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CHAPTER 5

FIELD RELATIONS: UNDERSTANDING SCIENTIFIC EXPLANATIONS

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MAKING SENSE

If you live away from the equator, the seasons are clear. Summer is hot, winter is cold and spring and autumn are somewhere in between, harbingers of what's to come. If you are a student of secondary-school science, this often becomes the starting point for a considerably more academic discussion: why do seasons occur? And the resulting explanation is far removed from everyday experience. It involves the rotation of the earth, its tilt, its division into northern and southern hemispheres, its orbit around the sun, the sun's emission of light and a number of effects resulting from some combination of these. Our everyday understanding of hot and cold throughout the year quickly transforms into a large complex of scientific 'facts'.

An explanation oriented to a popular audience, for example, explains: [i]

> **What Causes Seasons on Earth?**
>
> *Seasons happen because Earth's axis is tilted at an angle of about 23.4 degrees and different parts of Earth receive more solar energy than others.*
>
> Because of Earth's axial tilt (obliquity), our planet orbits the Sun on a slant which means different areas of Earth point toward or away from the Sun at different times of the year.
>
> Around the June solstice, the North Pole is tilted toward the Sun and the Northern Hemisphere gets more of the Sun's direct rays. This is why June, July and August are summer months in the Northern Hemisphere.

> **Opposite Seasons**
> At the same time, the Southern Hemisphere points away from the Sun, creating winter during the months of June, July and August. Summer in the Southern Hemisphere is in December, January, and February, when the South Pole is tilted toward the Sun and the Northern Hemisphere is tilted away.

Such an explanation pushes us far away from our everyday experience. But for students to be successful in science, they must be able to both read and write explanations of this kind regularly. Indeed explaining why seasons occur is a key topic in the first year of secondary school science in New South Wales, Australia.

In recent years, dialogue between Systemic Functional Linguistics (SFL) and Legitimation Code Theory (LCT) has been exploring the nature of such knowledge and the discourse used to organize it (Maton *et al*. 2016, Maton and Doran 2017, Martin 2011, Martin *et al.* 2020). A goal of this research across disciplines is to develop discipline-sensitive pedagogy and curriculum to improve the learning of subject-specific knowledge. As part of this endeavour, research has focused on different kinds of knowledge, how knowledge develops over time and how we can model the knowledge we find in spoken and written texts and across the vast range of multimodal semiotic resources used in school.

In terms of Legitimation Code Theory, for students to master the scientific knowledge involved in explaining the seasons, they need to be able to understand and manipulate intricate *constellations* of meaning (Maton 2014: 149–159; Maton and Doran, chapter 4 of this volume). These constellations organize large networks of meaning into specific arrangements according to the discipline, the year level and the phenomenon being explained. In science, what is foregrounded are *epistemological constellations* which focus on the ‘content’ of disciplines – discipline-specific configurations of causal relations, taxonomies and scientific procedures, along with methods for investigating the world. This is in contrast to *axiological constellations* that emphasize specific dispositions, political and aesthetic stances, morals and ethics, often found for example in the humanities (Maton 2014, Martin *et al.* 2010, Doran 2020).

From an epistemological constellation perspective, the key components in the constellation underpinning why seasons occur in this explanation can be synthesized from the text as follows:

> *Earth’s axial tilt is 23.4 degrees*

The amount of solar energy received by different parts of the earth at different times of the year varies.

The earth orbits around the sun

The earth is divided into hemispheres

Seasons occur

These components are not simply a bunch of isolated 'facts' about seasons. In order to explain seasons, they need to be brought together in specific configurations. For example, the variation in the amount of solar energy received by different parts of the earth that underpins seasons is caused by the particular combination of the Earth's 23.4 degree tilt, its orbit around the sun, its division into hemispheres and the fact that the sun emits light that hits the earth. Without any of these components, seasons would not occur.

The questions then for this chapter are: what are the relations that underpin scientific knowledge? And how do we *see* these relations in texts, both through language and other semiotic resources? Put another way, we are concerned with what it is that students are expected to learn when they 'do' science.

As far as SFL is concerned, one vantage point from which to explore this is through the register variable *field*. In SFL, field is one component of register, along with tenor and mode, and is concerned with what educators consider the content of language and semiosis. Seen in terms of SFL, field is a more abstract level of meaning positioned above the ideational meanings construed through language at the levels of discourse semantics, lexicogrammar and phonology/graphology. These levels of abstraction, called strata, are represented as co-tangential circles in Figure 5.1 (Martin 1992).

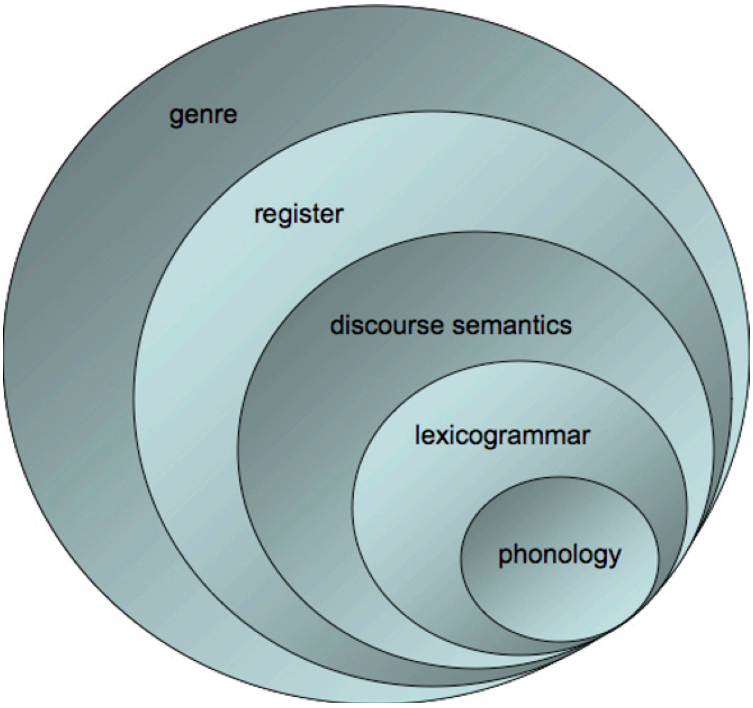

Figure 5.1 Strata of language in Systemic Functional Linguistics

Over a number of years, work on field and ideational meaning has provided a highly productive lens through which to view scientific understandings of the world (e.g. Lemke 1990, Halliday and Martin 1993, Martin and Veel 1998, Halliday 2004, Martin 2020). More recently, the model of field has been renovated, largely in response to SFL's dialogue with LCT (Martin *et al.* 2020, Martin *et al.* 2017, Martin and Maton 2013), the development of ideational discourse semantics by Hao (2015, 2018, 2020a, 2020b, 2020c, chapter 6 this volume), and investigations of a range of semiotic resources used in science, including mathematics, graphs, diagrams, animations, other formalisms and body language (Doran 2017, 2018, 2019, chapter 7 of this volume; Hood and Hao, chapter 10, this volume; Martin *et al.* in press; Unsworth 2020; He 2020).

This paper outlines these evolving understandings. It will introduce each component of the new model, drawing on a range of linguistic texts and semiotic resources. It will then use the model to explore seasons as they are taught in secondary school in New South Wales, Australia. In doing so, the chapter illustrates how field can make visible the knowledge teachers need to teach and students need to learn in order to achieve success in school science.

FIELD RELATIONS: STATIC AND DYNAMIC PERSPECTIVES

The model developed here expands on that of Martin (1992). At its most general level, field can be described as a resource for construing phenomena either *statically* as relations among items or *dynamically* as activities oriented to some global institutional purpose. Beginning with the *static* perspective, this orientation to field views phenomena as items organized into particular taxonomies. For example, our common-sense understanding distinguishes four seasons: winter, summer, autumn and spring. This can be modelled as a classification taxonomy, as in Figure 5.2.

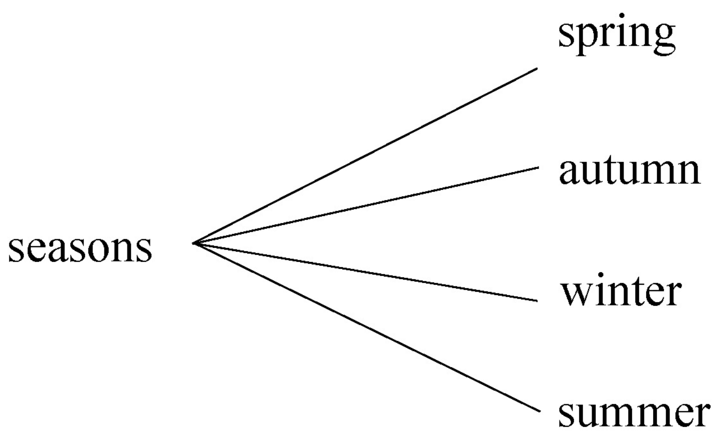

Figure 5.2 Classification taxonomy of the seasons

Classification views relations between items in terms of types and sub-types (class and sub-class). In terms of seasons, the items *spring, autumn, winter* and *summer* are all sub-classes in relation to the more general item of *seasons* and co-classes in relation to each other.

An alternate static perspective on phenomena is through composition – the part-whole relations among items. In terms of explaining the earth's seasons, composition relations are used to divide the solar system into the sun and the earth, and the earth in turn into the northern and southern hemispheres. The relevant composition taxonomy of the solar system for explaining seasons is show in Figure 5.3.

