Words in the language of science at pre-university level: a study of meanings and cultures in English and French

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ABSTRACT

French speaking scientists desiring to work in English often have recourse to bi-lingual technical dictionaries. Yet despite the acknowledged need for encyclopedic information sufficient to distinguish between degrees of equivalence (Bergenholtz & Tarp 1995:27), very little detailed work has been done. This article reports some of the results of a study of the baccalaureate science curriculum in French, and the information presented below indicates some the major areas where encyclopedic information is needed. The words come from the areas of chemical terminology, definitions, eponyms, affixes, and false cognates. The culturally dependent nature of the science is highlighted.

CONTENTS

INTRODUCTION

Bergenholtz & Tarp have expressed **the need for encyclopedic information to be included in technical dictionaries, and that this information should be detailed enough to distinguish between degrees of equivalence, especially where cross cultural differences between languages are involved** (1995:27). Heltai has argued that **cross-language comparisons of technical language are needed** for the writing of bilingual technical dictionaries (1988:2).

Despite the evident need, both from the perspective of research, and the potential market, **thorough comparisons have yet to be made**, especially of school level science. Yet school level science is the foundation for specialist science, and is the most accessible to all educated people. There is a market for quality useful comparisons as is shown by the popularity of writers such as Défourneaux (1980, 1983).

Lexicographers should be providing material in usable form that students and teachers alike can use and refer to, but very little has been published, even in the fields of technical translation and of ESP. Part of the problem is that such studies require a training both in the technical subject and in linguistics. Another problem is the presumed culture- independent nature of science, with the co-presumption of "full equivalence between LSP terms" (Bergenholtz & Tarp 1995:53) which has meant that very little work has been done to seek out and document areas of non-equivalence.

While the ESP professionals are aware of many of the differences, and do NOT argue that the technical language in English and French is fully international, it is easy for equivalence to be assumed by teachers, scientists, and poorly informed translators, especially given the poverty of the dictionaries, which are the main source of information for many foreign language users of science in English.

There is also a need to start from the bottom up, from the science at baccalaureate level, which is the common denominator of all specialist science, and is the most accessible to the non- science trained. The words presented here are examples of those which gave problems in baccalaureate biology, physics, and chemistry, and to some extent mathematics. As such they represent a minimum selection of problem words, and provide some hard to specify encyclopedic information that dictionaries so badly lack. The word studies also illustrate the depth of understanding of the subject which is needed for a full and comprehensive statement and explanation of the differences.

Heltai (1988) has a very helpful classification for the differences that may exist.

1. **Lexical gaps**
   Heltai asserts that "Such gaps are of course rare in the standardized terminologies of pure sciences". The evidence presented below would suggest that they are not that rare, and Annabi (1997) found that even words using Latin and Greek affixes which are thought of as being equivalent across European languages (Strevens 1977:153), are rarely so, with frequent use of circumlocutions instead of a lexical equivalent. Terminologies may not be as standardised as non-scientists might like to think, even in areas of science where, to the ill- informed, there is presumed standardisation of content and vocabulary. Taxonomy is a good example, (See Lowe 1992 for details) with its roots going back to Linnaeus in the eighteenth century, and the establishing of the binomial naming system. The popular view is that the language of science has now stabilised, and disputes are confined to the elucidation of problem cases, and newly discovered organisms. But, as the authoritative report of the Institute of Biology confirms, even the major division of organisms into five kingdoms is disputed, and there is much disagreement in classification of living things at the higher levels of phylum, class, and order. There is much more international agreement over the names for family, genus, and species (IOB 1989:14). It is not just that names can be changed within a level, but names can be promoted and demoted in level, and English and French do not always coincide.

   Therefore, even a cursory look at the field of Taxonomy, the field of biology where one might expect the best international agreement, shows there are differences between languages, and I have identified where most of these differences are likely within Taxonomy. For the lexicographer, this means that areas of agreement can be stated and differences sought in the areas of phylum, class, and order, and students can be warned to expect changes in the other areas.

