idea that empirical adequacy is a sufficient condition for a theory to be correct is very important. The 'scientific community' involved in performing such research considers itself responsible for explaining why some structures are grammatical and some


others are ungrammatical. Linguists are expected to produce theories that account for the empirical facts surrounding grammaticality.

In linguistics, several instances could be found where the same set of data could be explained by different theories. In fact, this is fundamental to linguistic theorisation. In such situations, it becomes important to have some ways of determining which is the best possible theory among the available theories which explains a set of observations. Two criteria often invoked by linguists for deciding the best theory are economy and elegance.

Method as the Central Feature of Science

Method is considered central to the scientific enterprise. Scientific method is relevant to the context of discovery and the context of justification of scientific generalisations. Gower (1997) observes that a similar method is what underlies the justification of vastly different scientific beliefs such as Newton's laws of motion and the idea that acids are electron acceptors. The reason why scientific method is given so much importance is that it helps us understand how a piece of knowledge gets accepted as part of the larger system of knowledge of science. It also helps us arrive at decisions about whether certain scientific conclusions are justified or not. Gower's position is that in spite of their specificities, certain common methodological features underlie all scientific disciplines. What we aim to go through in this section are the key methodological concepts which have informed philosophy of science since time of Galileo, starting from the period that is associated with the scientific revolution.

Galileo (1564–1642) is often given the status of being a founding figure of modern scientific method, which involves a combination of experimental work and theoretical explanation. According to Gower (1997), his contributions in mechanics and astronomy involved important skills in constructing effective tools for observation. It seems partly he was following a Euclidean method based on a small number of axioms and deriving a large number of theorems from those axioms. This is also the method.

22 Gower, Scientific Method, p 7. Also, The base for the discussion in this section is Gower's Scientific Method.
Archimedes had used to found statics. Galileo's emphasis on properties that can be quantified was also a major new step in scientific method. This led to mathematics becoming an important part of scientific discourse. Galileo is also well-known for his unique rhetorical style as seen in *Dialogue concerning two chief world systems*, which was in the form of a dramatic dialogue, quite different from what is common in contemporary scientific writing.

Gower (1997) critically examines the general impression of Galileo being an obsessive experimenter throwing down weights from the tower of Pisa. The fact seems to be that Galileo relied more on thought experiments than real empirical tests. In his dialogue about the two world systems, the way he proves how the weight of an object does not have any effect on the speed at which it hits the ground is illustrative. In the narrative, which is very unlike modern scientific texts because of its dialogic style, this thought experiment is presented by the character whom we understand to be the voice of Galileo. He assumes that the opposite of what he aims to prove is correct; in that sense, he uses a proof technique similar to *reductio ad absurdum.* The initial assumption is that the heavier of the objects would move faster towards the ground than the lighter one. So if two stones are dropped from a height, the heavier one would hit the ground faster than the lighter one. Now comes the thought experiment. Imagine a heavy stone and a light stone that are tied together. Going by the logic of heavier objects moving faster, the heavier stone in the whole contraption would have the property of moving fast while the lighter one would have the property of slowing down the system. So it seems logical to conclude that the whole system would travel to the ground at a speed lower than that of the heavy stone taken in isolation and faster than the light stone taken in isolation. But if

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23 *Reductio Ad Absurdum* is a method of proof used in mathematics which starts with an assumption which is the direct opposite of what one is trying to prove. For example, to prove that the square root of 2 is irrational, one starts with the assumption that it is rational and can be represented as p/q, where p and q are integers which do not have any common integer factors and q ≠ 0. If the equation that arises from this assumption is squared, it would turn out that p^2 is an even number and hence p is also divisible by 2. That would, in turn, lead to the inference that q is also divisible by 2. That would contradict the assumption that √2 can be represented as p/q. From this result, we infer that the initial assumption we started with was wrong. Thus we conclude that √2 is irrational.
we look at the whole system, we would observe a problem with this explanation. Since
the whole contraption is heavier than both the stones taken in isolation, it should move
faster than both. This leads to a contradiction, which suggests that the initial assumption
was wrong. Gower reminds us that thought experiments, as they do not require any
specialised apparatus, have an advantage of being convincing to everyone who can think
of the situation under discussion.

Francis Bacon's (1561–1626) attempts to theorise scientific method by giving
primacy to experimentation and interpretation of experimental evidence is well-known.
Bacon's ideas about experimentation were enthusiastically accepted by the Royal Society.
Some rejected Bacon's methods based on trivial objections; but some other rejections
were more philosophically grounded – such as the way Spinoza rejected Boyle's
descriptions of chemical experiments by observing that they were not mathematical.
Though it might seem strange now, an experimental method of doing natural philosophy
– what science used to be called then – was considered almost heretical.

Bacon made a connection between laws in the legal framework and natural laws in
science. Natural laws were put in place by God for the functioning of the natural world.
The scientist who is inquiring into nature and the judge who is looking into a case need
witness to provide evidence in support or against the accused. By mere observation of the
witness, the judge does not get the necessary information. The witness has to be asked
certain direct and indirect questions so that the judge can arrive at the truth of a case.
Sometimes the witness has to be “put under pressure” in order to obtain the truth. This
analogy is useful to understand why scientists design experiments and create situations
which might seem unnatural.

Gower mentions Henri Poincaré's contribution of bringing to focus the importance
of probability in experimental science. Experimental science works, according to
Poincaré, by using a reverse probabilistic reasoning to infer the cause from a pattern of

24 Gower, Scientific Method, p 60.
25 For more on Poincaré's ideas on scientific method, see Henri Poincaré, Science and Method, trans.
results. His broader view of science was that it performed the dual functions of descriptions of reality as we perceive it and provide us with conceptual categories which help us make sense of reality.

Pierre Duhem has added crucial substance to how philosophers of science have thought about scientific method.\(^{26}\) According to him, hypotheses about reality are not an essential part of a physical theory. What a theory should do is to present and classify experimental laws in an economical manner. His view was that the Newtonian method is flawed. The flaw is illustrated using how the force of gravitation was first proposed. Newton's principle of universal gravitation was derived from Kepler's laws of planetary motion by focusing on its mathematical part. Kepler's laws were the mathematical representation of planetary motion. But Newton's principle, strictly speaking, contradicts Kepler's laws. That is because although a planet is attracted to the sun by a force that is directly proportional to the product of the mass of the planet and the mass of the sun and inversely proportional to the square of the distance between them, the sun is also attracted, albeit by a very small force, by the planet.

Truth has always been a contentious topic in science because there is no clear sense in which we can say that the way we access nature is true. This is because of various factors, ranging from the limitations of human senses to reliance on instrumental perception and the way we place unobservable entities in our understanding of nature. According to Duhem, a theory is adopted not because it is true. A theory is adopted, in Gower's (1997) words, for its 'systematising power', 'convenience' and 'simplicity.'\(^{27}\)

Duhem, in addition to his contributions to theory, is also credited for pointing out a special ability that a scientist or an experimenter should have. In addition to mathematical and experimental abilities, she has to be a good judge also, capable of interpreting available evidence without being partisan and by remaining committed to facts. Such ability to make good judgments is called a good sense, which cannot be

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\(^{27}\) Gower, *Scientific Method*, p 148.
clearly explained using reason.

According to Karl Popper, confirmations of a theory are easy to get. This is why he thinks that theoretical projects like Marxism and Freudianism are not sciences. You get confirmations for any behaviour using a Freudian analysis. So what advances a scientific enquiry are refutations and not confirmations. Hence, falsifiability is proposed as what draws a line of demarcation between a science and a pseudo-science. Confirmations are useful only when they show that a risky prediction that was not in line with a theory was proved to be correct.

Induction is an ampliative inference. It goes beyond the scope of the individual observations. That is also the problem of induction, originally attributed to the Humean idea that induction cannot be justified. Even if you have a large number of observations that confirm your generalisation, a single counterexample can upset your attempt to arrive at an explanation. Stating it logically would make it clearer. If \( p \) is a theory and \( q \) is a set of observations. The question then is what the relationship between \( p \) and \( q \) is. Because of the problem of induction, \( p \) does not entail \( q \). However, \( \neg q \) entails \( \neg p \). So when an observation does not fall in line with a theory, the theory is said to have been falsified.

\[
\text{If } p, \text{ then } q \text{ is not a correct logical relationship; however,} \\
\neg q \to \neg p
\]

Since Popper's proposal is underlyingly deductive, his falsification-based view is called 'deductivism' as opposed to naive or refined inductivism.

Popper goes on to claim that that a 'genuine test' of a theory is aimed at falsifying it. However, he does not completely rule out confirmations. He uses the word 'corroborations' in order to avoid the unwanted 'inductive' implications of 'confirmation'. What he means by a 'corroborating evidence' is an instance of failure in the process of a genuine attempt at falsifying a theory.

Linguists seem to take Popper's idea of falsification quite seriously. For example,
Crain and Thornton (1998) have an elaborate experiment design for a Truth Value Judgement Task which is aimed at testing children's knowledge of grammar. As the authors hold the innatist position regarding language acquisition, they make it a point to respect the criterion of falsifiability in order to avoid biased results and to maintain the idea that what they are practising is a scientific enterprise. What they do is to make the null hypothesis the one that is not in line with the innatist position regarding language; that is, they start with the claim that 4-year-old children do not have an innate knowledge of grammar. Clearly, their objective is to give scientific validity to their results by falsifying the null hypothesis.

Imre Lakatos, when compared to Popper, held a more realistic view of theories and research programmes. He shows us that the way research programmes really work is not based on a simple adherence to an idea like Popperian falsifiability. Scientists are hard in disposition and they do not throw away theories because a few facts that are inconsistent with the theory are found. This is where Popper's idea of falsification was wrong in the practical sense in which research programmes work. They do not get killed as soon as a piece of contradictory evidence is found. A research programme takes several years to get established. During that time, it comes across several difficult pieces of data, which are dealt with and explained without throwing away the theory. One of the interesting examples given by Curd and Cover (1996) while discussing Lakatos' work on research programmes was the observation of the movement of Uranus, which did not fit in with the prediction made by Newton's law of gravitation. Although it was a piece of recalcitrant data, it did not lead the scientists to abandon the gravitational law; instead the existence of another planet was predicted, which caused the irregularity in Uranus' movement. This prediction was borne true with the discovery of Neptune.

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Predictability is the sign of a good research programme. Lakatos discusses the example of Edmund Halley's work, which was within the Newtonian research programme. Halley made the successful prediction that a comet would approach the earth once in 72 years. This is considered to be a remarkable example of the success of a research programme. Lakatos shows that predictability is also a criterion which exposes a system of knowledge like Marxism as a “pseudo-scientific dogma.” It has made very bold predictions about societies and nations. Anyone who knows recent world history knows that all these strong predictions were proved wrong in very clear and dramatic ways. This is clearly consistent with his criticism of thoughtless adherence to any particular theory.

Lakatos, in his work that carried forward Popper's conceptual concerns, came up with the ideas of unprovability and improbabilities of all theories. No scientific theory can be proved in a perfect sense because theories aim to explain a large number of objects in the universe and hence are highly ampliative. For example, Newton's law of gravitation should apply to all objects at all times in the universe. It is impossible to make a very confident claim that there are no exceptions to the law. Similarly, if we try to compute the probability of any theory, we will be led to the answer 'zero' because probability is calculated by keeping the total number of possibilities in the denominator and the number of possibilities is large, tending to infinity. Even in the case of a large number of confirming pieces of evidence, it will be zero because the denominator will continue to be infinity. In that sense, all theories are improbable also. Interestingly, this has particular relevance to linguistics because languages have a great deal of diversity in terms of patterns of word formation and syntactic structures. Obviously this should lead to some amount of theoretical humility to linguists who work with particular frameworks and with a limited number of languages.

Lakatos asks what kind of a research programme eventually gets to be adopted by

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34 Ibid., 5, 6.
scientists. He says that most scientists choose progressive research programmes as opposed to degenerating ones. An important feature of a progressive programme is its continuing prediction of novel facts.\textsuperscript{36}

Lakatos' idea of research programmes seems very relevant to the generative linguistics enterprise. The programme has seen data that contradicts the theory, from languages such as those where there is no overt Wh-movement. But such data has not caused the rejection of the research programme; instead the workers try to strengthen the programme by fixing it so that such 'recalcitrant' data can also be explained. Some linguists have also given reasons for why they think they have chosen progressive research programmes instead of degenerating ones.\textsuperscript{37}

Thomas Kuhn, who was almost a contemporary of Popper and Lakatos, described the process of how scientific revolutions happen. By paying attention to the community activity of the institution of science, he challenged the epistemic high ground that science had come to occupy. Increasing number of observations of data that do not fit in with the widely prevalent paradigm leads to the rejection of the paradigm for a better one. That is how the Copernican and Einsteinian revolutions in physics are explained.\textsuperscript{38}

Feminist philosophers of science have pointed out that science works with an androcentric bias. Kathleen Okruhlik (1994) connects the idea of underdetermination of theories to the manifestation of this bias which reflects in the kinds of questions asked in science and the interpretations given.\textsuperscript{39} Different philosophical attempts have been made in order to understand and overcome these biases in science. The project of 'feminist empiricism' was aimed at showing that the male bias was not an essential part of science and hence sought to bring in true objectivity and thus save science from that bias. A

\textsuperscript{36} Imre Lakatos, “Falsification and the Methodology of Scientific Research Programmes,” p 33, 34.
\textsuperscript{37} The relevance of Lakatos' work is clear from the fact that his ideas were discussed in the academic blog of Norbert Hornstein, a generative linguist. http://facultyoflanguage.blogspot.in/2013/07/falsifiability.html last accessed 27 October 2014.
contrasting position was that the perspective of the knower was integral to what is known and as a result, the male bias is an inherent part of science as it is practised currently. The thinkers who held this position – 'the standpoint epistemologists', as they are called – posited that if nature is understood from a woman's perspective or 'standpoint', it would lead to a version of science that is superior to what it is today. However, this position was challenged by the fact that there is no single standpoint that can be associated with all women. The next option was to move to the feminist postmodernist view which accepted that perhaps objectivity is not a realistic aim in science and call for an embrace of diverse standpoints.

Similar questions have been asked about post-colonial narratives of science, as it has also shown a Eurocentric bias in addition to an androcentric bias. Okruhlik (in press) explores whether feminist narratives of science can inform post-colonial narratives. To paraphrase Sandra Harding, the conceptual associations connecting the terms 'science', 'rationality' and 'modern' are so strong in the imagination of an individual well-trained in the modern rational disciplines that the possibility of science in 'traditional' cultures is not even considered a possibility. This type of analysis raises questions about the claims of culture-neutrality of science. To be more pertinent to this work, it makes us ask how we can approach the epistemological status of studies of language which were relatively well-developed in South Asia.