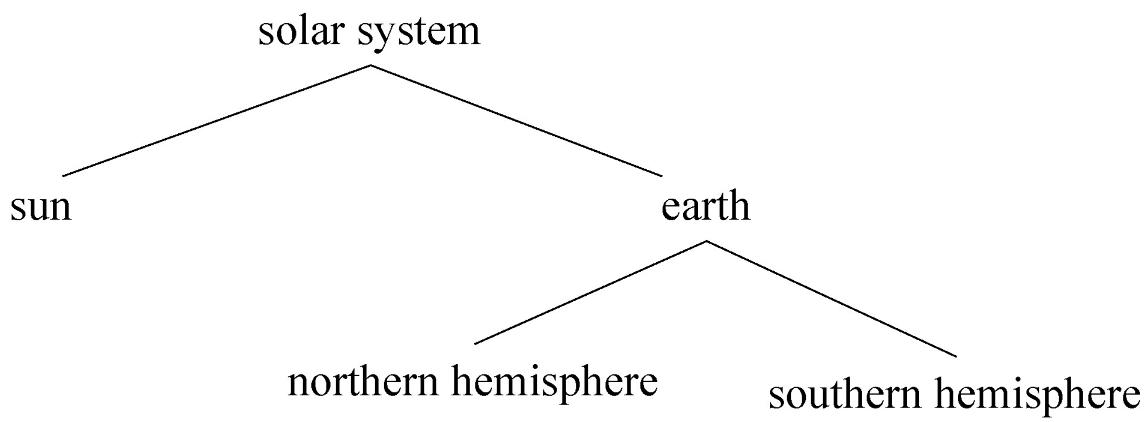

Figure 5.3. Composition taxonomy of the solar system

Our solar system of course contains many different components aside from the earth and the sun, and the seasons can be divided into many other configurations (northern Australians may well wonder where the wet season or the dry season or the build-up are in the classification introduced above). But the important point here is that for the particular problem of explaining how seasons work in junior high school, ethnocentric though it may be, these are the composition and classification relations that are relevant. In LCT terms, these meanings form part of the specific constellation comprising knowledge of the seasons.

As far as our model of field is concerned, taxonomies may be indefinitely wide or deep. For example the composition taxonomy introduced above indicates two parts for each level, whereas the classification taxonomy distinguishes four seasons. And in principle, there may be any number of subtypes or parts depending on what one is looking at. Similarly, the composition taxonomy of the solar system shows a slightly deeper hierarchical arrangement than the classification taxonomy, with three levels of the composition (solar system→ earth→ northern hemisphere, for example). Again, this may be expanded indefinitely, with any number of parts and wholes relevant for a given field. Indeed the expansion of taxonomies is one of the key features of scientific knowledge. This is one respect in which science differs from common-sense understandings whose utility tends to demand less width and depth of classification and composition (Wignell *et al.* 1989).

We can begin mapping the types of relations underpinning fields with the network in Figure 5.4. This network says that from a static perspective, a field may involve a single item or multiple items arranged into taxonomies of either composition or classification. The *n* above taxonomy indicates it may be indefinitely wide and/or deep.

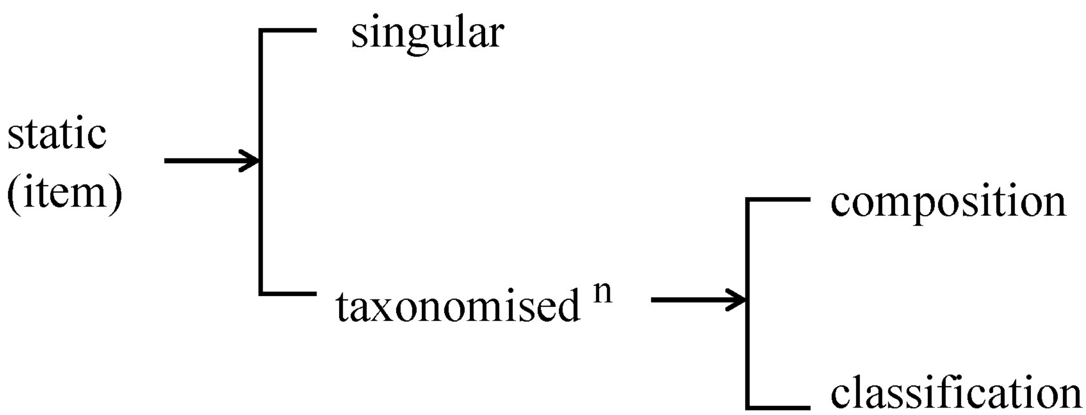

Figure 5.4. Network for a static perspective on field

An alternate perspective on field involves construing phenomena *dynamically* in terms of activities. Activity involves some sort of change that is oriented to some global everyday, professional or institutional purpose. One activity associated with the seasons, for example, is:

The sun warms the earth

This example gives a single, isolated activity, specified lexicogrammatically by the Process *warms*, and involving two items: *the sun* and *the earth*. In longer explanations, rather than construing just a single undivided activity, it is common for an activity to be construed as a series of smaller activities. For example, the above activity could be reconstrued as a series of activities as follows:

The sun emits light

^

which hits the earth

^

and warms it.

Here we have a *momented activity*, where a single activity (*the sun warms the earth*) is construed as three separate activities, all oriented to the more general activity of warming.[ii]

Each activity can be momented into any number of further activities within the limits of a field. For example in Figure 5.5 below, from a secondary school biology textbook (Greenwood and Allen 2004), the unmomented activity *inflammation* is momented through various subheadings into four stages:

Increased diameter and permeability of blood vessels

^

Phagocyte migration

^

Phagocytosis

^

Tissue repair

Each of these activities can in turn be momented into another series of activities. For example at the bottom of the figure, *phagocytosis* is momented as:

Detection

^

Ingestion

^

Phagosome forms

^

Fusion with lysosome

^

Digestion

^

Discharge

This produces three tiers of activity shown in Figure 5.5.

Tier 1

Tier 2

Tier 3

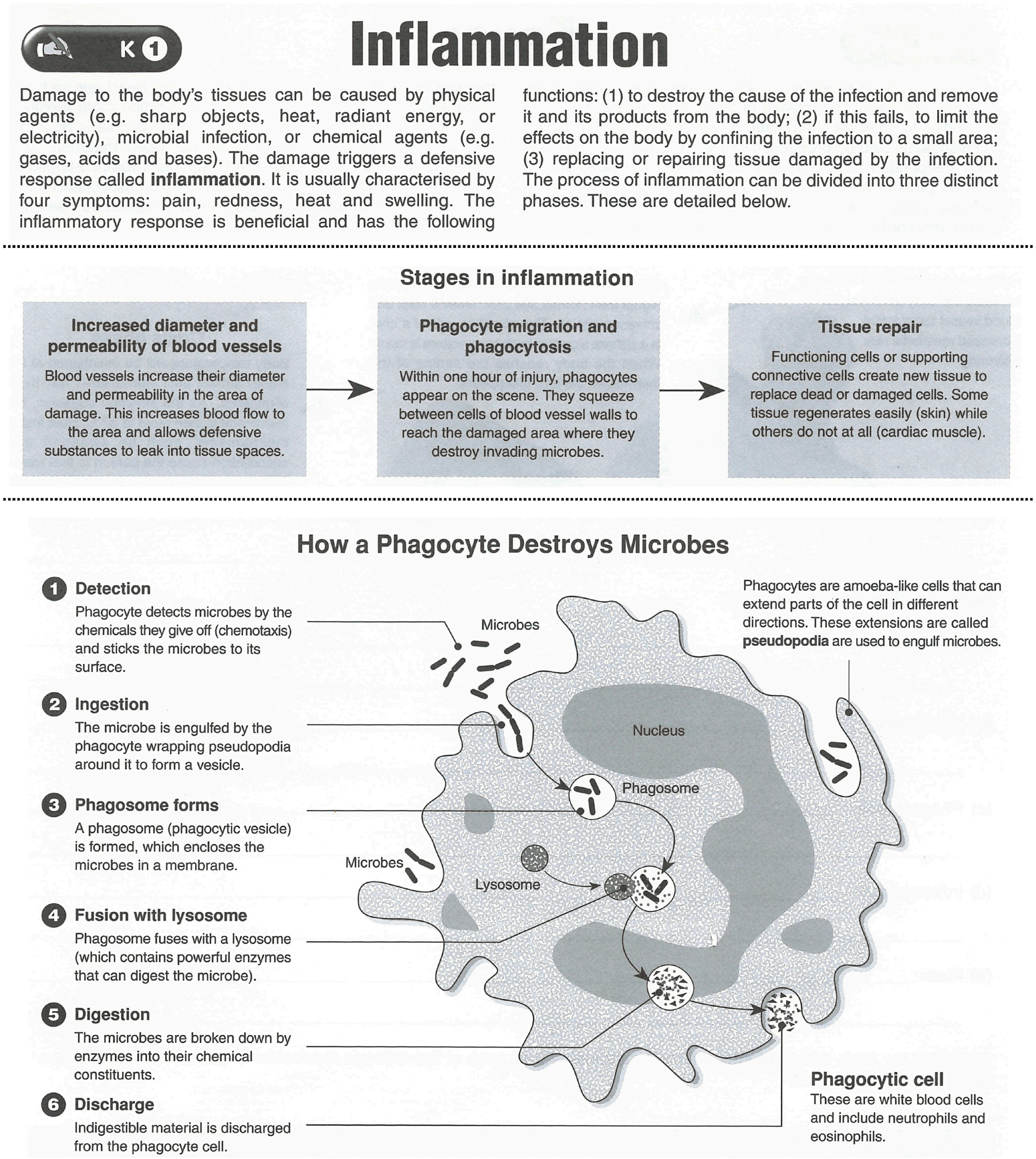

Figure 5.5. Momenting the activity *inflammation* (three tiers)

