Models of Nature
Science and Sanskrit Grammar

John Doran

Following on from last issue's articles on language and biology by Alyse Takayesu, and Chris Clarke's on Tops Logic, John Doran compares the logic of quantum theory and the grammar of Sanskrit. The article portrays how the logic of the elementary particle world evades causal local description, and how language can serve as a template for the way deeper meaning surfaces in tangible form - editor

Introduction

Western science has taken the physical world as the primary object of its investigation – that is, the material world as experienced by the senses. Centuries of study, thought and imagination have led, by the 20th century, to the sophisticated and beautiful theories of modern physics. These theories are abstract, often strange, seemingly paradoxical, even non-comprehensible in ordinary terms, but astoundingly successful in their purpose, which is the accurate description and prediction of physical phenomena. Science has been guided, and constrained, by the evidence of the world as it presents itself, initially in ordinary experience and eventually in detailed experimentation.

The ancient Sanskrit grammarians took the Sanskrit language as the primary object of their investigation – that is, the language as spoken by the śisas, those who were wise, and learned just for the sake of being so. Centuries of study, thought and imagination led, by the 5th century BC, to the sophisticated and beautiful theory of Pānini, as expressed in his Astādhyāyī. This theory is abstract, but astoundingly successful in its purpose, which is the accurate description of the Sanskrit language. The grammarians were guided, and constrained, by the evidence of the language as it presented itself.

The nature of these great scholarly pursuits, millennia and continents apart, is similar. Each sets out to describe an aspect of human experience – the material world or the Sanskrit language. Each believes, or has believed, its object of study to be divinely given, not created by man – the world created by god, and Sanskrit, the language of the gods.

What emerged are two systems of law – scientific law and grammatical law – systems that seem to define their respective ages. A comparison of these two systems, the system of western science and the system of the Sanskrit grammarians, as formulated by Pānini, is inviting. What kind of models did mankind build to describe his experiences in times of very different priorities and culture? Additional impetus is given to such a comparison by the following statement, by Śrī Śantānanda Sarasvatī:

"The grammatical rules are also the rules of the creation." [1]

There are some simple questions:
We have 'word' on the one hand, and 'that which word names' on the other hand. One is believed to be subject to law – as described in grammar. The other is believed to be subject to law – as described in science.

If 'word' and 'that which word names' are only apparently separate, being one at a deeper level, then the laws describing 'word' and 'that which word names' would be only apparently separate, being one at a deeper level. Is there evidence for this? Do we see something in the laws of each that tends to confirm this intuition? In this paper some preliminary comparisons are made between modern physics and Sanskrit grammar as systems of law, or models of aspects of nature, for the purpose of investigating these questions. What seem (to the present author) to be notable similarities are suggested.

There are, of course, also significant differences between these two systems. The most significant difference is the language in which the systems of law are formulated. In the case of western science the language is mathematics. In the case of Sanskrit grammar it is Pānini's metalanguage, consisting of pratyāhāras, indicatory letters, and well-defined case-ending conventions. Even in this fundamental difference between the two systems we see a striking commonality; in both cases the system derived its success from the invention/discovery of an appropriate 'artificial' language with which to frame its laws. It is hard to imagine western science having progressed in its description of nature without mathematics. Euler's recasting of Newton's Laws from Newton's original wordy Latin expressions into a simple mathematical form was a significant step in the proliferation of modern physics. It is also hard to imagine the science of Sanskrit grammar having progressed to the extent that it did if the laws had to be expressed in ordinary language. Ordinary, or natural, languages are excellent for communication. Artificial languages are excellent for developing systems of knowledge.

For the Greeks, mathematics was prerequisite. For the Indians, grammar was.