The question of standpoint is of relevance to how modern linguistics is done. The types of questions asked and the way theorising is done seem to have a relationship to ethnicity, gender and the primary language(s) of the scientist, as we will go on to see in chapter 6. Such facts suggest that sociological factors are not merely of peripheral importance to a scientific research programme.

When we examine the history of science, another crucial fact regarding scientific

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method does not fail to gain our attention. There is no single method that is used by all scientific disciplines, at all times. This led to philosophers like Paul Feyerabend to argue that there was no single method that may be associated with science. Feyerabend's argument against a monolithic picture of science seems to be of great significance to linguistics which has social, biological, physical and semiotic dimensions. A plurality of methods seems to be in some sense a 'natural' choice for such a discipline. Feyerabend unequivocally states the following, which looks like a useful dictum for a linguist who is keen on making the discipline scientific by paying utmost attention to empirical data: “A scientist who wishes to maximize the empirical content of the views he holds and who wants to understand them as clearly as he possibly can must therefore introduce other views; that is, he must adopt a pluralistic methodology.”

Feyerabend's commitment to plurality goes beyond the lines drawn by epistemological concerns based on western rationality and touches other worldviews and systems of thought. This position, which seems to show respect for different indigenous groups and their knowledge systems, is much desirable in linguistics for various reasons – epistemological, humane and democratic.

A question pertinent to linguistics is how amenable the ontological status of its object of enquiry is to scientific method. Many of the points raised by these scientists and philosophers – Galileo, Bacon, Duhem, Poincaré, Popper, Lakatos, Kuhn and others – concerning experiments, interpretations of experiments, research programmes and claims of scientific revolutions are relevant to linguistics also. With psycholinguistics coming to play an important role in the discipline, its experimental method and analysis have to be seriously examined. Regarding scientific revolutions, skeptical linguists like Newmeyer (1986) have critiqued claims that some of Chomsky's followers have made regarding the Chomskyan programme as a scientific revolution.

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43 Emphasis in original
Using a persuasive rhetorical style is also an important part of scientific method. It is terse and is presented like a factual report. Using the apparently impersonal language of mathematics and diagrams, it tries to present its arguments in the most convincing style of writing. The use of effective vocabulary is an important skill needed for an experimenter.45

In chapter 6 (on supplementary issues), we discuss Locke's (1992) treatment of Galileo and Einstein as examples of remarkable rhetorical styles employed by scientists who bring in paradigm-shifting ideas.46 In that context, we will explore Chomsky's rhetorical style and examine how that contributed to his stature as a linguist who brought in a new paradigm of studying language.

*Deduction and Induction*

In order to explain a phenomenon, science uses a method of inference from individual data points to generalisations. Broadly, there are two types of inferences, namely deduction and induction. Deduction makes a statement within the scope of the information given in the premises, but induction goes beyond the individual pieces of information that are available. In this sense, deduction is non-ampliative and induction is ampliative. This exactly is the problem with induction. A very large number of observations of the type 'X is Y' does not validate our generalisation that 'X is Y' because at any point we might come across a piece of data that disconfirms the generalisation. The philosophically controversial nature of inductive reasoning led Popper to do away with

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45 According to Gower (1997), apart from Galileo, William Harvey, Joseph Black, Henry Cavendish, Jakob Berzelius and Michael Faraday were all very adroit rhetoricians.

the idea of inductive confirmation and place 'falsificationism' in that place. Inductive
generalisations can be statistical, as pointed out in Curd and Cover's commentary about
explanations where they discuss Scriven's example of a particular type of paralysis occurs
to 10% of individuals with untreated syphilis.47

It is interesting to look at how induction and deduction work with respect to most
of theoretical linguistics as it uses a formal, axiomatic and deductive method. Rules are
formally laid out in an axiomatic manner. The way it is arrived at shows a deductive
rather than inductive style. We start with accepting certain representation for linguistic
categories. Then we arrive at a formal representation for larger linguistic units based on
observations of particular points of empirical data. For a discipline with such a huge
volume of empirical data, it is not clear if this is the ideal method.

Some inductive generalisations are statistical. Corpus-based computational studies
of language come up with such generalisations. In the last one decade or so, experts who
work with statistical data have posed serious questioned against some of the founding
assumptions of generative linguistics such as the poverty of stimulus. Generative linguists
have been forced to respond to statistical studies addressing the question of the role of
input needed by the child learner to arrive at a language setting or to determine acceptable
usages in languages.

The data we look for in sciences are about the external world. In generative
linguistics, we work with the mentalist framework and what we are observing is within
our minds. The fact that it is an 'internalist inquiry' is what forces Chomsky to give
elaborate reasons for why such an enquiry is also naturalistic. In chapter 4, we will
examine the problems posed by such claims and question whether Chomsky's description
of language is correct in a real-world sense.

Quine-Duhem Thesis
The construction of a theory is based on less data than what is needed for a confident
assertion of it. This would entail that multiple theories are consistent with the same set of

47 M. Curd and J. Cover, Philosophy of Science, 775.
data. No theory fully captures a phenomenon by itself; it always assumes several conditions are satisfied. These other conditions can be thought of as auxiliary hypotheses, which go alongside the main hypothesis. It is impossible to test a scientific hypothesis (which eventually might become a theory) in isolation because every hypothesis assumes one or more auxiliary hypothesis. For example, Newton's laws of motion work only in certain ideal conditions, which include a frictionless plain.

Auxiliary hypotheses have a role to play in linguistics. Sometimes when a theory does not explain empirical data, auxiliary hypothesis are resorted to. The auxiliary hypotheses in conjunction with the main hypothesis would explain the data. For example, in the double object construction which is discussed in chapter 5, the main hypothesis may be that every noun phrase needs a case; the auxiliary hypotheses may have to do with the existence of two types of cases – structural and inherent – and the requirements for structural configurations under which cases are assigned.

In linguistics, the idea of which theory is to be accepted as the most correct often comes up. A theory in linguistics is generally expected to satisfy three conditions – economy, motivation and predictiveness. The economy condition demands that the account be simple and it involves a minimum number of assumptions. For example, if we need to assume the presence of the god 'tojo' in the seventh heaven which is 8 angel-years away from the sun in order to explain a pronominal interpretation, then it is not an economical theory. The second condition requires that the explanatory category that is employed be independently motivated. So using these two conditions, a theory that explains a number of constructions at the same time would be more desirable than something that gives separate accounts for each construction. The third condition stipulates that the account be useful for predicting newer data.

*Inference to the best explanation*

This way of arriving at an explanation is also called abduction. It works in a way that is

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similar to deduction, but it is faithful to empirical data. So the explanation is deemed best, in light of the set of observations made. Interestingly, scholars like Sarukkai (2005) have noted that this is similar to certain explanatory models followed in Nyaya system of reasoning. Its application in linguistics seems to be a little doubtful, especially given the fact that authors like Deutcher (2002) have pointed out its irrelevance in certain explanations by showing that the invocation of 'abduction' to explain certain linguistic phenomena have been a red herring.

**Prediction**

The ability to make predictions is an important part of science. Theories help scientists to make predictions. Scientists make observations about nature and arrive at generalisations. Such generalisations help you make predictions about future or unknown things. For example, using Galileo and Newton’s equations of motion, one can predict the position of a body at any time, given its position at time 0, initial velocity and acceleration.

Hempel's view on this is that there is a symmetry between explanation and prediction. A good explanatory account has a predictive value also. However there are domains such as evolution in which explanation works, but prediction does not. An evolutionist cannot predict how a particular organism would evolve in the next millions of years. In chapter 5, we will see a similar problem in the domain of language change.

Predictions do not need a comprehensive explanatory system. A good classificatory system will have the same effect. Looking at the regularities of the periodic table, Mendeleyev was able to predict the existence of certain chemical elements which were later discovered. The chemical behaviours of elements are predicted on the basis of their position on groups (or columns) in the periodic table. Taxonomic systems, like the Linnaean one and the periodic table, help us make predictions. In linguistics, a

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taxonomical arrangement based on phonetic features help us make predictions.

**Realism and Anti-realism Debate**

A realist commitment entails a belief in the truth claims relating to an entity. But very often philosophers of science are non-committal about whether theoretical and unobservable entities are truly present or not. In that sense, they are antirealists. Two points are usually brought up in relation to this. One is the theoretical nature of even observable entities. The second is the position that you can think that a theory is correct even if you concede that you are not sure of its truth; what makes you accept the theory is that it is consistent with the empirical data – that is, its 'empirical adequacy'.

van Fraassen (1980) offers a critique of the main arguments for scientific realism. Scientific realism, in the parlance of philosophy of science, refers to how a scientific theory is to be made sense of. There is a sense of relating scientific realism with a commitment to truth. Since the progress of science involves unending “self-correction”, it probably is not correct to think that scientific realists really believe in the absolute truth of any particular scientific statement at a given time. After engaging with the idea that a plausible reason for thinking that a theory is correct has to do with getting convinced about the existence of the entities postulated by the theory, he goes on to redefine scientific realism: “Science aims to give us, in its theories, a literally true story of what the world is like; and acceptance of a scientific theory involves the belief that it is true.”

Anti-realism is broadly about a lack of commitment to the literal truth of a scientific theory. Realism in science indicates independence from other factors of the object of enquiry whereas anti-realism is associated with the dependence of the object on the subject or the instrument used for observation. While a realist thinks that the statement of a theory implies an assertion of the truth of theory on the part of the theorist, an anti-realist thinks that the theorist displays the truth of theory and claims certain positive

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van Fraassen's position is that a theory should be literally interpreted; at the same time, it need not be true. As he holds the position of a literal interpretation, he is neither taking a positivist position nor an instrumentalist position. He refers to his position as 'constructive empiricism', which means that a theory is correct if what it says about the observable world is true. Anti-realism is consistent with a coherence theory of truth because if a proposition is part of an overall belief system, it can be true even if it cannot be verified independently.\(^{53}\) Researchers often consider models as “tools for thinking and calculating.” In that sense, models are instrumental.

**Truth**

The idea of truth is central to science. A widely accepted notion is that science is a dispassionate pursuit of truth. The objective of truth is supposed to bring in a high moral quality to scientific pursuits. The idea of truth in science does not merely confine to what can be verified using perception. The truth of unobservable entities can be established when certain theoretical predictions are confirmed or disconfirmed using experiments. The question of the reality of unobservables such as atoms is a problem. They can be established only by testing the empirical laws which presuppose their existence.

The idea that there can be objects in the world that are not perceived by senses is the philosophical position of indirect realism. For example, the presence of an electron was inferred from the appearance of a ray emitted from the cathode in an experimental setting. Another example is the verification of the theory of relativity, which happened about fourteen years after the theory was proposed. Einstein's prediction about the measurement of deflection of light from a star because of the sun's gravitational force was found to be correct and this was a confirmation to the theory he had proposed.

Usually theories are claimed to be true by scientific researchers. No other researcher is obliged to accept it. Theoretical solutions and experimental results are never

\(^{53}\) The theoretical context seems to largely determine the meaning of an entity. This idea, which is also associated with theory-ladenness, can be illustrated by the fact that 'mass' has different meanings in classical physics and relativistic physics. See page 49 for Sarukkai's (2012) discussion of that.
considered to be beyond critical examination; questioning authority is a central part of the practice of science. Sarukkai (2012) notes that the only authority for science is the world as it is. If we apply this principle to linguistics, nobody can by diktat tell us what kind of language data is to be used for scientific analysis. All data in the world relevant to language is available for scientific use. If certain specifications are made about the type of data to be studied, such as Chomsky does, it can be argued to be against the spirit of realism that science is committed to.

The idea of truth in science is intimately linked to the notion of reason because the accepted wisdom in philosophy of science is that conclusions are arrived at using a deductive-nomological mode of reasoning. According to the deductive nomological method, we arrive at scientific truths such as laws using syllogistic reasoning from a number of premises (for syllogistic reasoning, there should be at least two premises) – at least one of which is a law. Since every human being is assumed to have the right and ability to reason, it does not make sense to say that there are individual or cultural variations with respect to truth. The collectivity of scientists has to be convinced of a fact or an explanation for it to be called a truth. For example, biologists often talk about evolution being a fact as well as a theory. In either case, the community of biologists have agreed to accept both the propositions as true. Thus these 'truths' transcend the status of mere individual beliefs held by particular scientists. The notion of a collective acceptance is key to understanding the concept of scientific truth.

Science's concern is understood to be fundamentally about truth. It tries to truthfully describe nature. All its claims are supposed to be verifiable. The word 'verifiability, which is often associated with science, has its origin in the Latin 'veritas', which means truth. A preliminary understanding about truth is that it refers to that which can be perceived by our senses. In that sense, it is connected to an empirical approach to knowledge. Because we make sense of the world through our senses, it was thought that a statement can be said to be true only if it can be verified. But a serious problem with this
view is that there is no way human beings (or any organisms) can be absolutely confident about the truth of what they perceive through their senses. This is because our perceptions are limited by the physical limitations of our sense organs and their neurological correlates.\(^\text{54}\) So we cannot with any level of confidence assert that how we perceive is how the world actually is.

One influential idea of truth was the requirement that a proposition correspond to a fact. In other words, the truth of a proposition marked its relationship to the world. Another idea was that a true statement is not seen in isolation; it is part of a larger system. A true statement has to make sense or to cohere within the larger schematisation of knowledge. A third notion of truth is to think of it as a system of beliefs in the mind, which constitutes the world. The coherence theory is clearly connected to it because any single belief in a whole system would have to be true if the system as a whole is true. Yet another approach is a practical one towards it, marked by the premises that truth marks the end of an enquiry and truth is that which is satisfactory to believe.\(^\text{55}\) It is important here to note that the initial idea of mapping a proposition to the world is essentially the notion of reference, which is the starting point of discussions on linguistic meaning.

Tarski’s theory of truth tried to connect truth to mathematical logic. The system consists of basic propositions and operations that connect these propositions. The natures of these operators and the truth values of the initial propositions would determine the truth values of the larger propositions. Stated in terms of logical operations performed on propositions, the truth value of a sentence which can be logically represented as derived from one or more basic propositions can be fully computed without any reference to the real world context.\(^\text{56}\) This is particularly relevant to linguistics because this notion of truth

\(^\text{54}\) In other words, we are working with certain a priori systems which we have no escape from. What I understand of this Kantian idea is that what we perceive is neither the world as it is, nor the creation of our minds. What is in the real world is filtered through the perceptive and cognitive systems that are biologically available to us and the result of that filtering is what is available to us. The idea of a priori systems is very significant for this work because the Chomskyan position is based on an innate and a priori system of language which human beings are born with.