2. **Missing derivatives**

3. **Absence of full conceptual equivalence**

4. **Divergent polysemy**
   As Heltai asserts, these are reasonably common areas for differences, and the evidence presented below supports this view, and provides some interesting examples.

5. **Synonymic relations**

6. **Preference for generic or specific term**
   Heltai rightly points out that these are related to not just the choice of synonym per se, but also matching general words with general words, technical words with technical words. Sometimes a language prefers to stick to technical words, even when addressed to lay people. Example 21 -phile illustrates this clearly.

7. **Grammar and collocations**
   Heltai (1988) and Berhenholtz & Tarp (1995:50) agree that at least a minimum of information needs providing, and this is provided when needed in the examples presented below.

8. **Abbreviations (ellipsis)**
   This has been covered in a previous article (Lowe 1996) of which an expanded version is presented on this website www.scientificlanguage.com/esp/nonverbals.pdf Further work still needs to be done to document and present differences for disciples at university level.

It is important for lexicographers to view the world through the eyes of the user. Therefore, while Heltai's framework is a useful starting point, and could usefully be presented to ESP learners, the material presented below uses a classification that is more familiar to a user, and indicates other areas of difference that need to be explored that do not fit Heltai's classification. In particular, the popularity of bi-lingual terminology handbooks where the material is classified by topic needs to be noted.

What users want, are not just bi-lingual dictionaries, but **bi- lingual topic comparisons**, where:
a. the similarities are noted (therefore a learner can safely transfer from L1 to L2 without re-learning),
b. the easily learned differences are noted,
c. the difficult areas are explained.

I know this because when I presented my research findings locally, teachers readily bought summaries of my material. Whatever the theoretical interests of the researchers in ESP and lexicography, such systematic comparisons are useful. They also fit with the great need in language education, which is to make language learning more efficient.

But where are such comparisons?

Different formats may need to be explored, and several used in one dictionary. Words often cluster -- there are a series of inter-related words, and untangling them is very much a pre- requisite to dictionary writing. Word or topic clusters, well indexed, I suspect are more useful to a user than the more usual lexeme-lexeme comparison lists.

Once some evidence has been presented, the question will be asked as to how culture-independent the language of science is.

METHODS

The research took place in a rather unusual, though very practical setting, of two secondary schools in Tunisia. In one of them sciences were taught in French, the other school being required to teach a similar science curriculum but this time in English. This requirement turned out to be very advantageous for the research in that it presented problems to the teachers, who were obliged to follow the French language as closely as possible both in their translations of the French textbooks and in the classroom.

By attending classes and teachers meetings, and comparing lessons in English with similar lessons in French, and regularly discussing points of tension, many areas of difficulty became apparent. I relied on my own background as a science teacher for specialist knowledge of English, and was able to supplement by consulting native speaker science teachers in English and French.

In addition, I surveyed the original textbooks and the translations, looking for language of science in the English which I as a former teacher of science judged to be unusual. Once a difference was suspected it was studied using informants and textbooks. In particular, material was consulted from the Association for Science Education, which as well as publishing a journal, the School Science Review, actively works for the improvement of science teaching in Britain. One of the ways it has enhanced science teaching is through the production or co-sponsorship of authoritative guides to nomenclature and terminology (ASE 1981, 1985, 1995 [1.] IOB 1989). Finally, in an important step of feedback to the people and country where I did the research and now teach, A 65 page summary of the findings which also covered symbols and non verbal devices, (see also Lowe 1996) was subsequently made available to teachers in Tunisia.

Particular care was taken with the words variously called "sub- technical" (Trimble 1985:128) or "semi-technical" (Robinson 1991:28), which means both those words having one or more meaning in general English, and one or more meaning in a science discipline. It has been reported from various sources that these words give the most problems to the learner, therefore need careful explanation, since they give "enormous problems for NNSs, even at advanced level" (Selinker 1979:199 cp Cassels & Johnstone 1984, 1985) and there are as yet no dictionaries for such words.

1. The Association for Science Education, referred to in the text as a source of authoritative information on school science in Britain, can be contacted at: ASE, College Lane, Hatfield, Herts, AL10 9AA.