"In philosophizing the Greeks made as much use as possible of mathematics. The Indians…made as much use as possible of grammatical theory and argument." Daniel Ingalls[2]

"Just as Plato reserved admission to his Academy for geometricians, Indian scholars and philosophers are expected to have first undergone a training in scientific linguistics, i.e., Sanskrit grammar….Historically speaking, Pānini's method has occupied a place (in Eastern thought) comparable to that held by Euclid's method in Western thought." Frits Staal[3]

In comparing these two systems one must be careful not to push analogies too far, and one must be restrained in making claims of significance. Comparisons between these two systems could be at a detailed level, where a particular grammatical law is compared to a particular scientific law. There may be a danger here of applying too much force to the comparison. Alternatively, comparisons could be at the more general level, looking at the operation of the overall systems. The latter approach is favoured in this paper. That is not to say that the detail is not important; it is of great importance in understanding and developing the overall system; it is in the detail that the formulation of the systems of law begins.

Systems of Law

Physics is a system of law for the material world. Vyākaran (grammar) is a system of law for the Sanskrit language. As a starting point in the comparison of these systems one can ask the question: 'What is a law?' Alternatively, 'what do laws do?' An answer is that 'laws' operate upon 'things'. So what is a 'thing'? A 'thing' is that which is acted upon by a 'law'. There is an essential duality between 'law' and 'thing'. It is hard to conceive of a 'thing' that is not acted upon by a 'law', or of a 'law' that does not act on a 'thing' – it would be a redundant idea.

Other words come into play with regard to 'things'. We think of 'things' as being 'objects' and as having 'properties'. These relate to common experience. It is through the objects and their properties that we have access to the 'things' and thus to the 'laws' that govern them (see Figure 1).

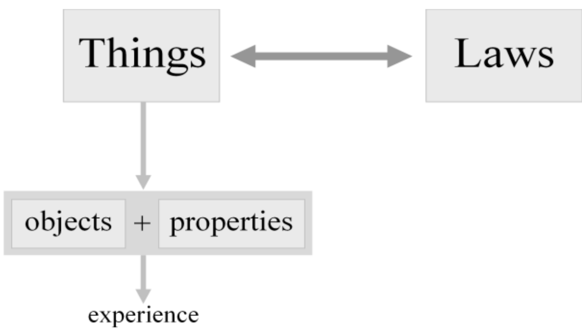

Figure 1

The system of law, or model of nature, consists in identifying the ‘things’ and the ‘laws’ that act upon them.

In the system of vyākarana the starting point is to identify the basic objects, which are the Sanskrit letters. Eventually the letters are organised into groupings according to the properties they share. Pānini begins his grammar with such a grouping of letters, the Māheśvarāni Sūtrāni.

a£Ñ-\ « Alºk\ « éao$\ « éeaOc\ «

hyvrq\ « l-\ « [m$-nm\ « !#[\ «

`W=x\ « jbgwdz\ « ,f¡Q'cqtv\ «

kpy\ « zxsr\ « hl\ »

Figure 2 The Māheśvarāni Sūtrāni

The Māheśvarān i Sūtrān arrangement is a highly efficient way to organise the letters in order to allow naming of the 42 groupings (pratyāhāras) that Pānini uses in his grammar. In fact, it is mathematically proven to be the most efficient possible way in which to organise the letters for this purpose.

The point is that the laws given by Pānini are formulated so as to act on objects (the letters) that have specified properties.

But there are also other properties that the objects (letters) can have that Pānini does not express using pratyāhāras. Letters can be assigned properties that relate to the method of their articulation – sprsta (contact), vivrtta (open), *etc.* – or by the position of articulation in the mouth – kanthya (guttural), osthya (labial), *etc*. – or method of articulation – ghosa (voiced), aghosa (unvoiced), aspirated, unaspirated, *etc*. – or by the duration of the enunciation – hrasva (short), dīrgha (long), pluta (prolonged) – or by the accent of enunciation – anudātta (low), udātta (high), svarita (mixed). When it is convenient, Pānini expresses laws in terms of these properties.

Letters can also have the property of being savarna (of the same ‘colour’) with a group of other letters, *i.e*., having the same mouth position and the same method of inner articulation. When it is convenient, Panini expresses laws in terms of this property.