\(^\text{56}\) This also seems to be the underlying logic behind asking for people’s intuitions about the meanings of
was used later by Davidson to work out a notion of meaning in language. The mathematical method used was to make a word to world mapping at the level of the basic unit of the word and then combine words to form phrases by a process of function application. The phrases then combine to form sentences and finally the truth value of the sentence is arrived at, thus the truth of a sentence is worked out to be a truth of mathematics.

Realism and truth have an intimate connection because the former is defined in terms of truth and reference. Thus the correspondence theory of truth which essentially looks at the word-world relationship is fundamentally based on the external and independent presence of objects in the world. Another notion of truth is the idea that a proposition that holds good in a coherent explanation of facts is considered true in a theory-internal sense. This is related to the idea of structural realism. In this line of thinking about truth, there is no absolute sense in which a theory is true; what it would mean is that it makes the correct predictions with regard to the observations made.

*Laws*

Among the several features associated with science, laws are quite prominent. Observations of nature lead to the postulation of concepts. One salient feature of these concepts is that they are measurable concepts. So if a scientist feels that there is a pattern in the way in which the numerical values corresponding to the concepts relate to each other, she would make the hypothesis that a mathematical relationship exists between the two. Then she would verify or disconfirm the hypothesis using more data. Once the mathematical relationship is established, it comes to be called a law. Boyle’s law, for example, states that the pressure of a fixed amount of gas is inversely proportional to its volume, with the temperature remaining constant. Notice that a law also specifies the conditions under which a law holds. It is also important to underscore the fact that the relationship is stated in a mathematical language. The special feature of a law is that it has individual sentences in isolation, an experimental method adopted in generative grammar.
universal applicability. Holton and Brush (2001) compare it to a fishing net,\textsuperscript{57} which tries to catch as much fish as possible because a law tries to capture all the relevant data in a simple statement or a mathematical equation.

Laws are essential markers of disciplines that aspire to the status of science. They are often considered necessary parts of scientific explanations. They help us characterise a large set of data in a simple way and predict certain phenomena. This belief lies at the core of how scientists and philosophers of science think of science. At the same time, an elucidation of the nature of laws has also been a matter of some difficulty. First of all, the belief that laws are essential markers of science have been challenged by the proliferation of 'scientific’ disciplines. Even in chemistry and biology, the nature of laws seem to be quite different from that of physics. Within the set of laws in physics, there are different types of laws, fundamental and phenomenological laws. moreover, many times it is unclear what kind of entities are laws given that physics has many terms that lawlike such as principles, equations and so on. When relationships are expressed in the form of a mathematical relationship, it is called a functional law.\textsuperscript{58} An important point about laws is that they need not always express a causal relationship. They can be stated in the form of equations, such as the equation for the ideal gas law. Such laws are called functional laws because they are stated in the form of mathematical functions.

There does not seem to be clear consistent classificatory criteria that distinguishes between principles, equations and laws. The famous energy-mass equivalence is called an equation, the fundamental equation in quantum mechanics is Schroedinger's equation while important principles include the uncertainty and exclusion principles. Are these equations and principles equivalent to laws? if so, how do we then create a typology of laws which include a large number of statements which are lawlike?

First, we can consider fundamental laws. For example, Newton's law of universal

\textsuperscript{57} Holton and Brush, in \textit{Physics, the Human Adventure} (Rutgers University Press, 2001) indicate that scientific laws emerged in the west and not in any other society which were quite advanced in their intellectual pursuits because of a predominant belief in laws governing nature and society.

\textsuperscript{58} 'Functional' because it is stated in the form of a mathematical law.
gravitation states that:

Every point mass attracts every single other point mass by a force pointing along the line intersecting both points. The force is proportional to the product of the two masses and inversely proportional to the square of the distance between them. It is represented by the equation: \( F = \frac{Gm_1m_2}{r^2} \).

As an example of a different kind of law, we can consider the Periodic law in chemistry:

The physical and chemical properties of the elements recur in a systematic and predictable way when the elements are arranged in order of increasing atomic number.

The periodic law, unlike the fundamental law which captures the universality of a particular phenomenon, is a law of arrangement. While it may be derivable from more fundamental principles, its purpose and force is in discovering certain patterns. The fact that these patterns are about natural phenomena suggests that there is a natural law which makes this pattern possible. Another set of laws that are influential in chemistry are the ideal gas laws, for example, \( PV = n RT \). This law captures a relation between an ideal notion of Pressure and Volume of an ideal gas – a gas that is modeled as a collection of smooth billiard balls moving without friction either in the air or in collisions with each other and the walls of the container.

As a good example of a law in biology, consider Mendel’s law of segregation, stated the following way: *Allele pairs separate or segregate during gamete formation, and randomly unite at fertilization.* The idea behind the law is that every individual possesses a pair of alleles (assuming diploidy – the presence of two sets of chromosomes) for any particular trait and that each parent passes a randomly selected copy (allele) of only one of these to its offspring. The offspring then receives its own pair of alleles for that trait. Whichever of the two alleles in the offspring is dominant determines how the offspring expresses that trait.

What kind of a law is Mendel's law? This certainly does not express a quantitative relationship like many 'functional laws' in physics. First of all, this example shows what is special to all these cases of laws described above. This law is firstly possible only if appropriate concepts like ‘allele pairs’, ‘gamete formation’ are known. The discovery of
appropriate concepts and properties is as important, if not more, as discovering laws.

Mathematics also shows many examples of lawlike structures. Goldbach’s conjecture about the distribution of primes that differ by two, is lawlike in that it describes a pattern among numbers. In a sense, just as chemistry or physics discovers patterns among the entities which they study, so too does mathematics discover many patterns that are recurring and repetitive, and such relations do seem lawlike. Fermat’s theorem is also a ‘law’ that captures a very interesting relation between numbers. Similarly the Law of large numbers states that “the average of the results obtained from a large number of trials should be close to the expected value, and will tend to become closer as more trials are performed.” This statement can be seen as not merely being about a pattern but about some other property of large numbers. However, it may not be really useful to characterise mathematical statements as laws since every such statement will be lawlike.

Linguistics has a law similar to this one. It is universal and it is stated using the mathematical relationship of proportionality. According to this law proposed by the linguist George Zipf, the frequency of any word in a language corpus is inversely proportional to its rank in the frequency table. For example, the word which is ranked first in the frequency table arranged in an descending order of frequency, is the highest frequency word and its frequency would be double that of the word that is second, which would in turn be significantly higher than the third and so on. What is really interesting is that this is an exponential distribution and because of the really high numbers of the highest frequency words, just above 100 words would account for more than half of a corpus in a language.\textsuperscript{59} This is similar to, and follows the same pattern as, the global distribution of wealth. The observed fact is that a very small percentage of the world population controls a huge chunk of resources of the world. Because of the occurrence of this pattern in other realms as well, Zipf’s law cannot be considered to be one that is unique to linguistics.

\textsuperscript{59} Just 135 words take up 50% of the Brown corpus in English.
Using the example of the inverse square law of gravitation, Cartwright (1980) shows that when a law becomes descriptively more accurate, its explanatory power diminishes.\textsuperscript{60} The descriptive power can be increased by specifying the other forces that influence the attraction between two objects, such as the inverse square law involving charges. But the addition of these other factors would result in the undesirable outcome of making the statement a less succinctly explanatory one. So Cartwright does not think of laws as exceptionless regularities, but instead as statements that signify causal powers.

\textit{Laws of Science}

There are many interesting views on the nature of scientific laws. Scientists, on the whole, seem to believe in the reality of laws. They tend to understand laws as real ‘forces’ in nature which govern natural phenomena. The idea that laws are governing principles of nature is deeply prevalent among scientists. However, such a view of governance or even of laws as being real in nature leads to serious philosophical problems. First of all, laws seem to be relations; what does it mean to say relations are real? If one understands laws as a ‘force’, a literal reading of the gravitational and electromagnetic forces, for example, then that leads to a different kind of problem. Even if we accept that these forces are real, how does it make the laws real? The idea of governance is more problematical since that implies some notion of agency to nature. Thus, although laws are so prevalent in the discourse of science, the nature of laws continues to pose important philosophical challenges.

The explanatory power that scientific laws have because of the fact that the necessary generalisations resulting from their dispositional properties need to be contrasted with accidental generalisations. Lange (2007) demonstrates the difference using the following example.\textsuperscript{61} It is a necessary generalisation that if a powder burns with yellow flame, it has to be a salt of sodium. However, it is an accidental fact that all the families in Lange's block have two children and his spouse and himself also have two

\textsuperscript{60} Nancy Cartwright, “Do the Laws of Physics state the Facts?” \textit{Pacific Philosophical Quarterly} 61 (1980) 75–84.

\textsuperscript{61} Marc Lange (ed.), \textit{Philosophy of Science: An Anthology}, (Malden, MA: Blackwell, 2007).
Thus the explanation that Lange has two children because every family in the block has two children cannot be a law.

Another interesting illustration of the contrast between an accidental generalisation and a necessary generalisation is the difference between the statements 'There exists no gold cube whose volume is more than a cubic mile' and 'There exists no uranium cube whose volume is more than a cubic mile'. The first one is an accidental generalisation related to the amount of gold on the planet and the second one is a necessary generalisation relating to the phenomenon of radioactivity. This again shows the importance of 'necessity' for universal laws.

Explanations can be stated in universal or probabilistic forms. In either case, an event is explained using laws. In both the cases, a deduction happens from two or more premises one of which is a law. In the former, the law that is referred to is stated in a universal form and in the latter, the law that is referred to is stated in a probabilistic form. Laws stated in universal form or universal laws are discussed under D-N model of explanations.

Laws are often present in science without being necessarily called 'laws'. Thus, equations like Einstein’s equation relating energy and mass or Schroedinger’s equation, and principles such as Heisenberg's Uncertainty Principle and Pauli’s principle also qualify to be laws. The fact that they are not called laws do not lead us to conclude that they are not laws.

There are basic elements of laws – they are global, they do not have indices like space, time or location, they are applicable across a wide variety of phenomena, and sometimes capture concomitant relations but other times suggest causal links between the terms occurring in laws. As mentioned earlier, they also do an important job of explaining phenomena in two ways at least: one, they provide explanations for counterfactuals and two, they are an essential ingredient in explanations as in the Deductive-Nomological

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However, a moment's reflection would tell us that the 'two children phenomenon' has much to do with a particular liberal democratic vision of families which sought to balance available resources with proper infra structure conditions for growth of children.
model of scientific explanation. In the case of the latter, explanation in science is a deductive conclusion of a set of premises which include lawlike statements. The implication of this is that scientific explanation is grounded within the nature of a law. Although there are some critiques of this position, it is worth considering how the idea of law seems to be closely related to certain types of explanation.

Universal laws escape the problem of induction because of the necessary nature of the relationships they describe. Irrespective of whether they came into being by an inductive process or by mathematical operations, they are necessary and universal. Ramsey (1928) described universal laws as similar to axioms in a deductive system. One way to understand this is to think of an idealised system in which laws are axioms from which truths can be deduced. Idealised models seem to be necessary for laws and their mathematical formulations. Such models seem to work well for physics and less so for disciplines like biology. They do not seem to be quite suited for special sciences such as psychology or linguistics. The use of such models seem almost verge on the ridiculous when it comes to disciplines such as literary theory or aesthetics. Probably the reasons why ideal models seem to be far-fetched for these disciplines must be the complexity of the phenomena they study and almost non-applicability of the notion of causality in them. On the other hand, probabilistic laws relate to data collected inductively. That is, patterns of occurrence are noticed when we make several observations. In that sense, probabilistic laws subsume induction.

The question of whether laws are true is often raised by philosophers who have opined that they are false as statements about the world. But Lange (2007) again notes that they “accurately describe certain scientific models that explain the behaviour of certain real systems.” Possible examples for such real systems are motion of objects explained by Newton's laws and ideal gas laws, which though 'ideal', help us understand

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64 Marc Lange, (ed.) Philosophy of Science: An Anthology.
the behaviour of real gases. This also seems to be the sense in which principles in generative grammar can be understood within the idealised model of grammar assumed by its proponents.

Laws in science are also very varied. There are fundamental laws like the laws of gravity and charge, and there are various other phenomenological laws which capture relations between different scientific properties of particular phenomena. Many laws, like the ideal gas laws, are actually about the relations between terms in an ideal model and not in the world as such. Thus, the ideal gas laws describe a relation between pressure and volume for instance, but this relation holds only under ideal conditions such as the model of molecules as smooth billiard balls, absence of friction and so on.

Laws in chemistry differ quite significantly from the fundamental laws in physics. While there are some common laws such as the very important principles of conservation, there are also chemical laws that are more like rules. Both in chemistry and physics, there is another interesting problem: along with well-known laws, there is a plethora of principles and equations which are lawlike but are not explicitly referred to as laws. For example, uncertainty principle in quantum mechanics or the mass energy equivalence relation function \( E = mc^2 \) like laws for all purposes. In biology, the problem becomes more complex and philosophers of science have pointed out repeatedly that laws in biology function in a way very different from the laws in physics or chemistry. If we consider laws in other scientific disciplines then the problem is more acute since a clear characterisation of laws does not seem to be available across various scientific disciplines.

However, laws are essential to the discourse of science. Independent of the structure of particular laws, what is most important to laws is that they capture a truth about nature which is necessary for science. Laws describe and sometimes explain the regularities of natural phenomena. They explain the relationship between certain properties and also describe the formal structure of this relationship. The fact that laws
are most often expressed in mathematical terms is only an illustration of this capacity to capture the formal elements of the relationship captured in laws.

Post-hoc explanations are considered to be problematic because they do not make predictions. But as indicated earlier, in disciplines such as evolutionary biology and historical linguistics, prediction does not work in the sense of Hempel's view of symmetry between explanations and predictions. Post-hoc explanations result in two situations – (i) when there is little preliminary analyses and classifications or (ii) when the observed data do not conform to the preliminary analysis.

One of the most important sets of laws that are of fundamental importance to physics, chemistry and biology, is conservation laws. These laws range from conservation of mass/energy to conservation of quantum numbers such as leptonic numbers. These conservation laws revolutionised modern particle physics since they were discovered to be consequence of underlying symmetries of nature. Specific symmetries of nature are associated with specific conservation laws. This is yet another way to see the importance of laws since they seem to capture some essential properties of nature and through this process also explain why certain conservation laws hold.

While the examples above have largely been taken from physics, we can look at the long list of laws in other disciplines such as chemistry, geology, biology and so on. As Lange points out, even if there is not much in common among all these ‘laws’, the idea of a law is powerfully embedded in the scientific enterprise.

There have been two approaches towards understanding laws – regularity approach and necessitarian approach. Dretske's idea is that laws are relations of necessitations between universals. However he holds that laws of nature are contingent, not necessary. It is challenging to understand how relations can be contingent between universals.