(Greenwood and Allen 2004: 118-119)

An unfolding series of activities can be related in one of two ways, through *implication* or *expectancy*. Implication relations describe series of activities where one activity necessarily entails another (if one activity happens, then another always does).[iii] In the following momented activity from a year seven science classroom, the activity *tides* is described as a necessary result of the *gravitational pull of the moon and the sun* and *the rotation of the earth*, through the Process *causes*:

'The gravitational pull of the moon and the sun, and the rotation of the earth causes tides.'[iv]

Implication series are most common in scientific explanations where events tend to be described in terms of causal or conditional relations of entailment. In terms of the ideational discourse semantic model developed by Hao (2020a) the activities *gravitational pull of the moon and the sun* and the *rotation of the earth* are realized by occurrence figures in discourse semantics that are in turn realized metaphorically through nominal groups, while the activity *tides* is realized by an activity entity (see Hao this volume). The implication relation linking these activities is realized discourse semantically by a causal connexion and lexicogrammatically by the Process *cause*.[v] This gives the implication series:

The gravitational pull of the moon and the sun, and the rotation of the earth

^ *(causes)*

tides

Analysed for multiple strata the realization of this momented activity in discourse semantics and lexicogrammar is:

	The gravitational pull of the sun and the moon and the rotation of the earth causes tides
field	momented implication activity
disc. sem.	sequence
lexicogram.	clause

Viewed in terms of the realisations of individual activities, this example is:

The gravitational pull of the sun and the moon	*and*	*the rotation of the earth*	*causes*	*tides*
activity		activity		activity
occurrence figure	connexion	occurrence figure	connexion	activity entity[vi]
nominal group		nominal group	verbal group	nominal group

If we unpack the grammatical metaphor in this example, we can see the implication series more clearly:

The moon and the sun are pulled by gravity *and the earth rotates,*

^ *(so)*

tides occur.

The use of the consequential connexion (*causes* or *so*) indicates that the tides necessarily arise due to the other two activities. As Hao (2018) has shown, in scientific explanations implication series can also be realized by temporal connexions. For example both series of activities below are related through implication (where one activity entails another), although one uses conditional connexion (*if… then*) and the other involves temporal connexion (*when*):

> *If you move an electron from one orbit to another then energy is either absorbed or released.*

> *When you move an electron from one orbit to another, energy is either absorbed or released.*

Whereas scientific explanations tend to be concerned with entailment, texts orienting toward how to *do* science (such as experimental procedures, procedural recounts or protocols, or stories of scientific discoveries) tend to construe activity in terms of expectancies rather than as logical necessities (Hood 2010, Hao 2015, 2020a). In these texts, temporal connexions are not used to realize a series of activities related by implication, but rather by *expectancy*. For example in the following description from a video shown in a high school science classroom of how data is collected to measure tides, the *gathering* and *uploading* are expected to occur together in a temporal sequence (linked by *and then*), but one activity does not necessarily entail the other. This kind of text records scientific activity rather than offers a scientific explanation of phenomena.

> ‘The data is gathered from the station and then is uploaded via the satellite every 6 minutes’

One of the key features of expectancy relations is that the series of activities can be interrupted or go against what is expected (as any science teacher or observer of a classroom experiment can attest). An interruption of an expectancy series is often shown through concessive connexion – for example *but* in *The data was gathered from the station but was not uploaded* *via the satellite*. The ability to play with expectancy in momented activities in this way is the basis of many story genres, where some unexpected and often dramatic activity occurs to establish the main complication of the story (Martin and Rose 2008).

Individual activities can take a number of forms. In the broadest terms, all activities involve some sort of change. As exemplified by the *orbit* and *revolve* activities in the explanation of seasons given above, this change can often be cyclical:

> *Our planet orbits the sun on a slant*.

> *Earth revolves around the sun*

Similarly, in the following brief explanation of tides, *rotation* indicates a cyclical activity:

> *The gravitational pull of the moon and the sun, and the rotation of the earth causes tides.*

These cyclical activities involve an event that recurs an indefinite number of times. Put another way, if *rotation* or *orbit* were to be momented, then the cycle would repeat indefinitely. Indeed, this is made explicit in a teacher's description of the rotation of the earth, where the cyclical activity *spinning* is momented into *it's moving day night, day night*:

> *The earth is spinning on its axis, happening every day. Every time it spins, it's moving day night, day night.*

In contrast, many activities involve linear unfolding, without recurrence. Such linear activities may involve some sort of culmination, as in the following when the motion of light ends at the earth:

> *The sun's light hits earth*

Alternatively there may be no indication of an end point:

> *The sun emits light*

These options are pulled together into a network in Figure 5.6. This network says that if a dynamic perspective is chosen, there are two sets of options available (the curly bracket { indicates simultaneous choices): if dynamic (activity), then choose from *both* MOMENTING and ACTIVITY TYPE). Within MOMENTING, an activity can be unmomented (given as a single whole), or it can be divided on another tier into multiple activities through the choice of momented. The superscript ^{n} indicates that an activity may be momented an indefinite number of times. If an activity is momented, then the series of activities which moment it may be related through implication or expectancy. The ACTIVITY TYPE system indicates that each activity may be either cyclical or linear, and if linear, may be either culminative or unending.

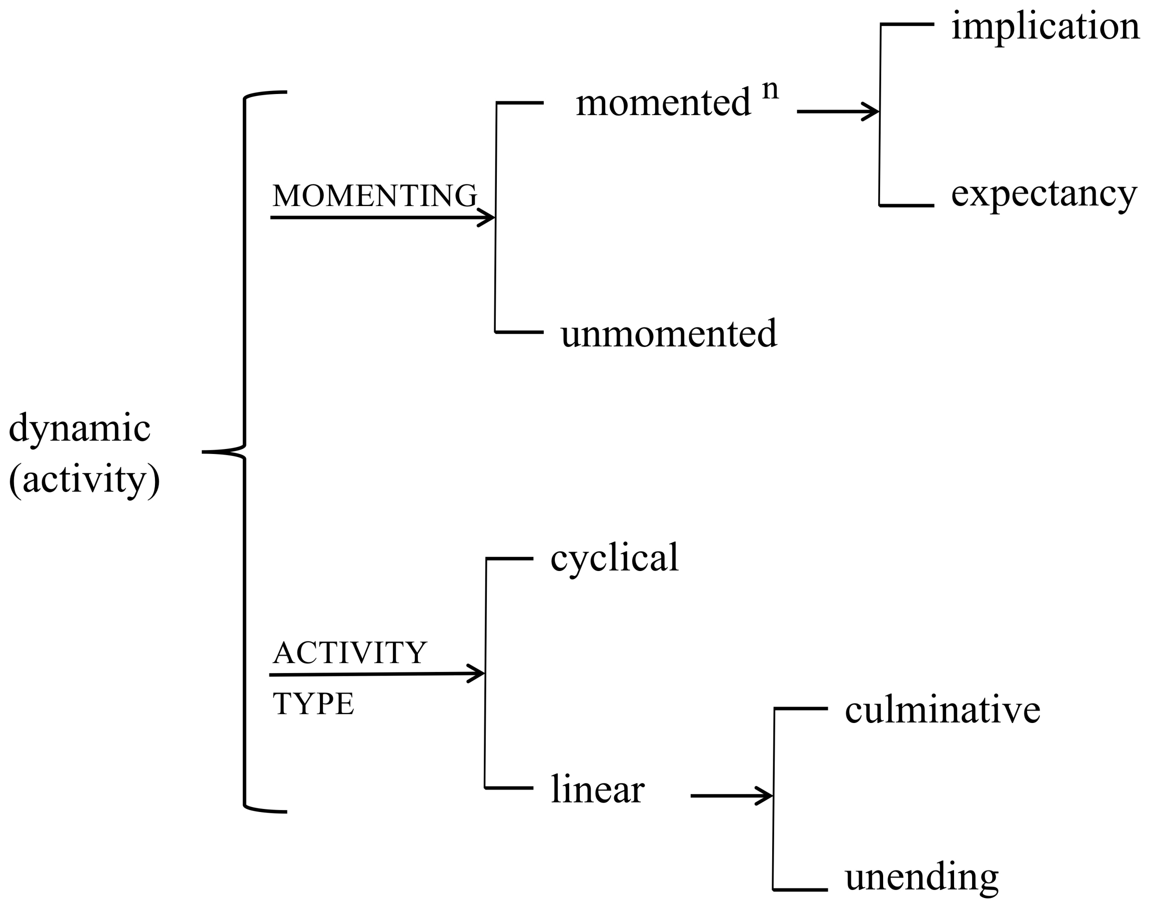

Figure 5.6. Network for a dynamic perspective on field

The dynamic activity and static item options offer alternative but complementary perspectives on phenomena. Although in any particular field one perspective will tend to be emphasized over the other, in principle all phenomena can be viewed in either way. For example, the cardiovascular system within the biological sciences can be viewed statically as a composition taxonomy of constituent items, including the heart, lungs, veins and arteries; or it can be viewed dynamically as the circulation of blood and transportation of nutrients, oxygen and the like to nourish, help fight disease and stabilize temperature. To show these alternate perspectives, the network in Figure 5.7 brings together the options for both a dynamic and static perspective on field.