The picture that emerges is of a set of objects, the letters, being assigned a host of different properties. Pānini uses these various properties in his system because grammatical laws are readily formulated in terms of them. The different properties are not in mutually exclusive sets, but are overlapping, nested, and definable in terms of each other.

In the system of modern physics the starting point is to identify the basic objects, which are the fundamental particles. (Note: modern physics is not a completed but an evolving model.) The particles are organised into groupings according to the properties they share. The fundamental particles, in the standard model of modern physics, are outlined in Figure 3.

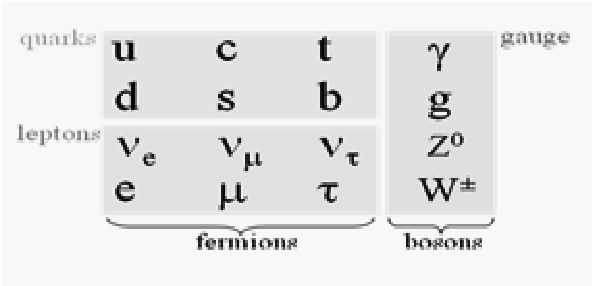

Figure 3 The fundamental particles in the standard model of modern physics.

These particles are arranged into three families: (1) the **quarks** (up-quark (u), down-quark (d), charm-quark (c), strange-quark (s), truth-quark (t), and beauty-quark (b)); (2) the **leptons** (electron (e), muon (□), taon (□), electron-neutrino ($□_e$), muon-neutrino ($□_□$), and taon-neutrino ($□_□$)); and, (3) the **gauge particles** (photon (□), gluon (g), Z-particle (Z^0) and W-particles ($W^{\pm}$)).

These particles are arranged into groups, or families, because they share properties. The quarks and leptons are fermions – they obey scientific laws that are formulated for fermions. The gauge particles are bosons – they obey scientific laws that are formulated for bosons.

There are a host of physical properties that are held by these particles. Particles may have mass, electrical charge, spin, isospin, nuclear colour, baryon number, *etc*. The particles will obey scientific laws that are formulated in terms of these properties.

The picture that emerges is of a set of objects, the particles, being assigned a host of different properties. Science uses these various properties in its system because scientific laws are readily formulated in terms of them. The different properties are not in mutually exclusive sets, but are overlapping, nested, and definable in terms of each other. For example, quarks have mass, charge, *etc*. Quarks are a subset of fermions. Even the division between the ‘object’ (particle) and the ‘properties’ is a convenience, *e.g*., an up-quark simply represents the manifestation of the set of properties {mass of $4.28x10^{-30}$ kilograms, charge of $1.07x10^{-19}$ coulombs, spin of ½, *etc.*}.

The above brief outline of the two systems of law shows a great similarity of general approach. Laws are expressed in terms of various groups of properties that the basic objects have. The properties are named because the laws are readily expressible in terms of them. Whatever is most convenient for expressing a law is chosen to express it.

Another commonality between the two systems lies in the fact that both systems are ‘atomistic’. The model presented is of underlying basic objects (the letters and the particles) and that from these basic objects is constructed a hierarchy of composite structures.

Scientific view of the material world
The basic particles, quarks, combine to form nucleons (protons and neutrons). The nucleons combine together to form nuclei. The nuclei combine with electrons to form atoms. Atoms combine to form molecules. Molecules combine in various ways to form gases, liquids and solids. Each level of composition comes about under well-defined scientific laws. Most of the levels of composition are abstract, inventions for the sake of analysis, beyond the range of direct experience. The direct connection with human experience occurs at the level of gases, liquids, solids. The sense experiences of the macroscopic material world are the starting point. Atoms, molecules, quarks, *etc*., are abstractions from that direct experience, invented for the sake of knowing the laws that are at play.