DIFFERENCES

1. FAUX AMIS

There are hundreds of faux amis between French and English. Thody & Evans (1985) have a useful discussion of the main ones affecting understanding of French culture, from a British viewpoint, while Swan & Houdart (1983:274-278) have a long concise list which is suitable for study in a language class. Van Roey *et al* (1988) is an excellent teaching resource in that faux amis are presented in the context of parallel sentences between English and French, the format lending itself to 'fill in the gaps' teaching exercises.

It is a matter of regret that faux amis in science get very little coverage, though it is reasonable to expect that these sources would at least cover the more common faux amis of science, ones likely to be encountered at school level and therefore not of a highly specialist nature. In this section, some of the main faux amis are discussed, with more listed in Appendix 1.

a. General

Example 1: 'science' and 'scientific'

In French, 'human sciences' refers to both the humanities such as history, and the human sciences such as psychology. Therefore '*sciences humaines*' is a bigger term in French than its direct equivalent in English. '*Science*' is also a much bigger word in French than in English and can refer to any subject studied systematically, and not just subjects accepted in English as 'sciences'. The *Centre National de la Recherche Scientifique (CNRS)* supports research into history and philosophy for instance, as well as sciences such as physics. Yet, in terms of teaching, when I describe myself in French as a former '*professeur de science*' this is invariably not understood because such a combination of subjects is not customary in French, and I therefore have to go on to specify that I taught all three sciences: physics, chemistry, and biology to Bac minus three level (UK: GCSE, USA: grade 11) and biology to Baccalaureate level (UK: A level, USA: first year University).

Example 2: *sciences naturelles*

The way of dividing up the subjects of school science used to be different in English and in French. The incorrect, but tempting English translation of '*les sciences naturelles*', is 'natural science.' The correct equivalent in English is 'natural history', as for instance in the name of a famous museum in London, the Natural History Museum. It is not just a question of the wording of equivalents, for the scope of the subjects is different: '*sciences naturelles*' includes geology whereas in Britain this subject is traditionally studied as part of geography, though that is changing in that it is now part of the general science syllabus. In France the trend is in the opposite direction, towards marginalising geology, and the current subject is '*biologie*'. Regrettably the Harrap's science dictionary (1985) fails to state these differences and calls 'natural science' '*sciences naturelles*' and vice-versa.

Example 3: evidence / *évidence*, proof / *preuve*

These are big and important words, deserving careful statement of the contrasts. Thody & Evans (1985:30) explain that 'une évidence' is "that which is self-evident or goes without saying". The French verb 'prouver' can have a wide range of translations, including, to show, establish, prove, demonstrate, support, justify, and testify to. The following phrases would best be translated using 'evidence' rather than 'proof'.

juger sans preuves	to judge without evidence
manquer de preuves	to lack evidence
preuve insuffisante	insufficient evidence
preuve directe	direct evidence
preuve indirecte	circumstantial evidence
preuve patente	proof positive
preuves intrinsèques ou naturelles	internal evidence
preuves extrinsèques ou artificielles	external evidence
document probant	written evidence
preuve littérale	documentary evidence
commencement de preuve	prima facie evidence
recueillir des témoignages	collect evidence

Often, the phrases '*les éléments de preuve*' and '*les éléments probants*' are used when parts of an argument, not fully fledged proofs, are referred to. It would be easy for a French speaker to refer to proof when they mean evidence. When going from English into French it would be easy to misuse 'évidence' when what may be meant is 'les preuves'.

For the Non Native Speakers, there are also important differences in grammar. As Vinay & Darbelnet (1977:119-120) explain, 'evidence' is a collective unlike the French equivalent, therefore English needs a phrase such as 'a piece of evidence' for the French singular 'une preuve', and 'the evidence' translates the plural 'les preuves'. These grammatical differences do need noting in dictionaries.

Example 4: control / *contrôle*
In the language of science in English, a control is an organism, culture etc used in an experiment in which the procedure or agent under test in a parallel experiment is omitted and which is used as a standard of comparison in judging experimental effects. (after Longman 1985).