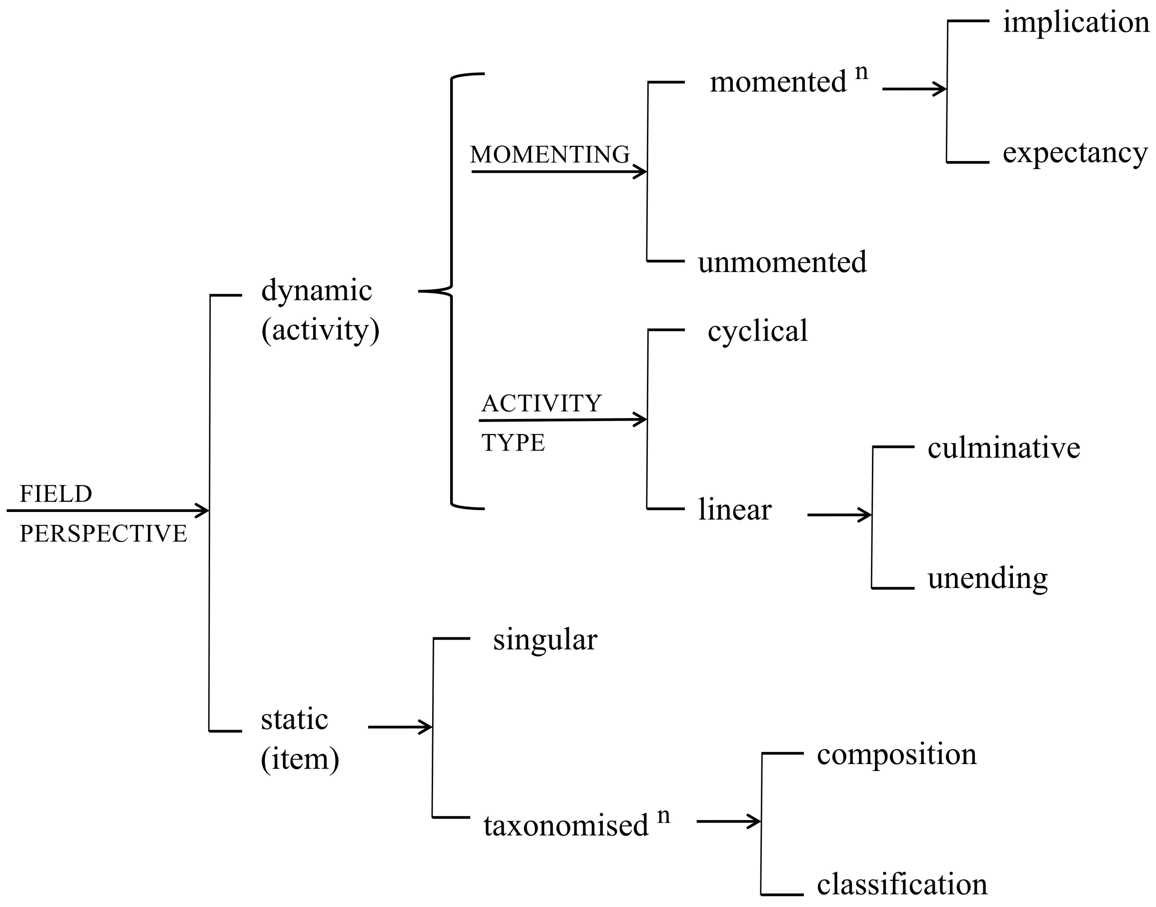

Figure 5.7. Dynamic and static perspectives on field

As far as explanations of seasons are concerned, we can use this network to show how particular sets of activities and taxonomies form its basic building blocks. The following passage from a year seven science teacher comes toward the end of a number of lessons introducing the key components underpinning the seasons. Here, the teacher is speaking over an animation of the earth orbiting the sun. The important activities for explaining the seasons are in italics:

> Now when *the sun's rays hit the earth*, the earth has that also other theoretical midline, the equator, that breaks it into half. Northern hemisphere and southern hemisphere.
>
> …
>
> Ok here we go. *The earth is spinning on its axis*, *happening every day*. Every time *it spins, it's moving day night, day night*…. And then *the earth is also moving around the sun*. You will notice at this point the northern hemisphere is closest to the sun, but when we started the southern hemisphere was closest to the sun. This is why we end up with opposite seasons. Because of that tilt in our axis puts us in different positions relationship to the sun.

The activities relevant here are to do with the Earth's rotation, both unmomented:

> *the earth is spinning*;
>
> *it spins*

and momented:

> *it's moving day night, day night*

The passage also deals with the earth's orbit around the sun:

> *the earth is also moving around the sun*

And it notes the emission of light from the sun to the earth:

> *the sun's rays hit the earth*

These activities are crucial components for eventually showing that there are different temperatures at different times of the year and thus that there are seasons. This however does not capture the additional fact that different parts of the earth are affected differently. For this, the teacher additionally partitions the earth into a compositional taxonomy of northern and southern hemispheres, divided by the equator:

> *the earth has that also other theoretical midline, the equator, that breaks it into half. Northern hemisphere and southern hemisphere*.

The activities of *orbit*, *rotation* and *light emission*, and the decomposition of earth into *northern* and *southern hemispheres* provide most of the information needed to explain the seasons. But the final sentence mentions one other crucial component not covered by the activity and item options in Figure 5.7, namely the *tilt* of the earth's axis. This tilt is crucial for any thorough explanation, as it accounts for the fact that different amounts of light hit different parts of the earth throughout the year. Indeed the following explanation by a student, which emphasizes tilt, is very positively evaluated by the teacher:

> **Student:** The seasons are created by the earth's 23.5 degree <u>tilt</u>. When the northern hemisphere is <u>tilted</u> towards the sun it is summer. As the earth orbits the sun the <u>tilt</u> stays the same, the side that's <u>tilted</u> towards the sun changes, making it winter in the northern hemisphere because it's furthest away.
>
> **Teacher:** Fantastic, I like that. That's a good one. All right. Hopefully yours says something similar to that.

Note that tilt is not an activity – it is not unfolding in any way and cannot be momented. Nor is tilt a part of the earth (we cannot say, for example, *the earth's tilt is a part of the earth*); nor is it a type of the earth. In order to account for tilt, we need to expand our model of field to introduce *properties*. To do this, we will take a step away from seasons into other areas of science and then return to how this affects the explanation of seasons considered above.

PROPERTY

In addition to activities and items, fields may be construed in terms of properties. Properties, in broad terms, organize potentially gradable qualities or positions that enable rich descriptions of phenomena. They often underpin distinctions between items and activities and are vital components of fields in themselves. They may characterize items, such as *the earth is <u>tilted</u>* or *the <u>negatively charged</u> particle*; or they may qualify activities as in *the electrons oscillate <u>rapidly</u>*, or *inflation is <u>high</u>*.

If characterizing items, they can provide the criteria organizing taxonomies. For example in nuclear physics, neutrons and protons are different types of nucleon, but are distinguished primarily by their charge: protons are *positively charged*, while neutrons are *neutrally charged*. Similarly, though different bands of electromagnetic radiation such as visible light, ultraviolet light, x-rays and radio waves are all oscillating light, it is their wavelength that distinguishes them: visible light waves are around *390-700 nanometres long*, while ultraviolet waves are between *10-390 nanometres long*. In a similar fashion, properties may be key features distinguishing moments in an activity, for example the activity of water freezing involves it getting *colder*, which means its particles move *more slowly*, and eventually they lock together to become ice.[vii]

As properties can optionally occur for both activities and items, we can set up a basic network as in Figure 5.8.

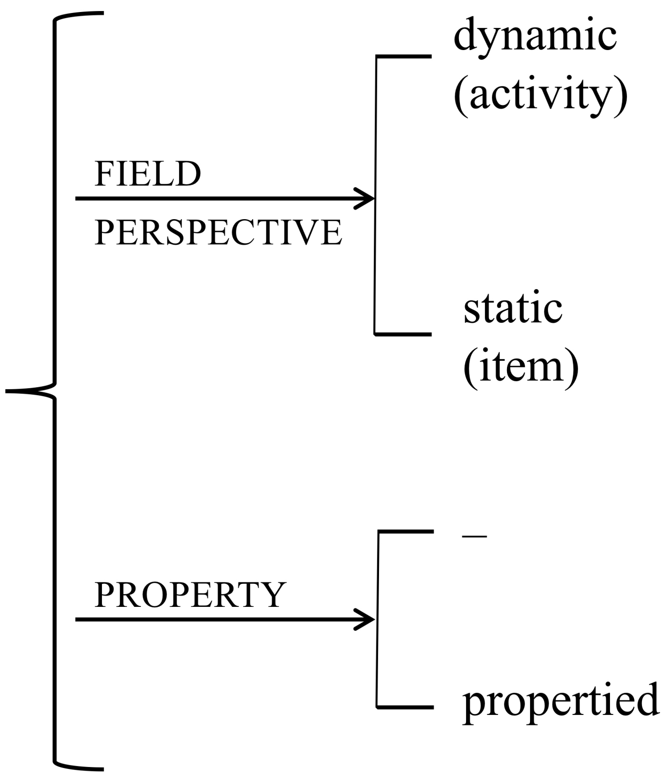

Figure 5.8. Basic parameters of field

Properties can take many forms. They may involve qualitative descriptions (*Everest is tall, it is climbed slowly*); or they may offer some spatio-temporal position (*Everest is in Asia,* *Everest's current height, they trudged through the snow*). In addition, these properties may be graded and potentially ordered into *arrays* in relation to other properties (*Everest is the tallest mountain on earth, The Himalayas stretch from China to Pakistan through Bhutan, Nepal and India*); this in turn opens the way for properties to be measured or quantified, what we will call *gauged* (*Everest is 8,848 m tall, Everest is 27.99º N, 86.93º E*).

Adding to our network, Figure 5.9 indicates that properties may be arrayed or not, and if arrayed, they may be gauged.