We can probably bring in a necessitarian vs regularist view of laws here. Swartz starts with an interesting observation that the necessitarian view is a modern version of
prescriptive laws, which are seen in religions. He gives the following definition for the regularist and necessitarian views:\(^{65}\)

Regularist: Physical laws derive their truth from the actual (i.e., instanced) connections (between states and between events) in the world. Physical laws, therefore, express only what does occur.

Necessitarian: Physical laws (and antecedent conditions) determine which connections can and cannot occur; physical laws, that is, express what must occur in particular circumstances.

Upon first inspection, linguistics seems to have both types of laws. Phonological rules seem to support the regularist view of laws and binding principles seem to support the necessitarian view of laws.

**Laws in Linguistics**

When we examine sound change rules in historical linguistics and assimilation rules in phonology, we often note that generalisations are often not exceptionless. Also, the fact that generalisations in linguistics are not often stated in mathematical terms make them appear very different from those in physical sciences like physics and chemistry. A possible response to this charge from linguists could be that there are different kinds of laws in different disciplines. For example, laws in biology, such as Mendel’s laws, are not mathematical relationships between concepts. Instead, they are statements about how hereditary characteristics are passed on from one generation to another. But again, we can respond to our indignant linguist by pointing out that Mendel’s laws are universal and not a set of statements about just one species or class.

Modern linguistics of the Chomskyan or the generative variety has proposed structural principles or conditions governing the interpretations of pronouns and reflexives (pronominals). Basically, they state the domain or locality in which a pronominal is free or co-referential. The variation in the domain depends on whether the pronominal is a pronoun or a reflexive. They are called the conditions in *Binding Theory*, following the idea that a pronominal is bound to a proper name for its interpretation.\(^{66}\)

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\(^{66}\) Pronouns like *he, she, it* or *they* may also be interpreted deictically; the binding theory considers only the non-deictic or referential cases where the original referent of the pronominal appeared in the
These conditions are said to hold good across languages. Empirical studies on these conditions suggest that structural constraints such as C-command determine the interpretations of these words.\(^\text{67}\)

The field of linguistic typology has carried out detailed comparisons of structures of different languages. Those studies have led to interesting empirical generalisations. Greenberg (1966) has revealed certain implicational relationships between two properties of languages.\(^\text{68}\) These ‘implicational universals’ are often stated in the form, 'If language P has property X, it will also have property Y.'\(^\text{69}\) Although these generalisations cannot be possibly considered laws, they need to be paid attention to because they claim to be universal, which is an important feature of scientific laws.

So why is it that linguistics does not seem to have the kind of universal laws that physics or chemistry does? One possible reason could be that accounts of ‘language’ which transcend the analyses of the grammars of particular languages are a fairly new development in the history of the already young discipline and perhaps as the field evolves, laws may come into being. Another possibility is that it is a totally different kind of field which works with other kinds of explanatory categories such as social structures. They are obviously based on biological foundations, but as Jones (2003) points out, not reducible to biological categories.\(^\text{70}\) Universality applies to language at least to the extent that all languages seem to have word classes, phrases whose heads are nouns or verbs, a set of speech sounds that it makes use of, possible syllabic structures along with consonant clusters and word-formation processes. But the existence of such universals does not amount to being laws because laws are more specific generalisations. For example, in the domain of word formation, if we go beyond saying that there are word

\(^{67}\) C-command is defined earlier. See footnote 51 on page 61.


\(^{69}\) Sometimes property x maybe associated with not just a second property y, but also a third property z, as in the case of 'universal 24' discussed on p. 225.

formation rules by making a specific claim about a process which applies to all or a large number of languages, it might be a contender for the status of a law or a lawlike generalisation. Chapter 5 is devoted to a more detailed examination of laws and lawlike statements in linguistics.

Reductionism

This is the idea that a discipline can be reduced to another one by going to more and more fundamental levels of explanations. In that sense, psychology can be reduced to biology, biology to chemistry, and chemistry, in turn, to physics. Fodor (1974) discusses the question of reductionism in detail in relation to the special sciences.\(^71\) One can infer that he is addressing the problem of non-physical sciences such as psychology and linguistics. He considers the question of whether any law in the special sciences should be reduced to a law in physics. Using various reasons, he argues against the assumption of the unity of sciences. His main argument is based on the idea that generalisations in special sciences are not seen to correspond to physical descriptions. Further, there may be generalisations that are explanatory and interesting within the special science but do not provide an interesting description in physics. He discusses a law called Gresham's law which is about monetary exchanges. It gives an interesting explanation of exchange of money in economics, but when considered in physical terms, it ceases to be of interest.\(^72\) It is an example that is perhaps relatable to linguistics in the sense that the abstract formal explanations of something like double object constructions (discussed in chapter 5) is perhaps not at all relevant in a physical sense.

The Role of Literary Imagination

Very often in science explanations are thought of as 'stories' that explain data. We can think of theoretical entities as characters that play roles in the phenomenon that is studied. At a more basic level also, fictional imagination is at work. Sarukkai (2012) shows that


\(^{72}\) Modes of exchange such as electronic, currency or coins have nothing to do with the explanation given by Gresham's law.
some of the basic concepts of physics and mathematics are largely fictitious. He illustrates this using the concepts of space and time in physics and the ideas of infinity and complex numbers (combinations of real numbers and an imaginary numbers) in mathematics and in turn, physics too.

Generative grammar often works with assumptions that are presented as logical necessities. It is not often clear if the categories that arise from such assumptions are absolutely warranted. The competence-performance distinction made while building up the basic premises for a science of language is one such assumption. Another case in point is Chomsky's presentation of ideas such as 'merge' and 'move' as the basic operations which form part of the faculty of language, also connecting it to fundamental physical principles. Generative linguistics often comes up with imaginative solutions to problems. But like natural sciences, it does not make it explicit that fictional imagination a part of its methodological toolkit.

**Application of Mathematics**

Scientific descriptions are expected to be impersonal and objective. A way to ensure it is by bringing in the supposedly neutral and unbiased language of mathematics. This is to keep subjective factors out of the discourse of science. With some sciences, like physics, mathematics seems to be a highly efficient tool. There is a widely accepted belief that mathematics is unreasonably effective in handling disciplines such as physics. Scientific abstraction goes hand in hand with mathematical formalism. Constructs of pure mathematics such as imaginary numbers seem to be particularly effective in quantum theory. Also, irrational numbers such as π and e are often used in equations in physics.

Mathematical entities, such as numbers and operators, are considered to Platonic entities which do not have any connection to the real world. So the fact that mathematical tools are very effective in a discipline such as physics, which tries to describe the real world, has puzzled some philosophers of science. One view of this is that mathematics is

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73 Sundar Sarukkai, *Translating the World: Science and Language*, (Lanham: University Press of America, 2002), presents a different position on the use of language in science. His point is that by using multiple sign systems, science produces rich and complex narratives about nature.
an ideal type of language to describe the physical world.

Sarukkai (2012) notes the following about the contributions of Galileo and Newton to modern science, specifically physics.\textsuperscript{74} The Galilean revolution in physics was to bring in the language of mathematics to descriptions of nature in a significant way. Newton's attempt was to make descriptions of nature precise and unambiguous. This has great relevance to linguistics because Chomsky attempts both these – mathematisation by bringing in a formal language based on set theory and precise description of the object of enquiry. Two issues have to be discussed here: the first, about arriving at the right kind of operations for developing a better understanding of the phenomenon you are studying and the second, about making abstractions that help us make precise descriptions.

First, let us look at arriving at new operations. If mathematics was at a different (and more rudimentary) stage where there were just numbers and operations like addition and subtraction with no multiplication or division, the Newtonian relation $F = ma$ or the equation of motion $S = ut + \frac{1}{2}at^2$ could not be arrived at. This aspect of mathematics could help us understand the relevance of operations such as C-command in syntax because it probably reflects the level of refinement in terms of formalisms that can be attained in linguistics at this point.

Now let us look at why scientific theories use a method of abstracting away from all aspects of reality. Some aspects of reality complicate the picture and make the subject difficult to engage with. Most often it is because the facts involved are not easily amenable to mathematical descriptions. For example, consider the idea of point masses in physics. Sarukkai (2012) notes that Descartes or Galileo could not arrive at Newton's formulations about falling bodies or the precise relationship between force, mass and acceleration because the former scholars worked with a notion of extended mass and not with a point mass assumption of Newton's, which helped him immensely on working out a mathematical model.

Sarukkai, in his discussion of the effectiveness of mathematics in science,
summarises the four broad approaches to philosophy of mathematics which are relevant when we try to understand its application in science.\textsuperscript{75} They are platonism, formalism, intuitionism and the idea that mathematics is a language. The platonist view is that mathematical entities exist in a different dimension outside reality. According to formalism, the central fact about mathematics is that it is about symbols and the operations that you perform on them. Intuitionism is associated with a commitment to the \textit{a priori} truth of mathematics. The idea that mathematics is a language combines aspects of formalism and anchoring mathematics in reality. Chomskyan linguistics calls upon both formalist and platonic approach and later, in chapter 5 on laws, we show how they have an impact on the practice of generative linguistics.

In his discussion on the application of mathematics in science, Sarukkai (2012) notes that mathematics is applied not to phenomena, but to descriptions of phenomena. Since descriptions are linguistic, what seems to be the case is that mathematics is applied to language and not to the world.

**How Linguistics Fits in**

*The Object of Inquiry in Linguistics*

The main object of enquiry for the discipline is language. There are several sub-objects such as phonemes, morphemes, words, phrases and sentences. Linguists also deal with concepts like nouns, verbs, adjectives, topic, focus, pidgin, creole, speech community, dialect, idiolect, competence, performance, sign and signified. In science, the objects that are studied are expected to be real. Let us try to look at the simple case of a word. Is a word a real object? Intuitively, there seems to be a belief that words are real.

What really is the object of our study when we are studying language? Language fundamentally seems to be about the relationship between sound and meaning. Beneath this broader insight, what does the subject do at a micro-level? It studies a vast array of things concerning language ranging between the nature of speech sounds to meanings to

the mapping between language and mind and the correspondence between parts of brain and 'modules' of language.76

As pointed out earlier, there is a huge variety of topics studied under linguistics. Phonetics and phonology study the place and manner of articulation of speech sounds, their variations depending on the phonetic contexts, stress patterns, intonations and the acoustic properties of speech sounds (such as their frequencies). Neurolinguistics addresses questions of relating parts of the brain with components of language such as syntax and phonology. Psycholinguistics studies language within the broader architecture of the human mind, dealing with topics such as the representation of linguistic knowledge in the mind, the roles of attention and memory in understanding and producing language and how children acquire the knowledge of language. Sociolinguistics studies how features of language are correlated with social groups such as races, professions, genders, sexual orientations, castes and social networks formed within communities. Computational linguistics and natural language processing study possibilities of machine-human interactions by making formal descriptions of natural languages using programs written in computer languages.77 Stylistics studies devices adopted by creative writers in communicating emotional power and producing aesthetic appeal.

Broadly speaking, what is language? Language seems to be about the world, which in turn is a larger collection of objects. But that does not answer the question of what it is. Let us rephrase the question: How do we conceptually understand language? Language seems to be the way a human being makes a connection between the world outside and the world inside. In that sense, language is neither external to human beings nor is it internal. There lies the basic problem about language; its problematic status as an

76 The conception of the mind as consisting of near-autonomous modules have been an influential idea in cognitive science since 1950's. The idea extends to language also because it is thought of as a faculty of the mind. Thus, syntax, meaning, sound, etc., are considered different modules related to language. For more details, see Jerry Fodor, *The Modularity of Mind*.

77 Computational linguistics is not always an applied field; sometimes the word 'computational' is used to refer to a methodological style in the cognitive sciences which help uncover the rules underlying mental systems like language. Sometimes computational modeling is adopted to address fundamental questions about the nature of language, which leads to the idea that computational linguistics can be part of 'pure' linguistics itself.
Here it might be useful to take a step back and find out the basis of the distinction made between Language and languages. There has been a long tradition of thinking about grammatical principles that are common for all languages. This is the basis for the idea of Universal Grammar, strongly associated with Chomsky's view of language as a species characteristic of human beings. It goes back to Roger Bacon (13th century) and Port Royal grammarians (17th century). Coming to more recent times, Saussure made a distinction between the system of language (langue) and the actual speech (parole). Chomsky's 'competence' – 'performance' distinction is very similar to Saussure's distinction yet subtly different. Both are similar to the extent that one in each pair ('competence' in Chomsky's view and 'langue' in Saussure's) is abstract whereas the other member of the pair is about concrete instances of usage ('performance' in Chomsky's and 'parole' in Saussure's). But the difference is that Chomsky's 'competence' is at the level of the mind and Saussure's 'langue' is at the level of the community. Also, another distinction is that 'performance' is not just about speech or production, it is also has to do with listening and comprehension; on the other hand, 'parole' has to do with speech.

There is a disagreement between the formalists on the one hand and the functionalists on the other, regarding why language evolved. One group, who connects language with sociability and general intelligence, thinks that language evolved as a tool for communication. The other group, prominent within whom is Chomsky, claim that language spontaneously came into being in homo sapiens as a result of some mutation.

The line of thinking of the first group goes like this. Language has a seriously instrumental role in helping human beings develop social cohesion and coordinate group behaviour, both of which contributed to the survival and success of the species. So, the argument goes, if the purpose of language was simply communication, it would have

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evolved along with the cognition or general intelligence in a particular ape-line in the evolutionary tree. Different species are associated with certain specific specialties or niches. The human niche of cognition would have led to the emergence of a sophisticated system of communication like language, which has powerful features of displacement, abstraction and recursion. If language is something that slowly evolved in a branch of apes, we might find a continuity between the properties of human language and those of other apes. There have been several attempts to demonstrate the level of sophistication in related ape species, but none of them seem to have given convincing reasons to think that the communication systems of those species have properties of displacement, use of abstract categories and recursion similar to that of human beings. This seems to be a big problem with the theory of gradual evolution.

Is it an object, as one would speak of a ‘tree’, or a ‘river’? A ‘tree’ or a ‘river’ is a real object because it satisfies the dual criteria of being independent and outside the observer. Is language independent and outside the observer? If a person observes her own language, at least a part of it is not outside of the observer. Even if a person observes another's language, it seems it is not entirely independent or outside because at least the meaning part is within the observer also. It appears the sound part of another's language is also not entirely outside because if the observer did not possess the knowledge of that system, she could not make sense of it.