Grammarians view of language
The basic objects, letters, combine to form a range of different composite entities, dhātus (roots), pratyayas (affixes), āgamas (augments), prātipadikas (noun stems), and angas (bases). These composite entities combine to form padas (words). The words combine to form the vākya (sentence). Each level of composition takes place under well-defined grammatical laws. Most of the levels of composition are abstract, inventions for the sake of analysis, beyond the range of human experience. The direct connection with human experience is at the level

of the sentence. The sentence is the indivisible linguistic unit, the starting point, expressing a meaning. Dhātus, pratyayas, prātipadikas, even words, are abstractions from the sentence, invented for the sake of knowing the laws that are at play.

These composite schemes are shown in Figure 4.

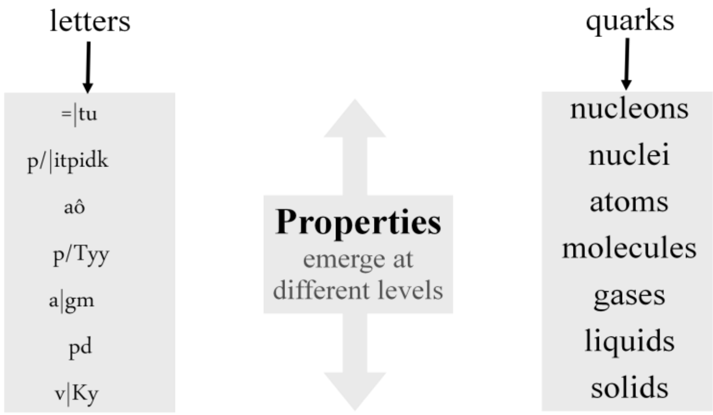

Figure 4 Composite structures in grammar and in science.

At each level of composition there are different families of law operating.

In science there are laws governing quarks (the laws of quantum chromodynamics), laws governing nucleons and nuclei (the laws of nuclear physics), laws governing atoms (the laws of atomic physics), laws governing molecules (the laws of chemistry), laws governing gases (the laws of thermodynamics, aerodynamics), laws governing fluids (laws of fluid dynamics), and laws governing solids (the laws of mechanics, *etc*.). Also, at different levels of composition there are properties that emerge that would have no meaning for deeper levels. For example, a gas may have the property of temperature. At other levels of composition the property of temperature would not have any real meaning, *e.g.*, for a single atom. A solid can have the property of elasticity, but not a quark. A fluid may be buoyant, but not a molecule. There are also laws that operate at all the levels of composition, *e.g.*, the laws of gravity. An important difference between science and vyākarana is that it is expected that the laws at higher levels of composition are derivable from those at the deeper levels.

Two points emerge from the above analysis: (1) modern scientists and ancient Sanskrit grammarians went about their business in similar ways – inventing, or using, an artificial language – and using that language, in a pragmatic manner, to formulate laws in terms of properties, some of which are intuitive, and some of which are abstract, but always opting for an expression of laws in terms of properties that are convenient for the purpose; (2) modern scientists and ancient Sanskrit grammarians developed an atomistic view of their chosen objects. They both analysed their objects of experience into a multilayered picture, with deeper levels being more abstract and with different families of laws operating at these distinct, but interconnected, levels.

Today we might say that the grammarians adopted a highly scientific approach, that the mind of the ancient grammarian was the same as the mind of the modern scientist. Pānini, had he been able to look forward by two millennia, might say that the mind of the modern scientist was the same as the mind of the grammarian.

The ancient grammarians and modern scientists both devised models of the different aspect of nature that were their respective fields of study – the physical world and the Sanskrit language. In the case of modern science this model of nature has been developed over several centuries of human effort. Several names stand out as having put in place key components of this model – Galileo, Newton, Maxwell, Einstein, Bohr, Heisenberg, and Schrödinger, are a few. Starting out with the experiences of everyday life – How do objects fall? What causes the tides? – over the centuries the model became more sophisticated, more abstract, more concerned with things that are removed from ordinary experience – What is the origin of fluctuations of the cosmic microwave background? What is dark matter? This model is a work in progress, although it may be argued that its essential features have not changed since the early decades of the 20th century, put in place by Einstein, and Bohr and the other quantum theorists.