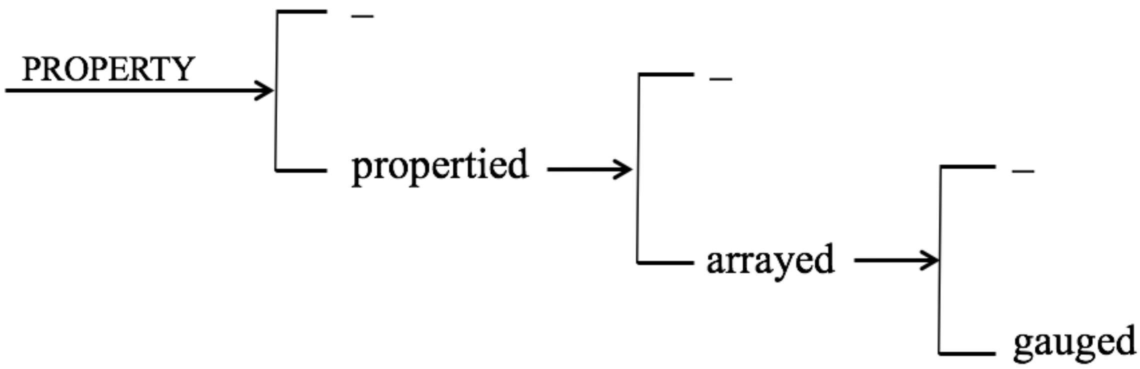

Figure 5.9. Network of PROPERTY, ARRAYING and GAUGING

Qualitative properties

We will explore properties through the following descriptive report from a field guide to Australian birds (Menkhorst *et al.* 2017: 472). In this text, properties permeate the description in order to evocatively describe the flame robin's physical qualities including its colour, shape and size. The properties not only allow birders to recognize flame robins, but also to distinguish between males and females, adults and juveniles, and other robins such as the dusky robin (bold and italics in original).

> **Flame Robin** *Petroica phoenicea*
> **Wing**: 73-83 mm **Bill** 13-15 mm **Wt** 11-15g
> Largest, most slender-looking *Petroica* robin; long-bodied appearance accentuated by smallish head and longish wings. **Ad** ♂ distinctive; note *slaty upperparts; small white forehead spot; underparts bright orange-red from chin to belly.* **Ad** ♀ differ from Scarlet ♀ by *sandier brown* upperparts, *small* white forehead spot (sometimes tinged

buff or wholly absent) and *light grey-brown breast* grading to whitish chin and belly. Some have diagnostic, but inconspicuous, traces of orange-yellow to orange on breast and belly. White eye-ring and bold wing-bars rule out Dusky Robin in Tas. **Juv** like Juv Scarlet with slightly finer white streaks on upperparts.

Voice: Contact call, a single note *tlip*, is sweeter than Scarlett Robin and seldom given on the non-breeding grounds. Musical warbling song, more complex and piping than other *Petroica* robins, often consists of 3 sets of 3 notes '*you may come, if you wish, to the sea*'.

Notes: Breeds mainly in upland eucalypt forests and woodlands, especially with open understory or small clearings; readily, but temporarily, colonizes cleared or burnt areas. Most leave the high country in autumn, wintering in more open habitats in lowlands including grasslands, farmland, and open forests and woodlands with grassy cover. Mostly seen singly or in pairs during the breeding season. Often seen in loose groups of up to 20 birds at other times, the only *Petroica* to form flocks.

We will focus initially on the first paragraph. This paragraph is primarily concerned with the physical appearance of the flame robin. As such it describes its properties such as colour, shape and size, and those of its various body parts (properties underlined):

<u>Largest</u>, <u>most slender-looking</u> Petroica robin

<u>long-bodied</u> appearance

<u>smallish</u> head

<u>longish</u> wings

<u>slaty</u> upperparts

<u>small</u> <u>white</u> forehead spot

underparts <u>bright orange-red</u> from chin to belly

<u>sandier brown</u> upperparts

sometimes <u>tinged buff</u> or <u>wholly absent</u>

<u>light grey-brown</u> breast

<u>whitish</u> chin and belly

traces of orange-yellow to orange on breast and belly

White eye-ring

bold wing-bars

slightly finer white streaks on upperparts

These precise verbal descriptions of colour (e.g. *slaty, whitish, sandier brown*), size (*largest, long-bodied, longish*) and shape (*most slender-looking*) are often supplemented by pictorial representations such as in Figure 5.10, to make it easier to recognize the bird in the wild (the original image is in colour, showing amongst other things, the distinct orange breast and belly of the adult male).

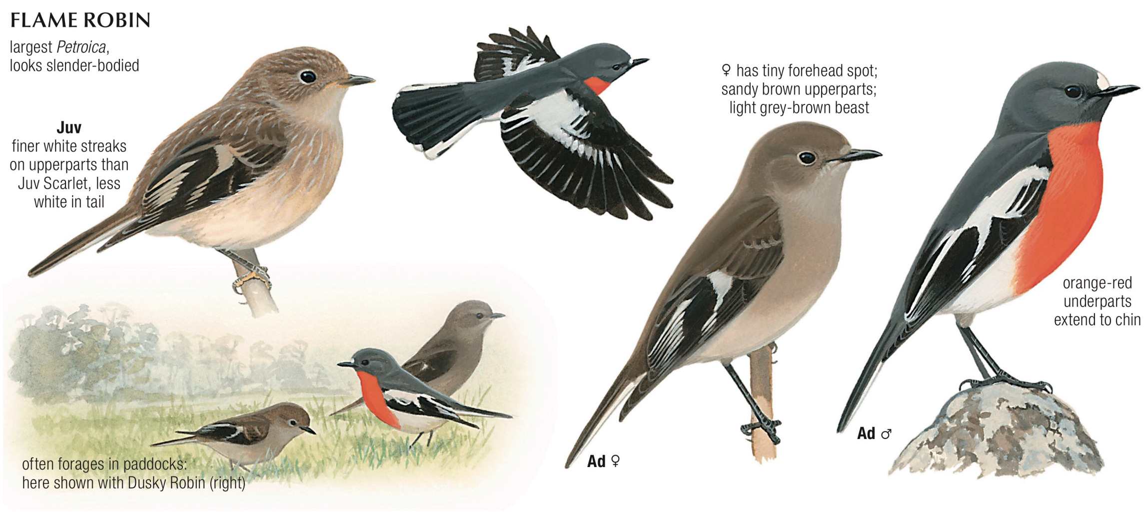

Figure 5.10. Picture of the flame robin showing its various properties.
Reproduced from Menkhorst et al. (2017: 473) with permission from CSIRO Publishing.
Original colour illustrations by Peter Marsack.

As this text shows, properties like colour, size and shape can be graded through *arraying*. In terms of field, arraying like this establishes degrees of a property in comparison to other more or less explicitly specified instances. For example the size and shape of the flame robin is arrayed as:

Largest, most slender-looking Petroica robin

Similarly, many of the colours are graded in terms of their brightness, or other qualities:

underparts <u>bright</u> orange-red from chin to belly

sandi<u>er</u> brown

<u>light</u> grey-brown breast

If more precision is required, arrays can be gauged. The sub-heading shows this by gauging the length of the flame robin's wing and bill in terms of millimetres (mm) and its weight in terms of grams:

Wing: <u>73-83 mm</u> **Bill** <u>13-15 mm</u> **Wt** <u>11-15g</u>

As students move through schooling, precise measurements of phenomena become more strongly emphasized. This is particularly the case for sciences such as physics where these measurements are regularly presented in graphs or long mathematical texts called quantifications (Doran 2018, this volume; Lemke 1998; Parodi 2012). The graph in Figure 5.11 is from a senior high school physics exam. This graph arrays two properties of a wire on the vertical and horizontal axes, *resistance* and *temperature*, and gauges them in ohms (Ω) and degrees Celsius (˚C) (*resistance* and *temperature* are in fact *itemised* properties, discussed below). A series of points (marked by X) and a trend line have been plotted by a student, giving specific measurements for both its resistance and temperature.