If we think of real objects as those that can be experienced using our sense organs and take up physical space, language seems to be an interesting case. We are able to experience language using our auditory, visual or tactile sense and make meanings from

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79 Displacement refers to the feature of human language that it can be used to talk about objects that are located away from the speech context in time and space. Abstraction is the idea that human language can refer to abstract ideas also in addition to concrete objects. According to recursion, a phrase or a sentence can be embedded within another. For example the noun phrase 'the man' is embedded within the noun phrase 'the man I met yesterday', which in turn is embedded within 'the story told by the man I met yesterday'. For more details, see Charles F. Hockett, “The origin of speech,” Scientific American 203 (1960) (88–96).

such input although it does not take up physical space.\textsuperscript{81} We are able to perceive sounds and get meanings. The mere fact that we are not sure about whether language takes up physical space is not reason enough to conclude that it is not a real object. Perhaps we need a different definition of what constitutes reality to bring in the question of experience in a meaningful manner.

Language is an essential part of the human reality that lets individuals come up with and share their thoughts and feelings, greet others and tell stories and do combinations of all these things.\textsuperscript{82} But if we look around, we would see that there are a large number of languages in the world around us. We associate a group of people with a language. Also, very often, any language, understood as a means of communication within the members of a geographical or cultural/political area, has several variants.

Scholars like Chomsky hold the position that studying all languages and their variants as independent and isolated entities is not a worthwhile project if your goal is to understand the principles that form the basis for the human faculty of language.\textsuperscript{83} If we work with all the languages and their variants, the project would seem almost insurmountable. To make sure that the enquiry does not get unwieldy, a particular view of language is adopted for theoretical purposes. While languages seem to be empirically concrete entities, the idea of language is a theoretical prerequisite and abstract. The theoretical ideal of a pure language, however, is questioned using empirical data and we will discuss that in chapter 4.\textsuperscript{84}

The multi-dimensionality of language – biological, social, symbolic – makes it a complex object to study. It seems that to learn everything about language, we need to know about the mind, the body and society. There is an extra dimension to this problem if

\textsuperscript{81} Visual sense is the relevant modality for a sign language user and a normal reader. A visually challenged reader uses the tactile mode to make sense of language. In that sense, human language is a modality-neutral cognitive faculty.

\textsuperscript{82} The idea that language is for communication, although correct prima facie, is a controversial one as we will see in chapter 4.

\textsuperscript{83} This was precisely the complaint the transformational generative grammarians (led by Chomsky) raised against the structuralists, who sought to give detailed descriptions to individual languages.

we want to consider language as a natural or a biological object. Many other species have
communication systems. The biological aspects of language would lead us to ask whether
human language is similar to the communication systems of other species. Do we find
continuities between human language and language in the animal world or a subset of it
(such as the mammalian world)?

Coming back to the question of reality of language, how do we begin to address
the question of whether language is a real object or not? What kind of facts or
observations would help us resolve this question? Since language is a complex object, we
cannot keep making random observations about it without using certain guiding
principles. We have to work within a specific framework which consists of a set of
axiomatic definitions and rules. Such definitions and rules guide our observations. That
would then mean that we are no longer observing facts of language as pure data. The
observation becomes theory-laden, and the question of the reality of the object becomes a
philosophical problem.

The word 'grammar' often comes up in discussions on language, which is often
used to refer to a set of rules which make up the structures of a language. Very often it is
used in a prescriptive sense, as some strict rules of language to be followed in language
use. Traditional grammar books were also mostly written as prescriptions for correct
usage. Later came a notion of grammar as a description of language use. The

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85 Noam Chomsky, Marc Hauser and Tecumseh Fitch, in “The Faculty of Language: What Is It, Who Has
It, and How Did It Evolve?” Science 298 (2002) 1569–1579, make a distinction between Faculty of
Language in Broad Sense (FLB) and Faculty of Language in a Narrow Sense (FLN). The former might
be what is common among different species and the latter may be specific to human beings.

86 The word 'grammar' relates to the idea of writing in its Latin and Greek roots. Although modern
linguistics gives primacy to speech as opposed to writing, the origin of the word suggests that grammar
evolved in the first place in connection to literacy. This will be taken up in chapter 6 on 'supplementary
issues'.

87 Grammars are often originally written as descriptive accounts, as was probably Pāṇini’s Sanskrit
grammar also (ca. 5th century BCE), considered to be a systematic and detailed description of the
structure of a language, which inspires linguists to this day (for an overview, see Paul Kiparsky,
“Paninian Linguistics,” in Encyclopedia of Languages and Linguistics, (ed.) R. E. Asher, Oxford:
Pergamon, 1993) 2918-23). However, it later seems to have become prescriptive to the extent that its
knowledge came to be considered as something that drew a line between social classes. Quoting
Sheldon Pollock, The Language of the Gods in the World of Men: Sanskrit, Culture, and Power in
between grammatical and political correctness are far-reaching. If the preservation of language sounds
grammarian would go to the real world and record people's use of language. A descriptive grammarian does not work with any absolute sense of correctness. In a more recent sense, also pertinent to the discussion in this dissertation, the generative framework views 'grammar' as a set of rules hardwired into the brain as a fundamental aspect of human nature. Grammar is considered to be an unobservable system of knowledge, like the information coded in genes. There are ways in which linguists try to uncover this knowledge. One method often used by generative linguists is to ask for native speakers' grammaticality judgments about sentences. When linguists seek such judgments, what they are doing can be thought of as something similar to a physicist using an instrument for measuring the presence and amount of an unobservable object of nature, such as magnetism. Here, the speakers' judgments on grammaticality act as instruments that help linguists talk about a system of knowledge which cannot be directly seen.

A striking observation in support of a naturalist view of language is that every human being, excluding those with serious and unfortunate biological conditions, acquires language. But which language a person acquires depends on which language she is exposed to, in the culture or society in which she is brought up. Chomsky specifies this notion in various ways, most well-known being the technical term I-language, which is described as 'internal' or 'intensional', so that social and contextual aspects of language are kept out of the scope of enquiry. The view of language as a part of the mind is an extension of the naturalist view. This idea involves the conception that category labels and rules of combinations are a property of the mind. The way entities are defined at the mental lead to the problem of whether mental objects can be real or not.

Having narrowed down our perspective on grammar to a descriptive account and specifically a cognitive faculty, we are led to the question of the connection between grammar and knowledge of language. Is it the knowledge of possible combinations of

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(varṇa) that grammar achieves was linked essentially to the preservation of the social orders (varṇa), and so to that of the polity at large, the obligation to maintain the order of language was no less than, and perhaps no different from, the obligation to maintain the political and spiritual order.”

These are the rules that describe how smaller units of language combine to form larger units.

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words to form sentences or the ability to use language in a socially appropriate manner, or a combination of the two? This has been one of the tensions of modern linguistics.

There are ways of tackling the problem of reality of language without immediately resorting to vague and fuzzy directions in the realm of the experience of language. Mainstream philosophy of science deals with the issue using concepts that are more in line with methods of natural science, which seems to lend it a greater amount of clarity. Such approaches seem to be continuous with physical sciences and are open to the idea that scientists may, in the future, conclusively establish the physicality of language using ideas from advanced physics and neuroscience. Till then, there needs to be some philosophical argumentation to show that language is a natural object, like any other that is dealt with by science. This has been Chomsky’s project – of arguing for a scientific approach to language by defining the object as well as the methodological issues in detail.

The creation of new scientific concepts leads to a modified understanding of reality. In light of the current state of research in physics, we talk about the realities of particles like electrons and ideas such as the expanding universe. As it is clear from the fact that newer research uncovered unknown particles such as neutrinos, muons and bosons, the set of objects studied under science keep increasing as more and more science gets done. But the difficulty of studying language might lead one to think that it is very different from objects studied by a hard core natural science like physics. So what is the problem posed to philosophy of science when linguistics creates concepts like *immediate constituents* or *feature checking* or *bounding nodes* or *derivation by phase*?\(^9\) At the same time, there seems to be a little more acceptance by philosophers of science when physics comes up with concepts such as dark matter or Higgs-Boson.\(^9\) What exactly is the problem here? Chomsky understands this as a discrepancy between the way in which natural objects are treated and the way in which mental objects are treated.

\(^9\) The definitions of these expressions are not directly relevant to this discussion.

\(^9\) For example, the chemical insight that water is H\(_2\)O is now considered a reality. Hilary Putnam, “The Meaning of Meaning,” *Minnesota Studies in the Philosophy of Science* 7 (1975) 131–193, uses H\(_2\)O as the exact meaning of the word ‘water’. His view of meaning is that it is a social fact and a scientific opinion is the correct meaning because it reflects an expert community’s understanding of it.
Chomsky thinks that mental objects can be studied just like one studies tangible physical objects. He uses the word 'naturalism' to refer to the methods adopted in the physical sciences; this is also what he proposes as the method to be used in studies of the mind also, including linguistics. His view is that approaches similar to those used in studying physical and natural objects can be used to study mental objects (including language). He contrasts methodological naturalism with methodological dualism. The former is the proposal that the studies of the mind should follow methods similar to those adopted for natural sciences; according to the latter, an approach different from that of physical sciences have to be put to use in studying the mind. He contests dualism because that is against the possibility of rational enquiry into language using accepted methods of natural science. However, this type of rational enquiry into language is entirely defined by Chomsky and it has several problems, as we will see in chapter 4.

The way objects are thought of in natural sciences also seem to depend on the scientific theories they are placed in. Sarukkai (2012) illustrates how the idea of mass changed as different theories evolved in physics. Mass was originally related to solid objects. Then it came to be related to microscopic matter and the atom; then it came to be related to the electromagnetic field and then to energy. Each of these conceptualisations made sense within the theories in which they were located. So just because linguistics studies objects associated with the mind such as conceptual structures and abstract mental representations of syntactic structures and sounds, they cannot be ruled out as scientific objects. However, as mentioned earlier, Chomsky's (1995) argues for the assumption of methodological unity in studying mental sciences similar to the practice in the natural sciences.

It seems correct to say that basic human conceptual structures and speech sounds act as substrata for human thought and communication, just like space and time act as substrata upon which all phenomena exist. In that sense, concepts and sounds (or thought and language) cannot be studied like other physical objects. In both rationalist and

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91 Sundar Sarukkai, *What is Science?*, p 105, 106.
empiricist frameworks, sounds are considered *a priori* and in a rationalist framework, concepts are also considered *a priori*.

The analysis of language usually starts from the level of the phoneme and goes up to the level of the sentence and beyond. This involves knowledge of sounds and how they vary depending on contexts, knowledge of affixes and their syntactic and semantic implications, phonological rules which accompany affixations, syntactic rules, how meanings of larger units like sentences are related to the meanings of smaller units and so on. One important thing to keep in mind is that the individual user’s knowledge of all these aspects of language is implicit or unconscious. One of the attempts at giving an explanation for the acquisition of such a system makes use of the idea of innateness in a very central way. If we assume that human beings are born with the ability to pick up language from their surroundings, our problem of explaining how children learn language would be much simplified. Notice that it is the principles of language learning which are proposed to be innate and not language itself. Instances of language in the surroundings enable the child to arrive at the rules governing the various levels. The alternative to an ‘innateness hypothesis’ would have been an inductive process which learned structures from available input. But this would not explain language acquisition because a 5- or 6-year-old child is able to produce much more than she had exposure to. Since all human beings (except those unfortunate individuals with severe brain defects) end up learning language and because environmental input is necessary for it, it is often compared to walking. After going through basic stages of body movement such as moving on all fours and walking with a bent posture, a child ends up walking erect on two legs. A child also needs the surroundings that are ideal for walking, such as a relatively plain surface. The similarity to walking underscores the fact that language is not learned in one fell swoop, but in different stages such as babbling, one word stage, two word stage and full sentences. Thus the innateness of language lies not in acquiring everything at once, but in

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92 For units larger than the sentence, the linguistic ability has to be supplemented by general principles of social interactions followed in conversations and writing.
following a pattern programmed by nature.

*Scientific Method in Linguistics*

In this section, we look at how linguists go about studying language. Linguists are particularly interested in the question of ‘method’ because the nature of their discipline might give the impression that they are not doing something rigorous enough to be called a science. It was pointed out earlier that for explanatory reasons, linguists study Language and not languages, by which in common parlance we refer to the modes of communication of various speech communities. What we refer to by Language is the knowledge (or cognitive) system underlying the production, perception and comprehension predominantly using sounds seen across the human species.

If a linguist is trying to study a language spoken by a particular tribe, she would first go to them and list out their words and sentences and isolate their morphemes and phonemes. This was the method followed by anthropological linguistics in early twentieth century. It is a systematic and classificatory process of listing sounds, tense and agreement markers, plural markers, meanings of words and different sentence structures. This process is basically about the description of the particular language under investigation. The linguist lists the sounds and observe the patterns of their occurrence. She writes out the words and classifies them into groups such as nouns and verbs and look at the mechanisms of word formation using the basic units of roots, stems and affixes and processes such as inflection, derivation and compounding. When she studies nouns, she notices features like case marking and plural marking. With respect to verbs, she notes their agreement markers in relation to the subject and object noun phrases in terms of person, number and gender. She lists longer utterances such as phrases and sentences and tries to describe how the smaller units combined to produce them.

The linguistics research community divides the whole research enterprise into language into several small chunks, each of which is tackled by a small group of researchers spread in different parts of the world. Even within phonology, morphology
and syntax, linguists would be performing more minute examination of details. For example, somebody might study question formation and some others might study the phonology of tones. Researchers would work with a small number of languages and try to relate the results of their work with that of the overall research done in that particular chunk or sub-field, so that their work becomes relevant to the whole of ‘language.’ From a field data collection perspective, the kinds of data immediately collected by linguists described are handled by the sub-disciplines of phonology (along with phonetics), morphology and syntax. Phonetics and phonology studies the set of sounds and their variations in the particular language. Morphology studies rules of word formation and syntax deals with combinations of words. Morphology and syntax are often seen as continuous because word formation processes have a clear impact on the sentence-level.93

Case and agreement markers and inflectional and derivational markers attached to words contribute to their morphological complexities. Case systems vary from language to language although there can be patterns with greater probability and less probability. Most languages have a nominative-accusative system where the subject's case marking is called ‘nominative’ and the object's an ‘accusative’ or objective case marking.94 There are also languages which follow an ergative-absolutive pattern. In an ergative-absolutive language, the case marking on the only argument of an intransitive verb would be the same as the case marking on the object argument of a transitive verb. For example, in such a language, the case marking on 'the train' in the sentence with an intransitive verb 'the train arrived' would be the same as the case marking on the object 'the man' in a

93 This idea can be substantiated with a theoretical device and an empirical fact. First the theoretical device: An assumption of X-bar theory (a theory that describes each phrase as resulting out of a two-level projection from a word level) is that the head of a sentence – called an IP or an Inflectional Phrase – is inflection, which is basically the tense and agreement markers attached to the verb. Now the empirical fact: There are languages where there are no clear word boundaries – morphemes just attach to the verb and the whole sentence looks like a single, continuous unit with no breaks inside. Mark Baker (2001) gives this Navajo example Ninááhwiishdlaad which means 'I am again plowing'. It consists of the prefix morphemes attached to the verb 'dlaad', which means to tear. Baker tells us that the word is formed as a combination of morphemes as follows: ni + náá + ho + hish + l + dlaad. See Mark Baker, Atoms of Language: The Mind’s Hidden Rules of Grammar, (New York: Basic Books, 2001).