In the case of Sanskrit grammar, this model of nature was almost certainly developed over centuries of human effort. Several names stand out from that tradition. Pānini refers to earlier grammarians, Śākatāyana, Śākalya, *etc.*, but Pānini brought the model to its (more or less) final form. Others have followed, explaining, modifying and expounding on Pānini's work, but the essential model is attributed to him. Starting out with the linguistic experiences of everyday life – What are the basic phonemes of the Sanskrit language and how are they correctly produced? How can we codify the link between the padapātha and samhitapātha versions of vedic recitation, and thus ensure fidelity of transmission of the Vedas? – over the centuries the model became more sophisticated, more abstract, more concerned with things that are removed from ordinary experience – What is the correct dhātu for ātman, and how would one decide? Does the bahiranga paribhāsa really operate?

Models of Nature

What is the philosophical significance of the models of nature presented to us by the scientists and by the grammarians? Do they have any philosophical significance? There are certainly philosophical principles guiding the development of these models, and applied in choosing from among possible alternatives. That which is most simple, most universal in its explanatory power, most elegantly or economically expressed, and most parsimonious in its use of assumptions, is always preferred. This is true of science, and clearly true of Pānini's grammar. The language can be complex (as mathematics and Pānini's metalanguage sometimes are), but the underlying principles are simple.

But what about philosophical insights arising from the models themselves? A study of Pānini's Astādhyāyī leaves the impression that Pānini does not make philosophical arguments or points. In fact, it would be detrimental to his work if he did so. His job is a different one – it is to construct a model of the language that works. Others may speculate about the philosophical significance of his model, what it suggests about the aspect of nature that he studied. Pānini himself may also have speculated about it – it would be hard to imagine that he did not – but there is no record of that. The same is true of science. The job of the scientist is to build a model of nature that works. The model that results may well provide a picture of nature that is rich for philosophical speculation and insight, and the scientist may enjoy this speculation – some do, some don't – but it is secondary to his main task.

We are fortunate to be able to speculate on the models of nature given to us by both the grammarians and the scientists, and to compare them. It is worth doing because the models are so good, and what they suggest is so interesting. Some such speculation forms the final part of this paper.

As mentioned above, in the construction of models of nature the journey begins with direct human experience. For the scientist the starting point is the experience of the objects of the world, perceived by the senses. The classical scientist conceives the world as being made up of 'billiard balls', things you can see and touch and hear. They move around and collide with each other. From watching them carefully the scientist discovers the principles of conservation of energy, and of momentum, and much more. This works very well for a long time. Eventually the scientist gets around to studying things, like atoms, that he cannot perceive with the senses. But while he can't see, hear, or touch, atoms, he assumes that they are essentially **like** 'billiard balls', just too small to be seen. They are not perceivable, but they are **like** the things that can be perceived. This works well for a while. The atom is conceived of as being made of tiny 'billiard balls' (protons) being orbited by even tinier 'billiard balls' (electrons). Eventually this picture starts to present problems – it doesn't work. With the advent of quantum theory the 'billiard ball' picture is abandoned, and the material of the world is instead thought of as being wave-like. It now becomes necessary to think of entities existing at the atomic level as being sometimes like particles and sometimes like waves. They are no longer even **like** the objects of ordinary experience. They are the 'wavefunctions' of quantum physics, highly abstract entities. In a way they are unknowable, but they are describable (with great precision) in the language of science, *i.e.*, mathematics. This is summarised on the right-hand-side of the Figure 5.