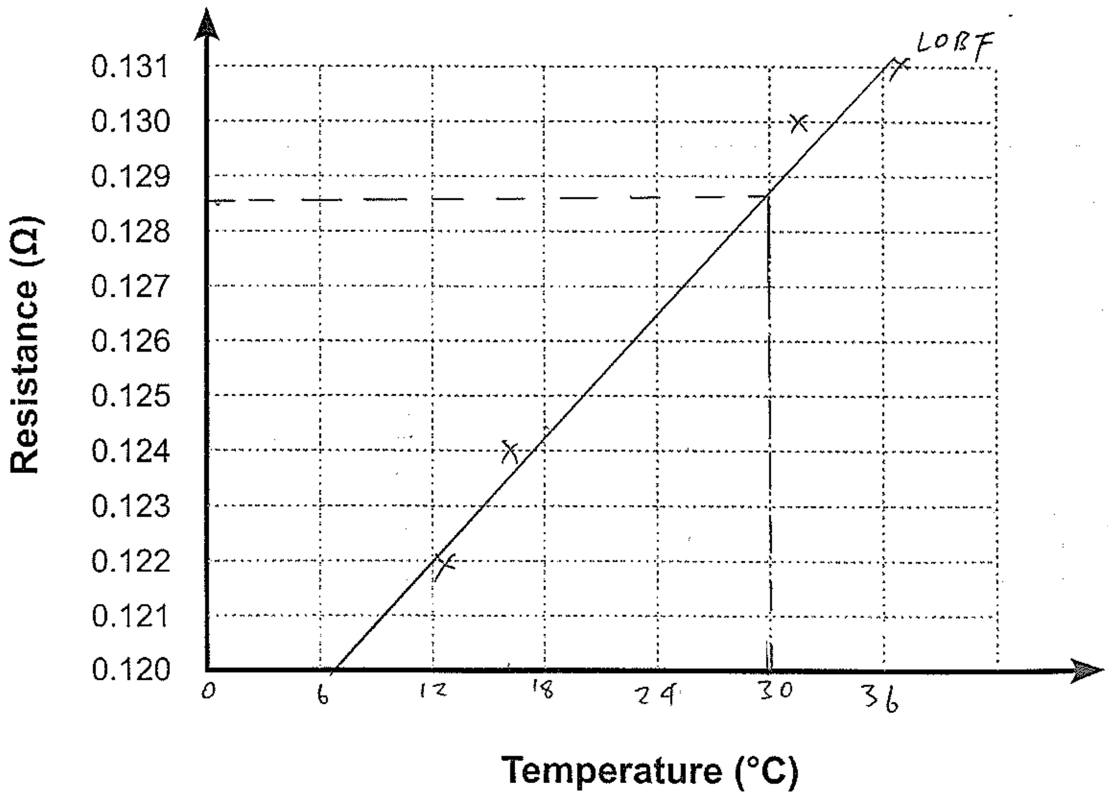

Figure 5.11. Graph of resistance and temperature, showing two gauged properties

In a sense, properties, which may be arrayed and gauged, establish an ideational perspective on gradable meanings that have generally been explored through the interpersonal system of graduation within appraisal (Martin and White 2005; Hood and Martin 2005).[viii] By putting forward the property network, we are suggesting that the instances of grading shown above are not necessarily geared toward making evaluative meanings, but are simply organizing the field of the *petroica robin*. It is likely that there will be some indeterminacy in this area, since properties supply an arena for attitudinal meanings invoked through graduation; indeed if we look at the second paragraph of the flame robin descriptive report, we see a handful of properties that could be read as invoked appreciations of the flame robin's call (graduated attitude, either inscribed or invoked, combined with arrayed properties underlined):

> **Voice:** Contact call, a single note *tlip*, is <u>sweeter than</u> Scarlett Robin and seldom given on the non-breeding grounds. Musical warbling song, <u>more complex and piping than</u> other *Petroica* robins, often consists of 3 sets of 3 notes '*you may come, if you wish, to the sea*'.

Spatio-temporal properties

A second type of property is concerned not with some quality of an item or activity, but rather with an item or activity's location in either space or time – termed *spatio-temporal* properties.

In our flame robin text, spatio-temporal properties are used extensively when detailing the flame robin's habitat and the time of year they can be observed (underlined):

> **Notes:** Breeds mainly in upland eucalypt forests and woodlands, especially with open understory or small clearings; readily, but temporarily, colonizes cleared or burnt areas. Most leave the high country in autumn, wintering in more open habitats in lowlands including grasslands, farmland, and open forests and woodlands with grassy cover. Mostly seen singly or in pairs during the breeding season. Often seen in loose groups of up to 20 birds at other times, the only *Petroica* to form flocks.

Like qualitative properties, spatio-temporal properties can occur for both activities and items. Examples of spatio-temporal properties of activities from the above excerpt include:

> *Breeds mainly in upland eucalypt forests and woodlands*
>
> *Most leave the high country in autumn*
>
> *wintering in more open habitats*
>
> *Mostly seen singly or in pairs during the breeding season*
>
> *Often seen in loose groups of up to 20 birds at other times*

Examples of spatio-temporal properties of an item from earlier in the text, include:

> *slightly finer white streaks on upperparts*[ix]
>
> *Some have diagnostic, but inconspicuous, traces of orange-yellow to orange on breast and belly*

Just like qualitative properties such as colour, size and shape, spatio-temporal properties can be arrayed by ordering their spatial or temporal positions in some way. In the initial description the underparts were described as:

bright orange-red from chin to belly.

Here, the chin and belly are arrayed as outerpoints that the bright-orange red colour occurs between. Such arraying of spatio-temporal properties are often more easily shown through diagrams and maps, such as in Figure 5.12 showing the areas of Australia the flame robin can be observed.

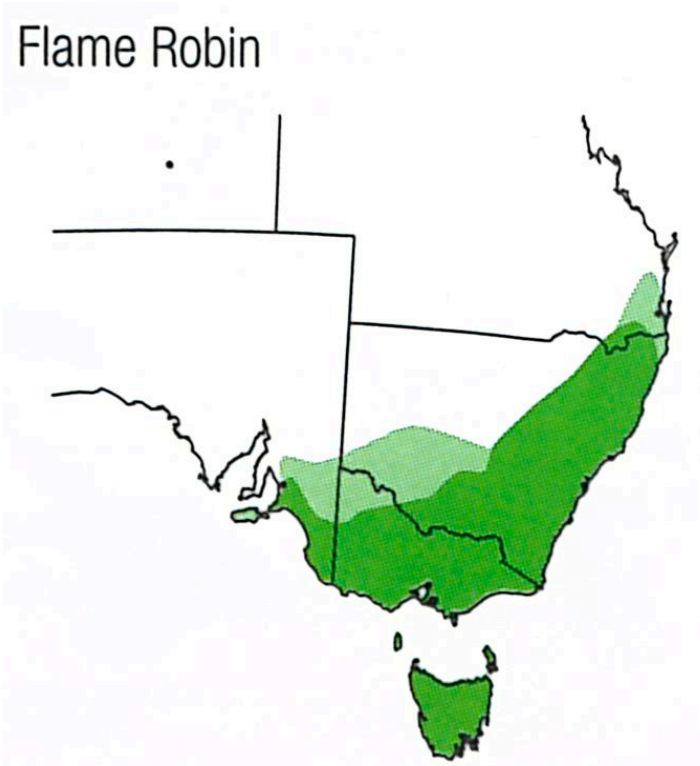

Figure 5.12. Map showing spatio-temporal property of the flame robin in Australia. Reproduced from Menkhorst et al. (2017: 472) with permission from CSIRO Publishing.

Finally, like all properties, spatio-temporal properties can be gauged. An example of this is the use of latitude and longitude, such as 34.0386° S, 151.1407° E. Or more commonly in everyday discourse, this is regularly seen when giving the time:

Be there 9 o'clock.

From the description so far, we can flesh out our network of properties as Figure 5.13.

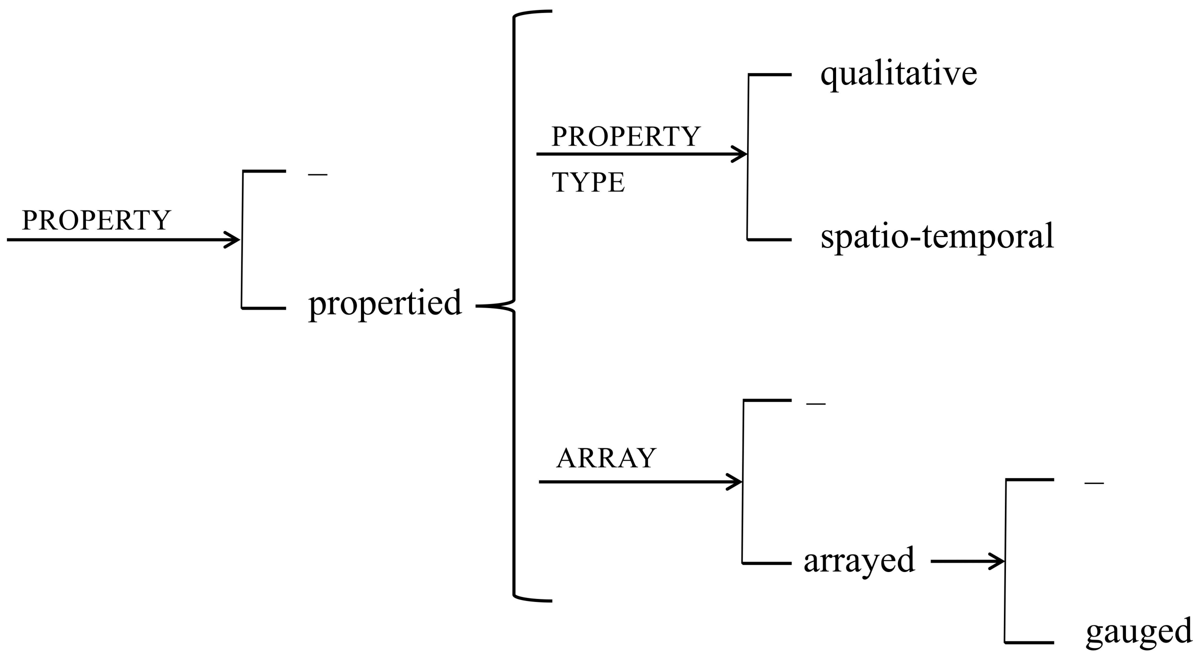

Figure 5.13. Network of PROPERTY

COMPLEX FIELDS

Activity, taxonomy and property systems provide the basic resources for construing field. But before we can return to mapping the explanation of seasons this chapter began with, there is one more system we need to introduce. This system makes room for interdependent variables that organize the complex constellations of meaning in technical discourses such as those of science. There are two basic ways of building interdependency: *reconstruing* and *interrelating*.