94 In many languages, there may be no overt nominative case marking. But even a null overt marking is considered real because it helps the explanation of case marking to be general. See next footnote also.
sentence with a transitive verb 'Anand saw the man.' Case and agreement markers indicate the relationships between words in a sentence. For example, an objective case marking is necessitated by the verb. Agreement markers indicate the person, number and gender features of the subject noun phrase (and sometimes of the object noun phrase also). In some languages, sometimes a subject might have a dative case instead of a nominative case. Often referred to as experiencer subjects, it conveys the idea of something (loosely 'referred to' by the object) 'approaching the subject'. In such languages, verbs such as 'want', 'own' and 'fond of' require the subject’s case to be dative. Apart from these "inherent" case markers which mark the subject and the object of a sentence, languages can have several other ‘structural’ case markers attached to nouns based on location, direction of movement, possession and so on. What is conveyed through case marking in some languages are conveyed through prepositions in another. The verb may have indicators of the person, number and gender features of the subject (and sometimes of the object too). These are the agreement markers. By careful examination of the forms of noun phrases in a language, case marking and agreement markings can be distinguished. Further, there can also be modals attached to the verb, which marks moods associated with an action such as permission, possibility, ability, volition, obligation and so on. Modality contributes to the meaning of the sentence.

One important thing that a student of a language would look for is the word order. Cross-linguistically, there seems to be some order of arrangement of units within the verb phrase. In what order are the words arranged in the sentence? Does the subject (S) come  

95 Also, English is rather impoverished when it comes to case marking, which is why the object 'the man' has no overt objective case marking.  
96 Many Indian languages allow subject noun phrases with dative cases (or 'experiencer' subjects). For example, Hindi marks it using 'ko' and Malayalam marks it using 'kku' (in some phonological contexts, there might be certain variations – for example, when a noun ends with /n/, the dative case is indicated by the addition of the vowel /ə/ (schwa). For example, consider the Malayalam sentence enikku chaaya venam [(I-Dative) tea want; I want tea]. The connection between the dative marker and the desired movement of 'tea' to the person is clear.  
97 In all these cases, the subject's possession or desire to get the object are clear.  
98 In semantics, modality is mathematically handled by the idea of 'possible worlds'. 'Necessity' is dealt with by the idea that in all possible worlds, a proposition 'p' is true. 'Possibility' is dealt with by the idea that there is at least one possible world where 'p' is true.

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first? Or is it the verb (V)? Or does it have a very rare word order in which the object (O) appears first? The word orders maybe represented as SVO, SOV, VSO, etc. Although the word order might seem to be an easy thing to figure out, it can be deceptive because a language might have one order in a simple sentence and another order in an embedded sentence. In such a situation, the final decision about the word order would need strong empirical evidence favouring one of the empirical facts.

Some of the empirical methods used in generative linguistics are contentious. Checking native speakers’ intuitions is one such problem. Linguists ask for native speakers’ judgements regarding the grammaticality and acceptability of linguistic expressions. The epistemological insight that is at the root of this method is that by working backwards from the sentences that are judged as grammatical or ungrammatical by the individual, we will be able to access her internal knowledge of language. We might recall that one of the purported goals of linguistic theory in the generative framework is to explain an individual’s knowledge of language.

The act of describing a language is not done without any presumptions, or with a blank mind. The linguist approaches a language with a set of ideas about how languages usually are; at a minimum, they would start with a sense of the different categories of words, types of phrases and sentences and so on. For example, there would be the assumption that every language has ‘nouns’, ‘verbs’, ‘number words’, ‘plural morphemes’, ‘relative clauses’, ‘filler-gap dependencies’ and so on. She is informed about the basic

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99 There can even be a perplexing word order in which object appears first, such as OVS. The linguist Desmond Derbyshire noticed that a language spoken by a tribe – Hixkaryana – who live near one of the tributaries of the Amazon had the unique word order of Object-Verb-Subject (OVS); see Desmond Derbyshire, “Word order universals and the existence of OVS languages,” Linguistic Inquiry 8, 3 (1977): 590–599.

100 An example for this pattern is German. It was thought to be an SVO language until further investigation revealed SOV in sentences with an auxiliary. For example 'Hans kauft ein Buch' (Hans bought a book), but 'Hans hat ein Buch gekauft' (Hans has bought a book). Note the position of the main verb (kauf/ gekauft) in both these sentences. It is interesting to note that children acquiring German produce the auxiliary sentences also with the SVO order ('Hans hat gekauft ein Buch') but later get the correct order. (This example and insight are from Victoria Fromkin, Robert Rodman and Nina Hyams, An Introduction to Language, Wadsworth: Boston, 2003, 380.)

101 This process is sometimes referred to as reverse-engineering; See Steven Pinker, How the Mind Works, (New York: W. W. Norton & Company, 1997).
categories and rules as part of her training. So we can see the inklings of a theory even in a non-explanatory attempt to describe a particular language.102

How does the linguist arrive at generalisations about language? The way we think about arriving at generalisations is by working from the particular to the general. This is the method of induction. The problem with induction is that you can never be confident about the generalisation you are making. It is because even if you make a thousand observations and you find the same principle at work in all those, the thousand-and-first can be contrary to that principle. So a pertinent question here is how a linguist would deal with a totally new piece of data. Would it be somehow brought under the existing theory by making some modifications to it? Or would the linguist be tempted to come up with a new theory? Or how much incongruous data does the linguist need to throw away a theory and come up with another?

Linguists use a formal language to describe the rules that describe the combinations of smaller units to form larger units, for example, how words combine to form sentences. This formal language is called a meta-language because it is a language used to describe natural phenomena, which in this case is language.103 This meta-language enables the theorist to analyse the sentences after removing them from the particular contexts that they were originally used in. It also makes it possible for the linguists to give formal descriptions for why some sentences are grammatical, some are ungrammatical, some acceptable and some unacceptable. In short, the use of formalisms in studies of language is motivated by reasons similar to the use of mathematics in the natural sciences.104


103 Meta-languages used in linguistic descriptions have a long history. Pāṇini, the Sanskrit grammarian of ca. 4th Century BCE, had an elaborate meta-language which described rules and rule ordering. See Paul Kiparsky on Pāṇini in the Encyclopedia of Language and Linguistics.

104 In this context, the reader might be interested in hearing about a conversation that happened between Einstein and the famous Bengali poet Rabindranath Tagore. Tagore believed that all truths, including those of physics, are human truths. On the other hand, Einstein thought that it was not possible to carry out physics without holding some notion of external reality. We find echoes of this debate in linguistics and cognitive science also. Formalists and computationalists like Chomsky hold an Einstein-like
Such a drive towards formalisation can be seen in a very pronounced manner in semantics, the study of meaning in language. Meanings of expressions often depend on contextual factors and they can be vague. They often depend on cultural factors and other non-linguistic factors such as facial expressions and gestures. To describe sentence meanings, formal semanticists make use of the idea of functions and arguments. This approach is used for explaining how the meaning of a sentence is worked out from the meanings of its constituents. They use a mathematical language based on logic to represent the meaning of a sentence. Finally these meanings are mapped onto a truth value so that the the truth or falsity of a proposition can be ascertained.

The use of intuitions is a controversial method of gathering data because they are thought to vary from person to person. Further, the same person might give different judgements under stressful conditions or when deprived of sleep. The question raised by the critics of this method is how unreliable data can be used to develop theories of language. Another response was by collecting data from a number of speakers of a speech community and asking for ratings for sentences on a scale rather than a binary yes/no judgement.

Knowledge in Linguistics

Linguistics, because it deals with an object like language, is not easily detached from societies, cultures, minds and brains. In other words, it is hard to think of language in itself, except perhaps in the contexts of extremely playful theatrical performances and some types of poetry. The problem of knowledge comes at the level of the individual speaker as well as at one’s conception of what constitutes knowledge in the discipline. If we look at an individual speaker’s knowledge of her mother tongue, it is a very detailed
system. Considerable amount of research has been done on people's knowledge of phonemes, words, tenses, aspects, modals, plural morphemes, phonological rules, word formation rules, phrase structures and sentence structures. Experts use theoretical as well as experimental approaches to ascertain the nature and extent of this knowledge. Theoretical linguists work with their own or their informants’ intuitions about language. The assumption underlying this type of work is that the intuitions of the speakers reflect their internal knowledge of language. This is a questionable assumption because it is not clear whether a theory that explains grammaticality and acceptability judgements of a native speaker is the same as a theory of the native speaker’s knowledge of language. This concern comes up in relation to the notion of ‘competence’ originally described in Chomsky’s 1965 *Aspects*. One question that comes up is whether ‘competence’ is a real object. This also becomes a pertinent question because science also purportedly studies real objects. Philosophers like Devitt (Devitt and Sterelny, 1989 and Devitt, 2006) questioned whether the notion of competence is different from an account of what gives a native speaker the intuition to judge whether a sentence in her language is grammatical or not.

Experimental work involves a large number of subjects, careful design and close analysis of data. The knowledge of sounds of really small babies is tested by psycholinguists using sucking-rate experiments and head-turning experiments. These are based on the assumption that sucking-rates and head turns indicate interest in the stimuli. A very interesting finding about knowledge of sounds is that in the smallest age group that was tested, babies showed the same preference for all sounds; however, as the babies began to have more input to their native languages, they began to show more interest in the sounds in their own languages than in other languages. Experimental results show that even by the age of 6 months, a baby's ability to perceive sounds are influenced by its

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linguistic experience. Babbling has been strongly suggested to be the precursor to language. One and half year olds have been argued to have knowledge of syntactic structures which enable them to give phrasal level interpretation for pronouns. Several experimental results suggest that 4 year-olds and 5 year-olds have sophisticated knowledge of syntactic constraints. Non-invasive brain imaging techniques used on children and psycholinguistic as well as neurolinguistic experiments on adults reveal their knowledge of language and how it is put to use in real-time comprehension of language.

Knowledge of the meanings of words is a thorny problem because there is no well-defined relationship between a word and the object it refers to. In many cases, the meaning of a word is context-dependent because it can be understood only from the sentence in which it is used. As an initial hypothesis, one might think that word learning starts with the idea of ‘pointing’ or direct referentiality. But problems to this would be posed by abstract nouns and predicates, which are relational and not referential.

Can models of language that are based on symbolic representations – such as the Chomskyian model – explain inter-speaker and intra-speaker variations? Variations can be syntactic, in which they can be easily detected using normal perceptions, or they can be phonological, in which case careful measuring apparatuses may be required for detecting them. Scientists have argued for treating grammars as complex dynamical systems because of the continuous variation observed by available measurements.

Predictions in Linguistics

For linguistics, prediction of unknown data is an important part of its theory. If it is observed that sounds of a particular type change in a rule-based manner in a context,
another sound of the same type is predicted to change in the same context. Such predictions are applied in synchronic as well as diachronic linguistics. Ferdinand de Saussure, considered the pioneer of modern structuralist linguistics, is well known for one such prediction. Based on studies of Indo-European languages, he predicted the existence of certain sounds in proto Indo-European. It has to be noted that this kind of prediction is not about future, they are about unknown things. There was no evidence for the existence of these sounds until a few manuscripts in an ancient Indo-European language called Hittite were discovered and its script decoded. Linguists observed that the sounds predicted by Saussure existed in Hittite and was an indication that probably the mother language of all Indo-European did have those sounds.\footnote{Rolf Noyer's course handout http://www.ling.upenn.edu/~rnoyer/courses/51/Ling512011Phon.pdf. Last accessed on 26 September 2014.}

Another interesting example of prediction is given in Radford et al.'s (2009) textbook of linguistics.\footnote{Radford, Andrew, Martin Atkinson, David Britain, Harald Clahsen and Andrew Spencer, \textit{Linguistics: An Introduction}, Cambridge University Press, 2009) p 54.} The four data sets given in the section titled \textit{Linguistically determined variation} are reproduced below.

Data set 1:

\begin{align*}
\text{best friend} & \quad \rightarrow \quad \text{[bɛst frɛnd]} \quad \text{– \quad [bɛs frɛnd]} \\
\text{cold weather} & \quad \rightarrow \quad \text{[koʊld weðə]} \quad \text{– \quad [koʊl weðə]} \\
\end{align*}

Data set 2:

\begin{align*}
\text{he stuffed the turkey} & \quad \rightarrow \quad \text{[hi: stʌft dθ te:ki:]} \quad \text{– \quad [hi: stʌf dθ te:ki:]} \\
\text{she seemed funny} & \quad \rightarrow \quad \text{[ʃi: si:md fʌni:]} \quad \text{– \quad [ʃi: si:m fʌni:]} \\
\end{align*}

Data set 3:

\begin{align*}
\text{most of the time} & \quad \rightarrow \quad \text{[moʊst Əv dθ təm]} \quad \text{– \quad [mous Əv dθ təm]} \\
\text{ground attack} & \quad \rightarrow \quad \text{[graʊnd Ətæk]} \quad \text{– \quad [graun Ətæk]} \\
\end{align*}

Data set 4:

\begin{align*}
\text{he seemed odd} & \quad \rightarrow \quad \text{[hi: siːmd ɒd]} \quad \text{– \quad [hi siːm ɒd]} \\
\text{she passed a test} & \quad \rightarrow \quad \text{[ʃiː paːst Ə tɛst]} \quad \text{– \quad [ʃi: pa:s Ə tɛst]} \\
\end{align*}

So the data set is about the deletion of the alveolar stops [t] and [d]. In data sets 1 and 2, the sounds in question are followed by consonants. In sets 3 and 4, they are followed by vowel. In 2 and 4, the use of those sounds are grammatically salient because they perform
the function of tense marking. In 4, the alveolar stop has a grammatical function and it is followed by a vowel. Its grammatical salience and the fact that it is followed by a vowel would make us predict that the deletion is highly unlikely and less probable than its deletion in sets 1, 2 and 3. This prediction is borne out in most cases.