In technical French, traditionally '*contrôle*(m)' means a test, verification, inspection, the sense of standard of comparison being absent. Therefore, to translate 'control', another word '*témoin*' (often mis-translated 'witness') is needed. Under the influence of English, the French word, and derived phrases, can nowadays carry the English sense, for instance, '*un groupe-témoin*' is used for 'a control group'. Similarly, the verb '*contrôler*' has become extremely ambiguous in French, in part due to the intruding English meanings, the so called 'half-anglicisms' . Therefore, the full context every time becomes very important.

The word 'control', a word which is so central to the methods scientists use, is missing from the English-French section of Harrap's science dictionary (1985).

b. Physics

Example 5: density

density	*masse spécifique*
specific gravity	*densité*

Note that the term 'specific gravity' is outmoded in Britain. If the concept is to be referred to at all, the Association for Science Education (ASE 1981:31) recommends the use of the phrase 'relative density', a phrase which is used by a modern physics textbook such as Whelan & Hodgson (1989:71).

Example 6: electrical engineer / *ingénieur électricien*

Maillot (1981:46) in giving this example points out that more than just a faux ami is involved, because 'électricien' is either a noun, with the English equivalent 'electrician', or an adjective, the English equivalent being 'electrical'. The cultural contexts need stating. The primary sense in French of engineer is of a highly qualified person, unlike general English where it is more likely to be that of a car mechanic.

Example 7: solid / *solide*, resistant / *résistant*

strong	*résistant*
mechanical strength	*la résistance mécanique*
weak (Défourneaux 1980:109)	*peu résistant*
positive work	*travail moteur*
negative work	*travail résistant*
subzero temperature	*température négative*
a strongly built house	*une maison solidement bâtie*
solid ground	*un terrain ferme*
solid granite	*granit résistant*

'Solid' refers to the state: neither liquid nor gas, or to an object that is not hollow, or to something that is strong. The French 'solide' can have most of these meanings, with additional ones such as secure, tough, sturdy, hardwearing, and well established (Van Roey et al 1988:660). But the French 'solide' does not usually have the meaning 'strong'. For that, the French 'résistant' is often needed (Défourneaux 1980:109,126).

It is worth considering in this context the different translations of the English 'positive' and 'negative', for though both these words exist in French, ('positif/ive , and 'négatif/ive') alternatives are used in this context. In French it is possible to refer to a 'negative temperature', which would be impossible in English which instead describes temperatures as 'sub-zero' or 'minus X0C'. Technical dictionaries need to note differences like these.

c. Chemistry
Example 8: troubled / ***troublé***
Limewater is a common test substance and in technical English it is described as turning 'milky' in the presence of carbon dioxide. In French, normal limewater ('eau de chaux') is described as 'limpide' and in the presence of carbon dioxide it becomes 'troublé'

Example 9: mineral / ***minéral***
The opposite of organic, in French, can be 'inorganique' or 'minéral'. 'Chimie organique' has as its opposite 'chimie minérale' (Robert 1984) not 'chimie inorganique'. Défourneaux (1983:81) states that the word 'mineral' exists in English to designate the products of a natural 'mineral' origin, and sometimes exists even as a synonym of 'inorganic'. But usually the English equivalent of 'minéral' is 'inorganic', not 'mineral'.

For other examples of faux amis in the language of science, see appendix 1.

2. CHEMICAL TERMINOLOGY

a. Names of the elements
Unlike the symbols for the elements, which are totally international, the names are not. Ignoring accents, 34 elements have differences in spelling. The seven elements which are totally different are: nitrogen (azote) iron (fer) copper (cuivre) silver (argent) tin (étain) gold (or) and lead (plomb). These differences are so few and obvious they should not cause problems to students, but are worth listing, and are a good example of studying a defined group of words, and drawing definite useful conclusions for a learner.

b. Inorganic chemistry
Most suffixes at school level are similar, except for the suffix for the halogen ions, which in French is '-ure' and in English is '-ide'. The difference is consistently maintained. A more important difference is in the word order, related to how compounds are formed in English and French. The word order in English is reversed in French, thus 'sodium chloride' becomes 'chlorure de sodium'.