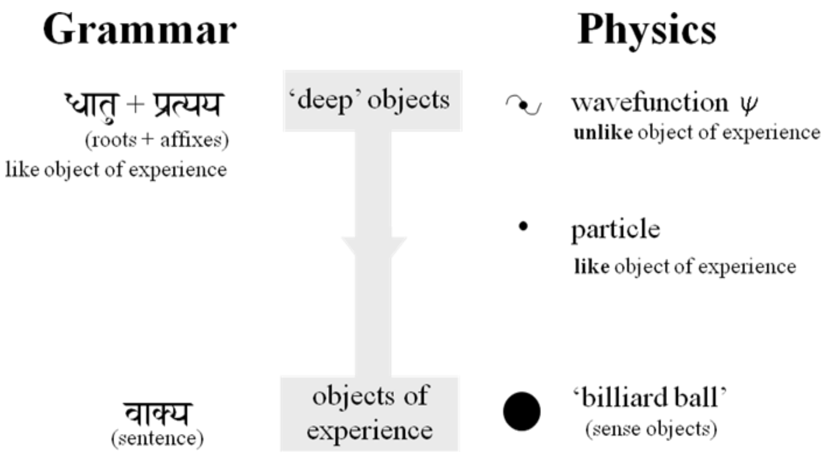

Figure 5 The objects of physics and grammar.

We have a move from the ordinary to the abstract. From that which is experienced to that which, though not perceivable, is easily conceivable, and then to that which is neither perceivable nor conceivable. From the object of experience to the 'deep object'.

The left-hand-side of Figure 5 shows what we find with language. The object of experience, linguistically, is the sentence (vākya). It is the sentence that is the unit of meaning, and it is meaning that is the content of language. Words are abstractions from the sentence. The 'word' (pada) is a useful idea, highly intuitive. Less immediately intuitive are the other inventions/discoveries of the grammarians, affixes (pratyayas), noun-stems (prātipadikas), and roots (dhātus). The object of experience, the sentence, gives way, under the analysis of the grammarians, to a string of roots, affixes, and augments, *i.e.*, to an abstract object. Examples are given further below. Again, we move from the ordinary to the abstract. From the object of experience to the 'deep object'.

This historical, and ontological, move from the object of experience to the abstract 'deep object' has another fascinating aspect. We will see that it illustrates, both in the case of the scientific model of the world, and in the case of the grammatical description of the sentence, a move from diversity in experience to a deeper unity.

Diversity to Unity / Unity to Diversity

The strangeness of quantum physics is well known[5]. The reason it is considered strange is because it says that things can simultaneously have seemingly contradictory properties. It can be both 'here' and 'there', simultaneously 'up' and 'down', *etc*. Let's say that we have a particle. The particle has a physical property that we will indicate as colour, although it's not really colour. The physical property can have two values that we will indicate as 'red' and 'blue'.

Quantum physics tells us that prior to a measurement being made the particle is not either 'red' or 'blue' but is actually a mixture of 'red' and 'blue'. It's not that we don't know which until the measurement is made. It's that it is, in some way, both 'red' and 'blue'. Mathematically, there is a 'red' wavefunction (ψ_{red}) and a 'blue' wavefunction (ψ_{blue}). Prior to measurement the actual wavefunction (ψ) of the particle is an equal mixture (superposition) of these two wavefunctions:

$$\psi = \frac{1}{\sqrt{2}}\{\psi_{\text{blue}} + \psi_{\text{red}}\}$$

Humans don't perceive particles as being simultaneously 'red' and 'blue' (by which is not meant 'purple'!). They see them as either 'red' or 'blue'. This particle is only ever seen as 'red' or 'blue'. So how does the particle change from being the mixed wavefunction ψ to being either ψ_{red} or ψ_{blue}? The answer that quantum physics gives is that the wavefunction somehow 'collapses' upon measurement, *i.e.*, upon observation. This is depicted in Figure 6.