Many of these predictions are seen in the domain of phonetics and phonology. This is probably because productions of sounds seem to be determined to a great extent by physical and biological principles, and hence belong to the natural world more easily than those aspects of the world on which we have a conscious ability to influence.\(^{115}\)

There are problems regarding the power of predictions in linguistics. As linguistics does not seem to have universal laws like natural sciences, predictability in linguistics is less powerful than predictability in natural sciences. The case of regular and irregular verbs demonstrate an interesting point about predictability. English has a regular rule for forming past tense, namely add \(-ed\). There are also irregular verbs which form their past tense by using a totally different stem. Examples are 'go – went' and patterns like 'bring – brought' and 'seek – sought' or the ones such as 'sing – sang', 'sink – sank' and 'drink – drank'. From the pattern of the last set consisting of the patterns of past tense formations of 'sing', 'sink' and 'drink', suppose we arrive at the generalisation that when a verb ends in a velar nasal, the vowel changes from i to æ, we would be proved to be wrong by the example of 'think – thought'. But if we had made a less specific generalisation that if the stem form of a verb ends in a nasal, the past tense would be formed by changing i to æ, we might get some pairs that support the generalisation such as 'swim – swam'. These examples just demonstrate the difficulty in making predictions in linguistics.\(^{116}\)

Hindi has an ergative marker \(-ne\), which is attached to the agentive subject Noun

\(^{115}\) This type of reasoning leads us to methodological questions of naturalism and dualism in relation to mental sciences, a recurring concern in this work.

\(^{116}\) Irregular morphology makes predictions difficult and the language learners as predictors fail when they apply the regular rule to the second class of verbs. So it seems language learners have to separately learn the past tense forms of the exceptions.
Phrase in past tense sentences, as in ‘raam ne roti khayi’. However, there are verbs such as bol, la, sak, etc., with which one cannot use the -ne marking on the subject. Here also, it would be wrong if the language learner predicted that any subject NP that feels like an agent of an act needs to have -ne attached to it. Here also, the learner has to create a list of exceptions in the mind.

Let us look at two examples of how predictions work when a theorist analyses morpho-phonological data. In the 1980's the ‘lexical phonology’ model which tried to explain the affixation of inflectional and derivational morphemes. Inflection and derivation are two word formation processes. Inflectional morphemes are those that do not change the word class (e.g., a plural morpheme or a past tense morpheme) and derivational morphemes are those that change a word class (e.g., a morpheme that changes a noun into an adjective or a verb into an adjective). Derivation is classified into classes 1 and 2 based on whether the affixation resulted in a change in the stressed syllable or not. Inflection can be regular and irregular. Compounding was another morphological process that was discussed along with inflection and derivation. To account for the different phonological rules that applied with respect to these processes, lexical phonology predicted the different levels at which these distinct morphological (word-formation) processes got done.

A different approach to doing phonology came up in the 1990's called ‘Optimality Theory.’ It assumes that the language system consists of two parts – one that generates linguistic forms and another that evaluates them. The evaluations are done using a set of universal constraints which were arranged in a language-specific manner. The constraints

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117 -ne, known as the ergative marker, is associated with another interesting effect. When -ne is attached to the subject, the verb agrees with the object instead of the subject. In the example given here, the gender agreement on the verb is feminine, resulting from the object roti and not the subject ram.

118 Morris Halle and K. P. Mohanan, “Segmental Phonology of Modern English,” *Linguistic Inquiry* 16, 1 (1985) 57–116, proposed four levels to account for the phonological changes associated with these different word formation processes. Here are the levels and the types of processes associated with each:
- Level 1: class 1 derivation and irregular inflection
- Level 2: class 2 derivation
- Level 3: compounding
- Level 4: regular inflection

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are universal, but the rankings are language specific. Since different languages have different constraint rankings, a candidate X might be preferred in language A whereas a candidate Y would be preferred in language B. The framework provided reasons for why certain linguistic forms are attested in specific languages and predicted the non-existence of certain other forms. Because linguistics is about ‘Language’ and not about particular languages, theorists have to constantly deal with problems of predictability and try to rework theories and models to explain the variety of data observed across languages.

Truth in linguistics

Linguists work with the goal of uncovering truths about language. Based on their beliefs about language which they got from various sources – such as observations, experimental results and interactions with scholars – they arrive at an understanding of the nature of linguistic truths. This influences the type of work they do and their attitudes about other types of conclusions about language.

We come to have certain beliefs about the world on the basis of what we got using our senses. Suppose a person – say Asra – walks in and announces, ‘I saw two king cobras outside this building’. You would be skeptical about what Asra said because you know that king cobras live in thick tropical forests and generally are not seen outside academic institutions set in urban areas. For you to trust her or to understand the truth of her statement, you will have to go out of the building and check whether there really are two king cobras outside. So a fundamental observation about truth is that its relevance arises when one person reports a state of affairs to another person using language. Every person can have private beliefs, but they become truths only when it is verified by at least one other person. This ‘social’ nature of truth makes sense in its connection to the word ‘trust’ because when somebody communicates to you about her belief and you trust her (maybe blindly,\textsuperscript{119} maybe because you verified it with your own senses), it becomes a truth. So when one says that science is a ‘dispassionate pursuit of truth,’ what it means is

\textsuperscript{119} This is often what happens in religion, where the followers are often expected to accept its doctrines without testing. Religious claims are often completely unverifiable also.
that it is an endeavour carried out by persons involved in the scientific activity to make statements about nature which can be verified by other persons using their senses or by using rules of logic to arrive at conclusions after starting from various premises. So the idea of persuading someone of your belief system by appealing to their senses and ability to reason is central to the working of science.

Linguists working within various frameworks start with a few assumptions about language and some goals for their research enterprise. For example, generative grammar is based on the assumption that language is used by an idealised native speaker-hearer in a homogeneous speech community. In what sense are the initial assumptions different from the beliefs that religious persons hold about the order of the universe? How do we understand the truths that emerge out of a combination of these assumptions and empirical observations? The assumptions of a field of inquiry would be logically justified by the researcher who introduces it. If it appeals to the reason of the readers, they would accept it as a working assumption which would help them address questions in the field. So there is some kind of trust in the assumption which emerges in the reader because it appeals to her 'common sense' and reason.\textsuperscript{120}

After starting with a set of assumptions, the scientist goes about trying to examine empirical facts. She comes up with certain generalisations, which, after a process of detailed examination by the community of scientists, get accepted or rejected. The ones that get accepted come to be considered truths. Such truths often generate newer research and eventually more truths.

The point about making the scientific community trust a given scientist is important in the way science moves forward. As a scientist, you have to show that your experimental and observational tools and methods were accurate and the reasoning involved in your analysis of the results were logically sound. To the extent that you have to convince a community of certain beliefs you hold about the objects you deal with,

\textsuperscript{120} Here we may note in passing that the overused notion of common sense may reflect the beliefs and assumptions of a small group of individuals. That is why the question 'don't you have common sense?' often implies another question, namely, 'why don't you accept certain social norms?'

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scientific truth is a social reality.

*Facts or Empirical Data*

By definition, linguistics studies language. This is as vague a statement as ‘biology studies life’. In its practice, biology deals with micro-entities like genes, chromosomes, DNA and ribosomes, macro-entities like species and eco-systems, micro-processes like glycogenesis which happens in an individual organism's body and macro-processes like evolution which happens across millions of years. Similarly linguistics also deals with micro-entities like phonemes, morphemes, words, phrases, sentences and so on. A speech sound or a phoneme is generally considered to be the most basic unit of language. A morpheme can be thought to be a small meaningful unit of language. A word has no easy definition. It can be as small as a sequence of two or three sounds which has a pause after it and a word class associated with it; it can be a combination of multiple morphemes and be as long as a sentence. A traditional definition of a word from Pāṇini says that a word is that which has a noun ending or a verb ending.\(^\text{121}\) A sentence is a large unit of language, but it is not the largest.\(^\text{122}\) There can be larger units such as paragraphs, conversations, whole books and speeches. Let us look at how the discipline studies the units, starting from the smallest ones like the phonemes through the intermediaries such as case and agreement markers to the larger ones, such as the sentences and beyond.

Language is broadly available to us in the forms of speech and writing. Most of the empirical work in linguistics deals with speech. The prominence given by the discipline to speech, as opposed to writing, comes from the belief that speech is more natural than writing. Every human being who is neurologically in tact comes to have speech. As a communication system, the message conveyed through speech is received by the hearer as soon as the speaker releases it. In that sense, speech has a sense of immediacy and spontaneity which writing does not. Writing is considered more cultural

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\(^\text{121}\) *suptinantām padam.*

\(^\text{122}\) Bhāratṛhari (5th Century CE) held the view that the sentence was the smallest unit of language. Because it stresses on the non-decomposability of the sentence, it is also called the idea of sentence-holism or akhandarthavada. Bhāratṛhari’s argument is that even if we make a very short utterance consisting of apparently only one word, we are using it as a shortened form of a sentence.
than natural because it requires a writing system and formal modes of transmission of knowledge. In writing, there is a time lag between the delivery of the message and its reception; speech does not have that. Sign language is considered similar to speech because deaf individuals naturally develop such a system to communicate with one another. There are studies which show how deaf children in Nicaragua developed their own sign language to talk to each other.\textsuperscript{123} It is also natural or spontaneous like speech. Sign language also has small units such as morphemes and big units such as sentences, conversations and so on. Since speech is the main modality of language studied by linguists, we will restrict our discussion to speech as linguistic data in this section.

Let us try a thought experiment. Suppose you have no meta-knowledge of language, and you don’t even know how to read and write. As an illiterate rustic, you are listening to someone speaking. Would you then, think that what the speaker says can be cut up into phonemes? Possibly not. The best that you can say is that you will be trying to get the meaning of what the other person is saying. So the idea of the phoneme seems to come from a conscious attempt to represent language. Researchers have argued that the unit of the phoneme arises from the idea of letters, which are used to represent the smallest units of written language.\textsuperscript{124} But there is a context when even as an illiterate, one would think about speech sounds. That happens when you perceive one word as another and you find out that the reason for the misperception was that you heard one of the sounds as different from your idea of how that sound should have ‘sounded’ if it were to occur in the right word in that speech context.\textsuperscript{125} Such mishearings might also point to the fact that a speech sound is not a strictly defined, absolute entity. A well-known case is the

\textsuperscript{125} This is the well-known ‘etic’/ ‘emic’ distinction which originated in linguistics and later came to be adopted in disciplines like anthropology. Kenneth Lee Pike, (ed.) \textit{Language in Relation to a Unified Theory of Structure of Human Behavior} (2nd ed.), (The Hague, Netherlands: Mouton, 1967). \textit{Emic} refers to the speakers’ knowledge of the distinction between the speech sounds in their language and \textit{etic} refers to the observer's (the linguist's) idea of how the speech sounds of a language relate to the set of sounds in human languages.
example of Japanese speakers being unable to distinguish /r/ and /l/. The division of the speech stream into various sounds is something that arises out of an attempt to understand language by decomposing it into its tiniest units, and as mentioned earlier, this process is aided by our knowledge of written language. Let us assume that it is correct to analyse language in such an atomic or ‘phonemic’ manner. Then if we slice the speech stream into various consonants and vowels, and look at the measurements corresponding to features such as vowel lengths and voice onset times for the same set of sounds spoken by different subjects or the same subject at different times, we would get differing values corresponding to one particular feature. This is why the idea of categorisation of sets of continuous values into a finite number of discrete classes is said to be a central aspect of human perceptual systems.

Earlier there was a discussion of how a linguist would study a totally new language. In the generative framework, language is mostly studied in terms of linguistic phenomena such as clefts, double-object constructions or interpretation of pronominals, which are observed cross-linguistically. This is different from the anthropological linguist's method of studying language X or language Y.

Technology

A science is often distinguished by what it does or what it is capable of doing. That is how ‘applicability' or 'technology' becomes an important feature of science. In natural language processing, a program describing the basic lexicon and the rules of a language have to be fed to the computer so that it can do the work of generating sentences in a natural language. Such a system has to be incorporated into a machine translation system also because the output of a translation task has to be grammatical and meaningful. A list of words (the lexicon) along with their parts of speech is supplied to the computer in the format required by the programming language used.

Phrase structure rules of the

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126 In Tamil, word initial /p/ in loan words get accepted with a lower Voice Onset Time and often sound /b/ to non-native Tamil speakers.
127 Chomsky, Hauser and Fitch (in “The Faculty of Language”, Science 2002) suggest that categorical perception extends to other species also.
128 PROLOG (Programming Logic) is a language that is considered a simple tool for doing natural
language are also given to it. Case markers and the agreement markers of the language also would be specified as part of the phrase structure rules. Entering multiple forms of a noun or a verb, with its different case or agreement markers, can be uneconomical. So roots and affixes are entered separately and specify the word formation rules along with the contexts.  

The phrase structure rules generate the grammatically correct sentences of the language by inserting the words of the specified parts of speech. The syntactic output can be specified using a mix of rules and constraints. The choice between rules or constraints has an interesting implication on the number of outputs. Phrase structure rules generate more outputs and constraints prevent outputs from being produced. Using Saussure’s terminology, if we think of language as consisting of signs, rules lead to more signs and constraints lead to less signs.  

Similar to the task of generation, parsing would be carried out by checking the given sentences with the lexicon and rules specified already in the input.

A problem with a system of generation of sentences involving vocabulary items and rules is that it will produce grammatical but semantically odd sentences like ‘My cat eats differential calculus.’ However, such grammatical yet semantically anomalous sentences would be blocked by probability. The probabilities of co-occurrences of words would be estimated from the available language corpora.

In computational linguistics, meanings of sentences become a problem. It is not clear how a function-argument approach used in semantics can work there. Using a combination of rules and probabilities, the computer might be able to produce grammatical and meaningful sentences of a language. However, several questions are raised by the computer’s use of language and the system of knowledge underlying that

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129 An example would be as follows. If we specify in a verb's lexical features that it requires a dative subject, assuming that the dative case marker is also fed into the system, the program would affix (or concatenate) the dative marker to the subject noun phrase.

use. Is it possible, for example, to claim that the computer knows language in the sense that a human does? Part of the reason is that a distinguishing feature of the human knowledge of meaning in language is intentionality. Is it at all possible to think of computers as having intentionality? Even if a computer is able to produce the right morphological and syntactic forms by combinations of basic units, would it be possible for the computer to have a human-like grasp over meaning? The answer is presumably 'no' because meaning is dependent on contextual factors and world knowledge, which strongly characterise human use of language. For example, the computer would meet with serious trouble when faced with metaphors because the mechanism for obtaining meaning hinges on a referential theory.

The theoretical apparatus of generative linguistics itself looks very technical because cognitive science uses the computer metaphor. Following a model of reverse engineering, it works backward from empirical data (grammatical and ungrammatical structures) to the system that may have produced it. The question would be: what kind of a device would it be if it produced a particular type of data? The avowedly serious practitioners of generative grammar clearly state that their project is different from computational linguistics, an engineering work involving grammars and lexicons of natural languages. They claim their attempt is to develop a theory of natural language grammars and not to do natural language programming for machines. They think of it as a science and not as engineering. They may propose technical sounding tools such as probe, but they claim that their concern is the mental grammar in the human organism and not the computational system in the machine.