Some gases, such as chlorine and oxygen, exist in nature in molecular, not atomic form. In English they are referred to as 'chlorine molecules' or 'oxygen molecules' (symbolised by Cl2 and O2) whereas in French the prefix 'di-' is preferred, as in 'dichlore or 'molécules de chlore', and 'dioxygène' or 'molécules d'oxygène'. The terms 'dichlorine gas' and 'dioxygen gas' do exist in English, but they are rare variant forms.

c. Organic chemistry NB some of this information is now out of date. In particular, the French have gone over to the English way of writing the formulae.

There are minor spelling differences, and the suffix '-ic' is used for the French '-ique'. The big differences are in the order of the component parts of organic chemistry names. Sometimes words are exactly the same (except for accents) eg 'monochloromethane'. In French, the numbers used in the names are put to the right of the relevant component, and in English they belong on the left. There are complicated differences concerning the use of dashes and spaces, and whereas in English a number can break up a component like octyne, in French numbers cannot break up the component, instead being placed afterwards. An example should illustrate the differences.

French: diméthyl-3,6 octyne-4
English: 3,6-dimethylocta-4-yne

The differences are particularly important for the harder productive skill of writing chemical formulae correctly in a different language system. In practice, it is extremely difficult to change between the systems, and any technical dictionary which included organic chemistry names would do well to include an article explaining the rules and providing stereotypical models as examples. The international standards have been agreed by the IUPAC convention (International Union of Pure and Applied Chemistry) which permits both forms. There are therefore two international styles which are in use and this fact alone is worth stating in a dictionary. Probably the best way students can be helped with these formulae is the provision of examples which can be studied, and the pattern adapted. For these purposes, baccalaureate chemistry textbooks in English prove particularly interesting, alongside published standards for schools such as ASE (1985). d) Chemicals in biology The names and the symbols for the amino acids found in man are the same in English and French, as are many of the sugars. The exceptions are fructose, which is known as 'lévulose' and starch which is known as 'amidon'. Lowe (1992) found that differences were greater for the superordinates as shown in Example 10 below.

Example 10: superordinates in chemicals in biology

carbohydrates	*les glucides*,
monosaccherides	*les oses* or *sucres simples*,
disaccherides	*les diholosides*,
minerals	*macrominéraux*,
trace elements	*microminéraux* or '*oligoéléments*.

Vitamins were largely the same with many synonyms within English in particular. Enzymes were not studied because the syllabus in Tunisia mentioned so few of them.

3. DEFINITIONS

Formal definition of concepts, using standardised words and formulae, is an important part of the pedagogy of science. Since definitions within dictionaries are so important, they merit special attention when cross-language comparisons are made.

a. Geology

Example 11: marl and *marne*

'*Marne*' in French refers to sedimentary clay and limestone (calcaire). The nearest equivalent in English, 'marl' is a wider word and covers soil which has a silt or clay base, with a layer of chalk on top.

b. Biology

Example 12: biosphere and related words

biosphère	=*ecosystème général /ecosphere*
biosystème/écosystème	=*ecosystème (communauté)*
community	=*biocénose*
population	=*population*
habitat	=*biotope (habitat)*

The word '*communauté* ' exists in French, but it is not applied to animals, though '*habitat*' is

(Robert 1984). '*Biocénose*' and '*biotope*' are the preferred words in French, not '*communauté*' and '*habitat*'. The English 'ecosystem' has a narrower meaning than the French '*écosystème*'. Harrap's science dictionary (1985) is misleading, giving the English for '*biocénose*' as "biocenosis, biocenose", instead of the better translation, 'community'.