Reconstruing variables

Beginning with the reconstrual of field variables, we can return to the *tilt* of the earth that we mentioned is crucial for explaining seasons. In one sense, we can now readily account for this in our expanded model – *tilt* is a property of the earth and so can be arrayed and gauged. Indeed our original text explaining the seasons does just that:

Seasons happen because Earth's axis is <u>tilted</u> at an angle of about <u>23.4 degrees</u>

In this form, where the *Earth's axis* is specified as being *tilted*, this analysis is unproblematic. However in the next sentence, the property realized verbally as *tilted* above is nominalized as *tilt*:

Earth's axial tilt

In addition, the nominalized *tilt* is classified by *axial.* This positions tilt in a classification taxonomy; axial tilt is a type of tilt. This is problematic for the outline of field resources canvassed thus far as classification is a key feature of items, not properties. Moreover in terms of Hao's model of ideational discourse semantics (2020a, this volume), the nominalized *axial tilt* is not a quality, which is the typical realization of property. Rather, it is a measured dimension of the earth that can be reorganized lexicogrammatically as a Focus^Thing structure:

Axial tilt of Earth

To reconcile these two seemingly conflicting analyses – *tilt* as a property and *tilt* as an item – what we will suggest here is that the property *tilted* is being reconstrued as an item *tilt*. This we will refer to as an *itemized property*. This analysis is based on the fact that *axial tilt* shows many of features of both properties and items: it can be arrayed and gauged like properties and can be taxonomized like items. And from the perspective of discourse semantics, it is not realized by a quality, which is the prototypical realization of qualitative properties, nor by an entity, which is the standard realization of items, but rather by a dimension of an entity.

Such itemized recontruals are regularly used to 'name' broader sets of properties. Indeed we have used a number of these throughout this paper to group together various properties. In the following examples, the underlined itemized properties are 'names' of the bolded properties:

*The <u>colours</u> (of the flame robin) are **slaty**, **whitish** and **sandier brown**.*

*The <u>shape</u> (of the flame robin) is described as **slender-looking.***

Itemized properties comparable to these are the basis for symbolic variables in mathematics (see Doran this volume). For example, in the following formula the *acceleration* of a moving body is symbolized as *a*, the *mass* of that body is *m* and the *force* on the body is *F*:

$\boldsymbol{F} = m\boldsymbol{a}$

Like all properties, each of these can be numerically gauged – in this case through Newtons (N), metres per second squared (m/s^2) and kilograms (kg):

$\boldsymbol{F} = 4$ N

$\boldsymbol{a} = 2\ m/s^2$

$m = 2$ kg

But like items, they can all be taxonomized:

angular acceleration, linear acceleration;

centripetal force, electrostatic force;

relativistic mass, rest mass.

Reconstruals of properties as items is a regular feature of many fields. Under this interpretation, field is a resource not just for construing items, activities and properties, it is also a resource for reconstruing meanings. It enables multiple overlapping perspectives on phenomena to be realized in a single instance. This is emphasized by the fact that in addition to being itemized, properties can also be reconstrued as activities. Similarly, items can be dynamized by being reconstrued as activities, and activities can in turn be itemized. Each of these options have typical realizations in discourse semantics, as introduced below.

When properties are reconstrued as activities, such *activated properties* enable a dynamic unfolding of a property:

It <u>gets hotter</u>

In terms of property, this indicates an array of temperature (degrees of heat). But in terms of activity, it can be used to moment a larger activity:

It <u>gets hotter</u>

^

And then eventually it melts.

This type of activation moves us into the realm of ‘becoming’, where properties are, in effect, dynamized.

Activating items very commonly involves them being positioned in a taxonomy. The following excerpt from a university physics textbook shows an example of this for composition (Young and Freedman 2012: 742):

> *… now we let the ball touch the inner wall… The surface of the ball becomes part of the cavity surface.*

Here, the part whole relation between the surface of a ball and the cavity surface of a wall is activated, and becomes a moment in a larger activity:

> *We let the ball touch the inner wall*
> ^
> *The surface of the ball becomes part of the cavity surface.*

Finally, as noted above, just as items can be activated, activities can be itemized.[x] This regularly happens in the process of technicalization, as scientific terms are distilled as activity entities (see Hao 2020a, this volume, for discussion of the discourse semantics of activity entities). One of our initial examples of a momented activity in fact showed a series of itemized activities that moment *phagocytosis* – itself an itemized activity; the itemized activities involved are underlined below:

> *Detection*
> ^
> *Ingestion*
> ^
> *Phagosome forms*
> ^
> *Fusion with lysosome*
> ^
> *Digestion*
> ^
> *Discharge*

Like all items, these itemised activities can enter into a taxonomy. For example *phagocytosis* is one type of *endocytosis*, along with *potocytosis* and *micropinocytosis*, which all contrast with *exocytosis*.

Table 5.1 shows various reconstruals and some typical discourse semantic realizations (from Hao 2020a). Note here that the order in which the reconstrual takes place is significant – an itemized activity is different from an activated item.

Field reconstruals	**Typical discourse semantic realization**	**Example**
itemized property	measured or perceived dimension	*The colour of skin*
activated property	occurrence figure	*It heats up*
	state figure	*It gets hotter*
itemized activity	activity entity	*Phagocytosis*
activated item	state figure	*You become part of the team*

Table 1. Field reconstruals

Interrelating fields and the explanation of seasons

We are now in a position to characterize each of the main elements of our initial explanation of the seasons, replayed here:

> **What Causes Seasons on Earth?**
>
> *Seasons happen because Earth's axis is tilted at an angle of about 23.4 degrees and different parts of Earth receive more solar energy than others.*
>
> Because of Earth's axial tilt (obliquity), our planet orbits the Sun on a slant which means different areas of Earth point toward or away from the Sun at different times of the year.
>
> Around the June solstice, the North Pole is tilted toward the Sun and the Northern Hemisphere gets more of the Sun's direct rays. This is why June, July and August are summer months in the Northern Hemisphere.

Opposite Seasons

At the same time, the Southern Hemisphere points away from the Sun, creating winter during the months of June, July and August. Summer in the Southern Hemisphere is in December, January, and February, when the South Pole is tilted toward the Sun and the Northern Hemisphere is tilted away.

For our discussion here, the main field components needed for this explanation are:

Earth's 23.4 degree axial tilt

Division of earth into northern and southern hemispheres

Earth's orbit of the sun

Earth receipt of solar energy

Different parts of the earth receive more solar energy than others at different times of the year

Seasons of summer and winter

Each of these components is classified with reference to field resources in Table 5.2. For ease of reference, each of the components is named in small caps (TILT, HEMISPHERES etc.).

Factors in explanation of seasons	Field relation
TILT *Earth's 23.4 degree axial tilt*	classified itemized gauged property
HEMISPHERES *Division of earth into northern and southern hemispheres*	composition taxonomy of items
ORBIT *Earth's orbit of the sun*	itemised cyclical activity

RECEIPT OF SOLAR ENERGY	
Earth receives solar energy	culminative activity
VARIATION IN SOLAR ENERGY	
Different parts of the earth receive more solar energy than others at different times of the year	compositional taxonomy (*different parts of the earth*) ordered into an array of an itemized qualitative property (*more solar energy*) ordered into another array of an itemized spatio-temporal property (*different times of the year*)
SEASONS	
Seasons of summer and winter	classification taxonomy of items

Table 5.2. Field relations in an explanation of the seasons

The first thing to note is that far more than a common sense understanding of the seasons is involved. For a full explanation, students need to attend to both the classification and composition of items, two types of activity and both gauged and an arrayed properties. In addition, they need to conceptualize three itemized properties, and a set of items ordered into two separate arrays. This is already a conceptual challenge for most junior secondary school students.

But there is more going on. As set out in Table 5.2, more than one factor is needed for the explanation, however we have not yet however specified the relations among them. In order to explain seasons, specific types of logical interdependency have to be established. To model this, we will introduce the second way of linking field variables – *interrelating* (complementing reconstruing as introduced above).

Interrelating is concerned with how different elements of field are associated with each other. In broad terms, there are two means of interrelating elements: they can be positioned as relatively independent of one another or they can be positioned as in some sense dependent on each other (although not precisely the same, this closely relates to the dependent and independent links for constellations introduced in Maton and Doran Chapter 4 this volume).

Let's focus first on the relatively independent relation. In the seasons explanation, the TILT, HEMISPHERES, ORBIT and RECEIPT OF SOLAR ENERGY are not dependent on each other in any way. One can vary or not exist at all without affecting the others. The fact that the earth is tilted, for example, has no bearing on the fact that the sun emits solar energy that hits the earth. Similarly, the fact that there are hemispheres on earth has no impact on whether it orbits the sun.

To describe this relation, we can borrow from Halliday and Matthiessen's (2014) logico-semantic relations for English clause complexing and call this *extension* (signified by a +). Here we are analogizing from an 'and' relation, where multiple elements are coordinated but are not ordered in any way (ideationally speaking). The extending factors in this relationship can be usefully laid out in parallel, as follows:

TILT	+	**HEMISPHERES**	+	**ORBIT**	+	**RECEIPT OF SOLAR ENERGY**
itemized property		composition of items		cyclical activity		culminative activity

In contrast, some elements of field are dependent on others. For example, the VARIATION IN SOLAR ENERGY factor is the result of the combination of the TILT, ORBIT, HEMISPHERES and RECEIPT OF SOLAR ENERGY factors. Without each of these factors, the precise form of the VARIATION IN SOLAR ENERGY would not occur. This in part accounts for the complexity of seasons explanations. VARIATION IN SOLAR ENERGY takes the compositional taxonomy from the HEMISPHERES, orders it into an array of *solar energy* involved in the RECEIPT OF SOLAR ENERGY, reinterprets the ORBIT of the sun as an array of time through the year and, through a couple of unspecified steps resulting from the TILT, additionally arrays the variation in solar energy at different parts of the earth according to the time of the year. Analogizing again from Halliday and Matthiessen's logico-semantic relations, we will call this dependency relation *enhancing* (signified by an x).