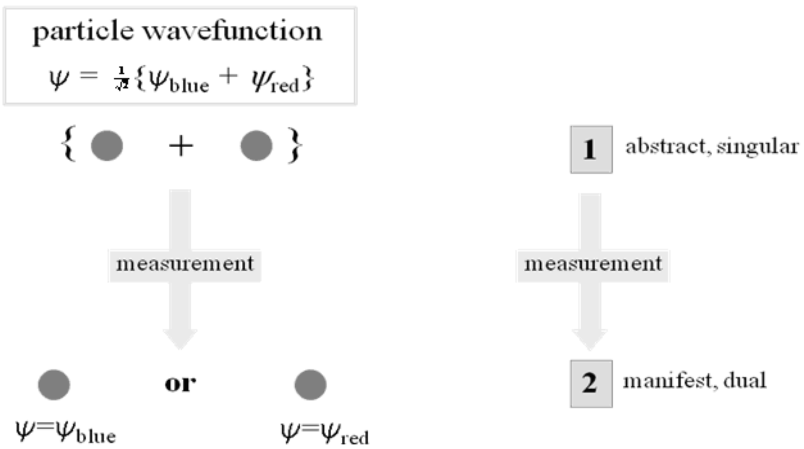

Figure 6 Measurement in quantum physics.

We see that at the 'deep' level there is a single entity, a wavefunction $\psi = \left(\frac{1}{\sqrt{2}}\right)\{\psi_{red} + \psi_{blue}\}$ while at the level of experience (what is directly observed) there is duality, either ψ_{red} or ψ_{blue}. This move from underlying unity to manifest duality comes about by the act of observation.

What is meant by observation here is technically, and philosophically, loaded. Does it mean 'observation by a conscious observer?' Does it mean 'interaction with the thermal bath of a macroscopic measuring device, which decoheres the wavefunction giving rise to the collapse'? These questions remain unresolved. What is clear in the description of the particle offered by quantum physics is that a move is made from something singular to something dual, and that this change comes not from within the physical system itself, but from outside it, by its being observed.

This move from an underlying unity to a manifest duality (or multiplicity) that is seen in the modern physicist's superbly accurate description of the physical world has a stunning analogue in Sanskrit grammar. And it is extremely simple and obvious.

Consider the picture inside the box at the top of Figure 7, and how it relates to language. A function of language is to represent this picture. The speaker means to represent some particular aspect of the picture, and forms a sentence that captures that meaning. In this picture the blue figure is Rāma, and the red figure is Sītā. The arrow indicates that Rāma is going in direction of Sītā. All of this is happening in the present.

Pānini's grammar generates, in a simple and elegant manner, correct sentences to represent this picture. Words are constructed to represent the main action in the picture (in this case 'going'), and words are constructed to represent the players in that action (in this case Rāma and Sītā). All of these words are constructed from base material (dhātus, *etc.*) under strict grammatical laws. Then the words are put together to form a sentence (vākya), again under strict grammatical law. Of course, the sentence really comes first, but in grammatical construction it can be thought of as the other way around.

Strings of grammatical entities such as above are not a sentence as spoken by humans. In fact, the sentence spoken by humans could come out in two different grammatically correct ways (more than two, actually, but we'll just consider two). It could be:

Rāma goes to Sītā (active voice)

or it could be

Sītā is being gone to by Rama (passive voice)

It is the choice of the speaker that determines which sentence emerges. They are entirely equivalent. They have the same meaning. Only the surface form is different. How is the problem of the move from the abstract 'deep sentence' to the different surface forms solved within the system of Pānini, which sets out to construct, under law, all the grammatically correct sentences of the language?

Pānini builds his model of Sanskrit sentences around the well-known idea of the kārakas, (which are abstract case relations between nouns or noun phrases and the verb). Specifically, he demands that each relevant kāraka must be 'expressed', but that it can only be 'expressed' once. (Pānini uses the term abhihita 'expressed'.) This solves our problem, and many others, in a remarkable way. Once the form of the verb, passive or active, has been chosen by the speaker, then the rest of the sentence falls naturally and simply into place, under Pānini's various grammatical rules. The technical details of this don't need to be outlined here. It is enough to say that the choice of voice, in this case, relates directly to the 'expression' of the kārakas.