Example 13: eurytherms and sténotherms
The definition in French of '*sténotherme*', an organism which can tolerate only a small range of temperatures, is restricted to marine animals (Larousse 1984). The related words 'poikilothermic' and 'homeothermic' do have similar meanings in English and French.

c. Physics

Example 14: a force
In English, a force is characterised by its magnitude and direction. In French, there are three essential features that must be described, namely 'valeur','direction', and 'sens' (Kamoun et al 1988:89). In English, one word, 'direction' carries the meaning of two words in French, 'direction' and 'sens'. This distinction, which is compulsory in French, is rare at school level in Britain, though it does exist in describing the forces of circular motion (Whelan & Hodgson 1989:400). The nearest English equivalents to the French 'direction' are, 'horizontal direction', or 'vertical direction'. A vertical direction can then have an upward or a downward sense.

The difference has wide ramifications, and affects the wording of derived definitions. When in English the well known statement is made that 'every force is matched by an equal force of OPPOSITE direction', in French 'every force has an equal opposing force that has the SAME direction but OPPOSITE sense' ('sens contraire').

In normal French usage, a phrase like 'sens unique' is used for 'one way street'. It is also possible to say in French, 'they were going in the direction of' ('ils allaient dans la direction de') (Van Roey et al 1988:226). Therefore there are no grounds for arguing that in English, direction always includes sense, whereas in French, direction can never implicitly include the meaning of sense. What can be confidently said is that when a force is described, the conventional definition in English has only 'direction' whereas in French 'direction' and 'sens' must be specified.

In addition, the 'unit vector' system of mathematics is almost invariably used in France and Tunisia, but not necessarily at school level in England. One example of the basic formula used at baccalaureate level is given in figure 1. [FIGURE 1 NEAR HERE]

FIGURE 1: NEWTON'S SECOND LAW IN ENGLISH AND IN FRENCH

(1) <u>English</u>: $F \quad \frac{d}{dt}(mv).$ Whelan & Hodgson (1989:34)

(2) <u>French</u>: $\_ \quad F\,(\overset{n}{\underset{i=1}{\text{ext}}})i = \frac{dp}{dt} = M$ Ouederni *et al*(1988:119)

The symbols used in the definition of a force in French include unit vectors, while in English they are usually absent (at school level). In this case, the definition at the level of words cannot be adequate without considering the symbols. Note how in French the mathematical representation is more sophisticated than in English. This is directly related to the greater importance of mathematics in French thought, as shown in the relative importance given to subjects that are examined for the bacalaureate. The definition of a force at school level is therefore not identical in English and French, partly due to the French use of unit vectors, and partly due to the French distinction between 'direction' and 'sens', a distinction that must be made explicit in French, whereas it is usually left as implicit in the English versions.

d. Chemistry

Example 15: Definition of an acid: pH

The quantity pH is taken at school level in Britain as,

$-\lg\{[H^+]/(mol\_dm^{-3})\}$ (ASE 1985:19). This is read aloud as "minus log of the concentration of hydrogen ions, in moles per cubic decimetre". Sometimes hydrogen ions are also called protons, so an alternative reading would be "minus log of the concentration of protons, in moles per cubic decimetre".

This means that pH is related to the concentration of H^+ ions, pH being a measure of acidity.

In Tunisia in contrast, while an acid is initially defined in terms of H^+ ions, pH is defined in terms of H_3O^+ ions.

$[H_3O^+] = 10^{-pH}$ (Kamoun *et al* 1988:72,73,75).

The definitions are different, both in the mathematical form, and in the choice of ion. The French preference for a use of $[H_3O^+]$ instead of $[H^+]$ has repercussions for the writing of the formulae of acids. Thus Corrigés (1988:33) has '*l'acide chlorhydrique*' as $(H_3O^+ + Cl^-)$, instead of the more usual English expression $(H^+ + Cl^-)$.

Example 16: Standard Pressure
Current recommendations at school level are that 'atmospheres' be used only as a unit for rough comparisons. (ASE 1985). Many calculations in chemistry are made based on the "Standard Pressure for gases". This used to be one atmosphere, ie 101 325 Pa or 760 millimetres of mercury (760mmHg) (Défourneaux 1983:46). In a change since the previous edition of ASE's 'Chemical Nomenclature' in 1979, IUPAC now apparently recommends that the standard pressure for reporting thermo-dynamic data be 105 Pa, but that normal boiling points be reported assuming a pressure of 101 325 Pa as before. Standard Temperature and Pressure (s.t.p.) used to be "273K & 760mmHg".