Finally, the SEASONS reorganises the VARIATION IN SOLAR ENERGY from an array of temperatures to a classification taxonomy of items – summer, winter, autumn, spring. This in effect names components of these variations and distils its meaning into the technical term 'seasons'. Following our analogy with Halliday and Matthiessen's logico-semantic relations, we will call this naming relation *elaboration* (signified by =).

Pulling these interrelation types together with our previous description, we can visualize the field variables underpinning the explanation of the seasons as follows (with enhancing factors laid out vertically in relation to what they depend upon):

TILT	+	**HEMISPHERES**	+	**ORBIT**	+	**RECEIPT OF SOLAR ENERGY**
itemized property		composition of items		cyclical activity		culminative activity

x

VARIATION IN SOLAR ENERGY

compositional taxonomy on an arrayed itemized property on another arrayed itemized property

=

SEASONS

classification taxonomy of items

This outlines how the relatively independent components of the TILT, HEMISPHERES, ORBIT and RECEIPT OF SOLAR ENERGY together produce the VARIATION IN SOLAR ENERGY, which in turn produces the SEASONS. The mapping effectively displays the complexity underpinning a scientific explanation of a phenomenon we all experience in everyday terms.

As far as our broader model of field is concerned, this completes the description. The options for building interdependency in fields produces the network in Figure 5.14.

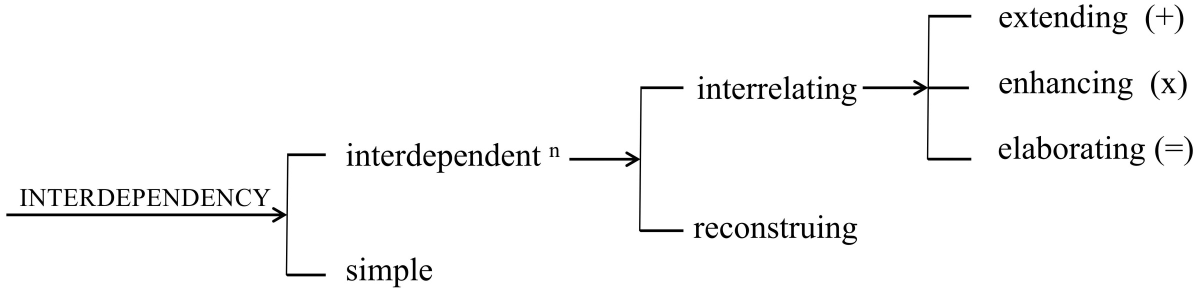

Figure 5.14. Network for INTERDEPENDENCY

Pulling this together with the rest of the field network gives the basic systems of field shown in Figure 5.15. This network indicates that construals of field can adopt either a dynamic or a static perspective, can be optionally propertied and can be related to other aspects of a field.

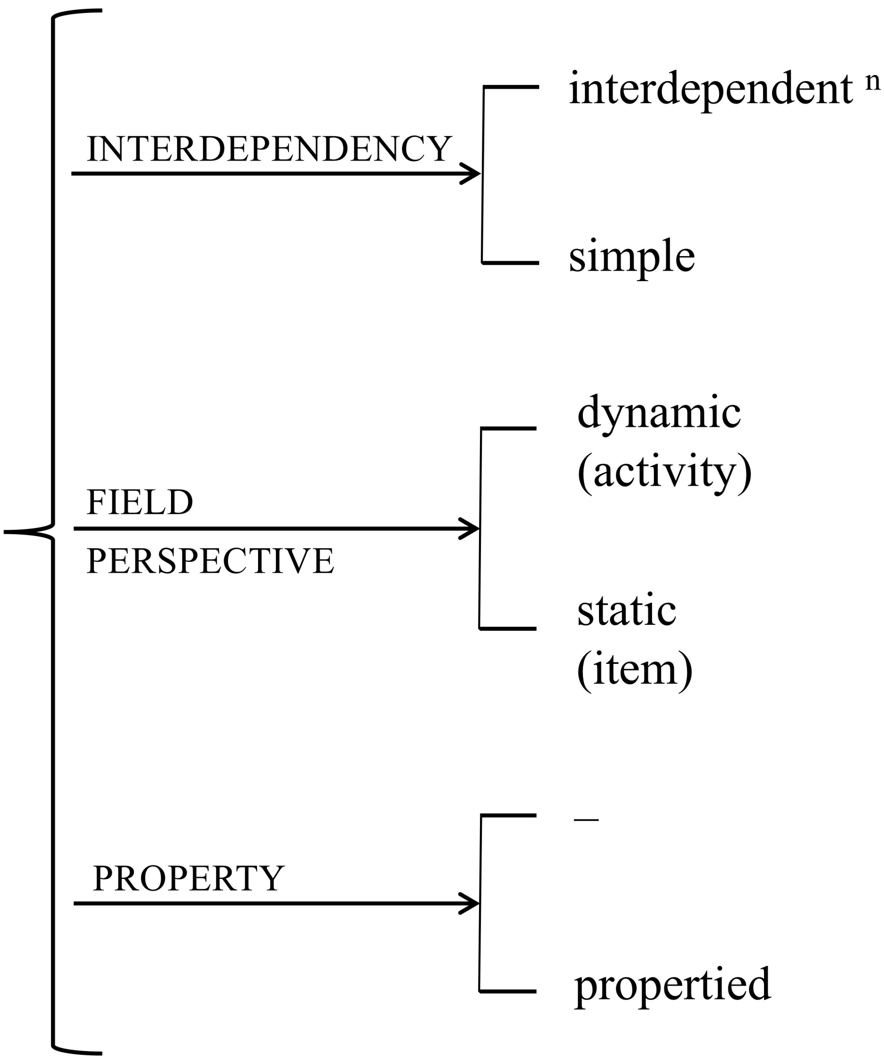

Figure 5.15. Network of field

MAKING UNCOMMON SENSE

From the perspective of educational linguistics, our model of field as a resource for construing phenomena reveals the complexity of science fields at even the lower levels of secondary school. The explanation that we focused on for this paper is a relatively simple one in the broader scheme of things. It did not take into account the effect of variation in the length of the day arising from the rotation of the earth; nor did it go into detail about how the earth's tilt actually produces variation in light intensity in different part of the earth at different times of the year; nor did it conceptualize the hemispheres as a continuous array of latitude (affecting how 'summery' or 'wintery' it is depending on how far you are from the poles); nor did it consider this explanation in relation to other meteorological and astronomical phenomena. And it definitely did not consider how this conception of seasons is related to seasonal change in parts of the world where a wet-dry distinction is more relevant (and in doing so can be critiqued from a post-colonial perspective). As scientific knowledge develops through schooling, more and more of these additional elements are interrelated and then presumed. For an educational program that aims to develop a discipline-specific pedagogy based on the varying ways knowledge is built, managing this complexity such a through a model of this kind is crucial.

As far as functional linguistics is concerned, our model of field builds on Hao's modelling of ideational discourse semantics (2020a) and opens up the possibility of explicitly differentiating and linking ideational meaning resources across strata (register, discourse semantics and lexicogrammar – specifically, field realized through ideation and connexion, and ideation and connexion realized through clause complexing, transitivity and nominal group structure). It has done so in a way that is proving productive not just for language, but for a range of semiotic resources used in science (see Doran, chapter 7, this volume). This places functional linguistics and semiotics in a far stronger position to manage the distinctive complexity of knowledge building across disciplines, and within disciplines across modalities of communication. Making sense of uncommon sense depends on robust modelling of this kind.

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[i] https://www.timeanddate.com/astronomy/seasons-causes.html

[ii] A little closer to everyday life, following Barthes (1977: 101), we could alternatively moment the activity *having a drink,* into the series *ordering a drink, obtaining it, paying for it, drinking it*.

[iii] Previously, series of activities were termed *activity sequences*. However in light of Hao's work on ideational discourse semantics (2015, 2018, 2020a), *series* will be used here for strings of activities in field and *sequences* will be reserved for strings of figures in discourse semantics.

[iv] This and a number of other examples in this chapter come from a study examining classroom practice in secondary schools in New South Wales, Australia, led by Karl Maton, J. R. Martin, Len Unsworth and Sarah Howard and funded by the Australian Research Council (DP130100481)

[v] We will again follow Hao (2018, 2020a) here in using CONNEXION for the discourse semantic relation between figures, previously known as CONJUNCTION in Martin (1992) and Martin and Rose (2007). This is in order to distinguish the discourse semantic system from the word-class conjunction within lexicogrammar.

[vi] Here *tides* is an activity entity that is caused by the previous occurrence figures. However, under Hao's model (2020a: 94), it is in fact part of a presented state figure within the larger sequence, alternatively realised as *The gravitational pull of the sun and the moon and the rotation of the earth causes (the forming of) tides* (Hao personal communication). Hao argues that sequences such as this are one means through which activity entities like *tides* can be presented in scientific texts.

[vii] Thanks to Dragana Stosic, Sally Humphrey and Jing Hao for this example. This raises the broader point that all perspectives on field (activity, taxonomy, property) can be used as criteria for distinguishing and defining all other perspectives. For any particular field, its interlocked networks of field relations are such that its technical meanings will be mutually defining.

[viii] A complementary ideational perspective on gradable meanings from the perspective of discourse semantics is given by Hao (2015, 2020a) and Hood and Hao (chapter 10, this volume), in terms of qualities of entities and items.

[ix] This is not saying that the upperparts are white (i.e. it is not attributing a qualitative property to the upperparts). Rather is locating the streaks as being *on* the upperparts.

[x] Note that we do not need to account for *propertied items* or *propertied activities* in this section as this is already accounted for in our initial system in Figure 5.8, where either an activity or an item can take a property.