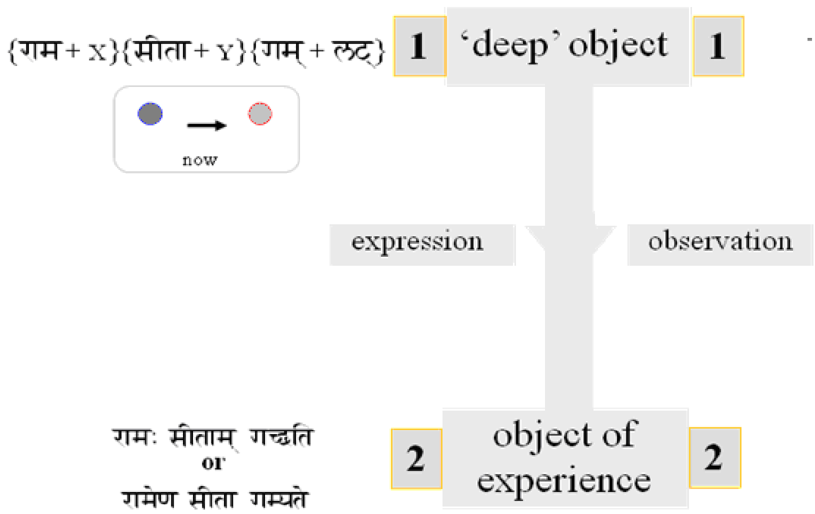

Figure 7 Sentence generation in Sanskrit grammar

We see that at the 'deep' level there is a single entity, an abstract sentence, while at the level of experience (what is directly spoken or heard) there is duality. This move from underlying unity to manifest duality comes about by the act of expression.

What is meant by 'expression' here is technical, but philosophically loaded. Technically, it means 'expression of a kāraka by an affix'. What is clear in the description of the sentence offered by Pānini's Astādhyāyī is that a move is made from something singular to something dual, and that this change comes not from within the grammatical system itself, but from outside it, by its being expressed.

What is presented above outlines the models of nature put forward by modern science and by the Sanskrit grammarians. They both start from the surface experience and move to a deeper level of description. In moving back out again they both face a similar problem. How to make the step from the singular to the dual, and they solve it in similar ways.

In physics there is a deep object, unitary and abstract, which manifests in different forms, as coloured 'billiard balls' experienced by the senses. The step from unity to duality comes by 'observation', or measurement. In Sanskrit grammar there is a deep object, unitary and abstract, which manifests in different forms, as spoken sentences. The step from unity to duality comes by 'expression'.

In both of these systems, this step does not come about from within the system, but requires an impulse from without, from the conscious acts of observation and expression.

Conclusion

The instrumentalist view of science says that wavefunctions and other abstract entities that arise from theories and scientific model-building have no real significance. They are merely inventions that happen to work well at explaining and predicting the behaviour of the physical world as observed by the senses. The realist view of science is different – it says that these discoveries of science do have real significance; they tell us what actually is underlying the observed world. There will be corresponding instrumentalist and realist views of vyākarana.

It has been seen above that the modern scientist and the ancient Sanskrit grammarian are close cousins. They have been engaged in similar exercises, and have gone about it in similar ways. Their inventions/discoveries are strikingly similar - the artificial languages, the objects with multifarious properties that are acted on by laws, the multi-layered picture of nature from the deep abstract layers to the surface layers of ordinary experience, and, most strikingly, their solutions for moving between these layers by the mediation of the conscious acts of 'observation' and 'expression'.

It is not necessary to settle the argument between the instrumentalist and realist views of these models of nature to be struck by the deep similarities.

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2. Ingalls, D.H.H (1954) *Journal of Oriental Research*, Vol. 22, pp. 1-11
3. Staal, F. (1965) *Philosophy East and West*, Vol. 15, pp. 99-116
4. The grammarian, operating in an oral tradition, must have a way of expressing properties so that laws can be devised that operate on them. He does this by using vocal devices such as accents and indicatory letters. The scientist, operating in a written tradition, does it differently. Properties are represented using a written device, such as a symbol, or a style of typeface, or a subscript or superscript, *etc*.
5. A good basic introduction to the ideas of quantum physics is *Quantum Physics: Illusion or Reality*, by Alastair I. M. Rae, Cambridge University Press (2004).

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