A new 'Standard Pressure' means that two standards are operating under the same name. Anyone reading English will need to take care that they know which s.t.p. is being referred to.

e. Mathematics
Example 17: a line
There is a distinction in French between a 'line' ['ligne'] and a 'straight line' ['(ligne) droite']. A line in French can be curved, whereas in English a line is assumed to be straight unless there is indication to the contrary. A 'curvi-ligne' would normally be translated as a 'curve', not a 'curvy-line', because a line in English, is by definition considered to be straight.

There is a second major difference, based upon the customary definitions of a line. In English, a line is the shortest distance between two points, which is closest to the French use of 'segment de droite' for a line limited at both ends. In French, a line is more usually defined as coming from and going to infinity. Therefore there is the concept of a 'demi- droite', which translates as a 'line' in English, not 'half a straight line', because a 'half line' is impossible in the English understanding of the words. Once again, the French appears to be more systematic, precise and detailed than the English.

Example 18: an angle
'Angle rectiligne' is difficult to translate into English, for the closest terms are 'linear angle' or 'rectilinear angle', both of which are nonsensical. The reason why the expression 'angle rectiligne' is possible in French derives from the definitions of a line and an angle. In the French system, an angle can exist either between two planes or between two lines, therefore 'angle rectiligne' is used to emphasise that the angle is between two lines, not two planes. In common use is the term 'angle droit' for 'right angle' (ie 90o). In contrast, the context in English, not the terms, determine whether an angle is between lines or between planes.

Example 19: mean / *la moyenne*
British school students are usually taught by the fifth year of secondary school the difference between the mean, the median, and the mode. In addition English has the related words, 'class average', and 'passmark'. French students generally learn such statistical differences much later, if at all.

There are several problems. The concept of a variable passmark in examinations scarcely exists in French, 'la moyenne' having primarily two senses, the mean, and the passmark. It is generally assumed that the passmark is fifty percent, or, as it is more usually expressed in French, 10/20. Given this context, it is reasonable in French to refer to the passmark as the average. In addition, 'class average' is translated by 'la moyenne arithmétique' and this too can be called 'la moyenne'.

Harrap's science dictionary (1985) is lacking once again at this point in that it translates 'mean' as 'la moyenne' without comment, omitting the nouns 'median' and 'mode', equivalents in French being 'la médiane and 'le mode'.

The words have interesting general implications for English teaching in North Africa. I frequently hear students say, "I didn't get the average". I have given this sentence to many of my students and asked them what was wrong with the sentence. To date no student has been able to correct the sentence, no one has suspected that the problem with the sentence was with the word 'average' and not with its grammatical construction.

4. EPONYMS

Maillot (1981:141-2) sees the almost total unanimity of the way names of scientists are used to name a phenomenon or object, as evidence for the supranational nature of science. [1.]

Newmark (1988:199) is less optimistic and notes that the authenticity of the discoverer may be disputed, or a technical or descriptive term may replace the use of an eponym. Two examples have been selected for detailed comment.

Figure 2: Table of eponyms at school level in English and French

FIGURE 2: EPONYMS

English	French
BIOLOGY	
1. --	*l'indice d'aridité de Martonne*
2. --	*quotient pluviothermique d'Emberger*
3. --	*échelle de Braun Blanquet*
4. giant nerve fibre of squid.	*axone géant de Seiche/Calmer*
5. ovarian follicle (English: school use) Graffian follicle (old English)	*follicule de De Graaf*
PHYSICS	
6. Boyle's law	*la loi de Mariotte*
7. eddy currents	*courants de Foucault*
8. I^2R losses (energy losses due to resistance in a wire)	*pertes Joule*
9. plimsoll marks	*les marques de franco-bord*
10. Voltage	*tension*
11. to de-gauss (Gauss is an eponym)	*démagnétiser*
12. inductance meter	*henrymètre*
13. Maltese Cross tube	*tube à croix mobile*
14. aneroid barometer	*baromètre de Vidi*
15. Newton's 2nd law of motion	*la relation fondamentale de la dynamique*
16. no name, equation used F = BQv sin _	*la loi de Laplace*
17. moment of inertia	*théorème de Huygen*

Example 20:6, Boyle's Law = *La loi de Mariotte*
This example is quite important: Boyle's Gas laws are fundamental and basic to science. Défourneaux merely notes the difference (1983:47) but Beeching explains, Boyle's Law is also known as *Mariotte's Law* from the French physicist Edme Mariotte (1620?-84) who confirmed Boyle's principle quite independently of the British scientist. (1988: Boyle's Law).