If we consider language as a structure building mechanism that starts from small, non-decomposable units (the phonemes) which combine with each other to form larger units, (words, phrases, sentences, texts), we would notice that computational linguistics handles the basic units fairly accurately and as the size of the units gets larger, the system

132 Since many of the metaphorical expressions are language-specific, machine translation also would have messy outcomes.
tends to have difficulties and begins to show more wrong results. One approach to explaining this is to say that systems like holistic knowledge and consciousness are in a fundamental sense part of human cognition and cannot be mimicked by artificial systems. An alternative is to say that this actually is similar to human cognition, which is not always perfect in its results and it reaches an optimum level of performance by learning from the large number of lessons it is exposed to. Such a comparison of the computer model of language logically takes us to the next section on the attempts to model the human linguistic system. The first seems more plausible because human cognition seems to be a lot more vague than the computer's precise representations.

*Modelling in linguistics*

In science, models are used to abstract away from the messy data which form part of the phenomena that are studied. Models make simple assumptions about the world which make theorisation possible. An example for such an assumption is that of a frictionless plain which was essential for Newton to arrive at his first law of motion. Such assumptions help the practitioners of a field to arrive at idealisations about the object of their enquiry. An illustration from linguistics is the assumption of the human organism who possesses the knowledge of language uncorrupted by other linguistic influences by being located in a homogeneous speech community. Another early assumption in the same tradition of autonomous linguistics is the conception of language itself. Language was seen as a set of Deep Structures of sentences which underwent transformations to form the Surface Structures, which interfaced with a logical form and a phonetic form, which contributed respectively to the meaning and sound components of language.

Autonomous linguistics (in the sense of Newmeyer, 1986) uses such assumptions in the models of language that it studies primarily by working with a system consisting of symbols such as S, NP, VP, Det, N, V and Adj. However, in this section, we will look at connectionist models, which have gained considerable popularity in recent times because they were able to produce fairly good results with regard to certain questions in language,
such as language production. The basic structure of a connectionist model is that of a number of input nodes connected to output nodes, with varying connection weights. There could also be hidden nodes between the input nodes and the output nodes. The connectionist model is a bottom-up approach where different nodes are connected to each other and produce results. On the other hand, the symbolic approach is top-down because it pre-specifies certain rules which define the composition of large units. An advantage that connectionist networks are said to have over symbolic networks is that it probably captures the neurological reality better than the latter. If the symbolic approach was correct, each symbol may have corresponded to a unit such as a neuron, which does not seem to be what is observed with regard to the brain.

A connectionist model can be represented in a local manner or a distributed manner. In a localist representation, a basic unit of language, like a phoneme, a letter or a word is represented by a single node. In a distributed network, the basic unit is represented by activities in multiple nodes. Since it is a model that involves training using inputs and outputs and the redefining the first set of outputs as inputs to another operation, this is similar to a stimulus-response model, used in behaviourist psychology. Although localist networks are easier to visualise than the distributed ones, they are less neurologically plausible than the latter, which offers “a rich basis for understanding learning, generalisation, and the flexibility and productivity of cognition.”

How does one ascertain whether a computational model, be it symbolic or connectionist, capture the reality of human cognition? According to Christiansen and Chater, the models should meet three criteria, namely, data contact, task veridicality and input representativeness. They deal with how faithful the models are in simulating the kind of linguistic processing that people do in their normal lives. His finding is that the

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models have a long way to go before satisfactorily meeting all these criteria with the four types of tasks he tested, namely, speech processing, sentence processing, language production and reading aloud.

Computational psycholinguists have worked with different kinds of networks to produce results that are closer to reality. There are feed-forward networks in which data flow only in one direction. There are also networks in which information from some of the intermediate layers feed information back to the input layers. A commonly used network is the simple recurrent network in which data flows in a feed-forward fashion, and in addition has a basic feedback mechanism to apply new information that is learned.

Connectionist models have been shown to produce effects similar to children’s learning of past tense form of English verbs. The U-shaped curve observed in this regard was surprising because they seemed to do well on past tense forms to start with and then there was a dip followed by a stage of production of correct forms. Such performance was attributed to an initial phase marked by learning by rote followed by a stage of overgeneralisation (which results from the learning of the ‘add -ed rule’) and then a third stage where children distinguish between regular verbs which follow the ‘add-ed’ rule and the irregular verbs which introduce entirely new stems as past tense forms or follow vowel change patterns.

Researchers have tried to introduce randomness to the network by giving ‘noisy’ data. Interestingly, instead of producing bad results, the outcomes were positive in the sense that they were closer to human performance. This is reminiscent of the claim that variation plays a positive role in language learning and repudiates the Chomskyan assumption of a homogeneous speech community as a working hypothesis because it is completely counter to reality.

136 This process is called back propagation.
The Situatedness of Scientific Practice and the Rhetoric of Science

So far we have been looking at the philosophical or epistemological questions related to science. Current insights show that even ideas from the history, sociology and the rhetoric of science throw light on the practice of science. We will try to see if these factors have an effect on linguistics.

It is often said that science is value-neutral. That idea can be read between the lines in the following excerpt from the preface to a popular science book written by the physicist and science-populariser Michio Kaku:138

We ignore the impossible at our peril. In the 1920s and 1930s Robert Goddard, the founder of modern rocketry, was the subject of intense criticism by those who thought that rockets could never travel in outer space. They sarcastically called his pursuit Goddard's Folly. In 1921 the editors of the New York Times railed against Dr. Goddard's work: "Professor Goddard does not know the relation between action and reaction and the need to have something better than a vacuum against which to react. He seems to lack the basic knowledge ladled out daily in high schools. "Rockets were impossible, the editors huffed, because there was no air to push against in outer space. Sadly, one head of state did understand the implications of Goddard's "impossible" rockets – Adolf Hitler. During World War II, Germany's barrage of impossibly advanced V-2 rockets rained death and destruction on London, almost bringing it to its knees.

The excerpt suggests the following. When the benevolent power, the United States – symbolised by its influential newspaper, the New York Times – did not accept Goddard's idea, he was forced to approach the evil dictator who made use of the technology to destructive purposes. But the problem with the logic of this argument is that we do not have any reason to believe that had the United States accepted the value of the technology, it would have used it to the benefit of humanity or for pushing the frontiers of knowledge. From whatever we can infer from analogy with the other great technology that was developed in the twentieth century, namely the atom, it could have been put to a destructive use by the liberal enlightened democratic state.

A theory of multicultural origins of science has been an influential one since Bala (2006).139 The thesis there is that it is incorrect to merely associate modern science with

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139 Arun Bala, The Dialogue of Civilizations in the Birth of Modern Science, (New York: Palgrave
the western world. The reason why science came into its present shape in the west is that it happened to be an interesting meeting point of various ideas from various regions such as Africa, the Arabian peninsula, Persia, India and China. The reason why Europe happened to be a 'confluence' of all these is because of the vigorous trade and colonisation that it was engaged in with various parts of the world.

In the last few decades, there has been an increase in the awareness of how sociological factors influence the practice of science. Collins and Pinch (1993) gives several examples where sociological factors influenced the outcomes of some well-known experimental studies. One of those cases – the study about gravitational waves – was discussed later by Collins, who revealed a very interesting sociological fact about institutional structures which had an impact on the nature of knowledge that was discovered and disseminated. The experimental results concerning the research question were analysed differently by American groups as opposed to “certain non-American” groups. The non-American groups showed a more positive attitude towards the possibility of the existence of such waves whereas the American groups showed strong resistance to that. Collins attributed these divergent attitudes to the different institutional structures of science associated with these two regions. In the non-American contexts discussed, scientists are public servants who have greater freedom in publishing their results and analysing their data. On the other hand, scientists in the United States are funded by and are always answerable to large grant-giving agencies in which some key figures in the US scientific establishment play decisive roles. This institutional feature makes it difficult for an individual scientist to argue for a position which does not sit well with a major scientist who holds a top position in the establishment.

Also, very often, the state along with its defence establishments support scientific


research and hence decide what kind of questions should be studied. In a talk he gave on 20 October 2013, Freeman Dyson of the Institute for Advanced Study in Princeton, USA mentioned that a company called General Atomic that was set up by some physicists in 1956 to build nuclear spaceships now produces the controversial unmanned drone aircrafts, which have been used for bombing Afghanistan and western Pakistan.

The question of representation is also important in science. The science establishment often shows overrepresentation of some dominant groups. In the United States, a strikingly large majority of physicists are white men. A study showed that only 1% of the PhDs awarded in the US between 1986 and 2001 were to African Americans. In most of the important Indian scientific institutions, a large number of faculty are Brahmin or upper caste men. According to a report which looked at the significantly small number of women in Indian scientific institutions, women constituted only 7.5% of the scientists in the Indian Institute of Science (IISc) in Bengaluru in 2008.

Anecdotes suggest that during the last NDA government in India (1999–2004), there was an increased amount of research that tried to establish the medicinal properties of cow urine. Although I do not have much evidence to back that claim, here is a paper on the healthful properties of cow urine, which was accepted by the journal in 2003, when the NDA was in power: K. Krishnamurthi, Dipanwita Dutta, S. D. Sivanesan and T. Chakrabarti, “Protective Effect of Distillate and Redistillate of Cow’s Urine in Human Polymorphonuclear Leukocytes Challenged With Established Genotoxic Chemicals,” Biomedical and Environmental Sciences 17 (2004) 247-256. Also, notice the initial references to the ancient period and Veda in the paper.

The present author had attended this talk.

A common observation about American academia, including generative linguistics, is that there is a high representation of Jews in it.

Report: “Lost in a Black Hole: The Near Total Absence of African Americans in the Academic Study of Physics,” The Journal of Blacks in Higher Education 40 (2003) 41–43. The report says: “Dr.Nelson, who is white, examined the faculties of the 50 physics university departments with the largest research and development budgets in the nation. Her survey found that 12 blacks taught physics at these universities. All told, there are 1,988 physics faculty members in these 50 physics departments. Therefore African Americans make up 0.6 percent of all physics faculty at these 50 universities. All of the African-American physics department faculty are men.”

This figure is from a Department of Science and Technology (DST) Report of National Task Force for Women in Science released in 2010 titled Evaluating and Enhancing Women’s Participation in Scientific and Technological Research: The Indian Initiatives. The report on Women in Science says even at the level of intake at the postgraduate level in the IIISC, there was only 14 to 17% women 2001-02 and 2007-08. The same report gives the figure 16.05% as the proportion of women scientists in the Council of Scientific and Industrial Research (CSIR); in the Department of Biotechnology (DBT) it is much higher – 27.4%. (Citation: DST, Evaluating and Enhancing Women’s Participation in Scientific and Technological Research: The Indian Initiatives, Report of the National Task Force for Women in Science, Department of Science and Technology, Govt of India, New Delhi, 2010; www.ias.ac.in/womeninscience/taskforce-report.pdf, accessed 11 July 2014.)
Feminist studies on epistemology showed that the standpoint of the speaker influences the way an object is studied.\textsuperscript{147} Because scientific thought follows a particular type of thinking associated with a geographically and culturally located male person, this approach fundamentally questions the nature of scientific objectivity. Objectivity is perceived as a masculine ideal and because of this, Keller (1983) observes that the predominance of men in science is a “consequence rather than a cause of the attribution of masculinity to scientific thought.”\textsuperscript{148}

A non-mainstream person may perceive an object differently from that of a person with a normative identity because of her particular context which is a result of her biological and environmental factors. So if such a person is a scientist, it has the potential to generate a radically different conception of the objects that are studied. The question of standpoint has special relevance to linguistics. It is possible that linguistic theory in the generative or biolinguistic tradition is dependent on particular world views, modes of reasoning as well as languages spoken by its propounders.\textsuperscript{149}

The foundational assumptions of science are not available for critique. The society of scientists would resist strongly if someone tries to challenge the foundations of a discipline. There are few foundational assumptions which apply to the whole of linguistics because of the multiple frameworks in which language is studied. But within a framework, loyalty to a set of basic notions associated with a pioneering thinker are considered almost sacred.

Of late, there has been considerable attention paid to the view that the way natural

\textsuperscript{149} Chomsky's basic frameworks in syntax and Chomsky and Halle's framework in phonology are based on facts in English. See Chomsky's \textit{Syntactic Structures} and and Chomsky and Halle's \textit{The Sound Pattern of English}. Richard Kayne's idea of antisymmetry, which aims to explain word order across languages, considers English word order as basic for all languages and the other orders are derived from it. See Richard Kayne's \textit{The Antisymmetry of Syntax} (MIT Press, 1994). This problem is taken up in more detail in Chapter 4.
science is presented – the rhetoric – is also integral to its practice.\textsuperscript{150} Science tends to emphasise objectivity by avoiding 'I' and statements about individuals' thoughts, feelings and beliefs. Passive sentences are often preferred to active sentences in order to downplay the importance of particular human agents in the doing of scientific experiments and theoretical problem-solving.

In the case of 'mental' disciplines like linguistics and psychology, the rhetorical device of de-emphasising subjectivity has particular relevance. This is because there seems to be a widespread notion among thinkers that a different methodology of collecting knowledge has to be followed with respect to mental sciences as opposed to natural sciences because of their integral connection to individual perceptions and thoughts. The idea that a different methodology has to be practised is termed 'methodological dualism', as opposed to 'methodological naturalism', which is associated with natural sciences. Chomsky advocates methodological naturalism for mental sciences also because similar intellectual means are put to use in acquiring knowledge in natural sciences as well as mental sciences. In fact this question of whether to practise methodological dualism or methodological naturalism might be after all a matter of rhetoric.

\textbf{Conclusion}

The attempt in this chapter was to cover most of what we understand by science in an everyday sense as well as in a historically and philosophically informed sense. We also saw how science is situated in a social and political context. However, there could be flaws in this understanding because it only minimally deals with the practice of science from a scientist's own perspective. Here we see a classic instance of the question who can represent a group described by a particular identity. Rogers suggests that the scientist has a privileged perspective compared to the historian and philosopher.\textsuperscript{151} Similar questions

\textsuperscript{150} At the same time, in social sciences, there is a current tendency to place the author in relation to the work she is doing; so, we would notice the presence of 'I', expressions of subjectivity and so on.

\textsuperscript{151} Eric M. Rogers, \textit{Physics For The Inquiring Mind}, (Princeton: Princeton University Press, 1960). In the introduction to his book that included the history, philosophy and methods of the discipline in addition to the theoretical aspects of the subject, Rogers observes that attitudes to science held by historians and
have been asked in relation to other identities, including the question of who can speak for a Dalit in the Indian context.\textsuperscript{152} This question of exclusion of non-mainstream groups will be briefly discussed in chapter 6.