Example 20:15, Newton's second law of motion, or, *la relation fondamentale de la dynamique*
Newton's second law of motion states that, the rate of change of momentum of a body is proportional to the resultant force that acts on it. (Whelan & Hodgson 1989:34b). The law is perhaps more well known as expressed in the formula F = ma (Whelan & Hodgson 1989:36b).

In French this law is known as *la relation fondamentale de la dynamique*, it is abbreviated to R.F.D. (Corrigés 1988:61) and does not have Newton's name attached to it.

Newton's second law in English is regarded as the fundamental law in French, which is a valid viewpoint in terms of the principles of physics. Asimov (1987:804ff), in his one volume survey of the whole of science, a book which, though getting dated, is still very comprehensive and readable and therefore potentially very useful to the non- science trained ESP teacher, shows how historically the first law was derived before the second law by Stevinus, and later by Galileo. English therefore gives precedence to history, and French gives precedence to physics.

When the examples from figure two are taken into account, it is clear that English sometimes uses an eponym where French does not and vice-versa, with greatly different connotations. Also, different people can be chosen. Whatever the reasons, the existence of differences generates difficulties for translators and anyone attempting to follow one language while using another, and is one more category where the language of science is not always international.

5. AFFIXES

The language of science has a common stock of prefixes, suffixes, and root words deriving mainly from Latin and Greek. (Richards 1976:page xi, Strevens 1973, 1977:153, Austin & Howson 1979:169). Therefore there is the expectation that words formed using these affixes will be constant across languages. There are also the further assumptions that the range of meaning will be the same when two languages are compared, and that minor spelling differences are small enough to make it possible to ignore them. A selection of the differences is presented below.

Example 21: multiplier prefixes
French and English have the same Latin and Greek series', with one small spelling difference: 'bi-' and 'tri-' in French can both have the extra letter 's' added eg 'bisannuel' for 'bi- annual' and 'trisannuel' for 'triannual'.
**Latin: uni-, bi-, tri-, quadri-. . . , multi-/pluri-
**Greek: mono-, di-, tri-, tétra-. . . , poly-

A different choice of prefix is sometimes made. When French uses 'bioxyde' for 'dioxide', French is using the prefix from the Latin series and English is using the prefix from the Greek series of prefixes. Similarly, 'tetra-' and 'quad-' can interchange, eg quadrivalent = tetravalent and tetragonal = quadrilatère. The prefix 'multi-' deserves special comment, for it has an equivalent 'pluri-' which is more common in French than in English. A 'multidisciplinary seminar' becomes 'seminaire pluridisciplinaire', while a 'perennial plant' is a 'plante pluriannuelle' or 'plante vivace'. In fact there seems to be an implicit hierarchy in French, going from a few to many: inter-, pluri-, multi-, poly-

As pointed out by Maillot (1981:86) English has an extra two sets of multipliers, which are also part of the scientific vocabulary.

**single, two, three. . . . multi/poly, (with a preference for multi-). eg single-phase, two-phase, three-phase, multi-phase

**double, triple, eg double-pole, triple-pole, in use for in the French 'disjoncteur bipolaire/ tripolaire'.

A multiplier prefix can also be translated by an adjective, as in 'generalised lymphadenopathy' for 'polyadénopathie' (Newmark 1988:250).

The English prefix 'bi-' can be ambiguous in English, but not in French. The English word 'biannual' refers to every two years (Fr: 'bisannuel' or 'biennal') or to twice a year, (Fr: 'semestriel'). 'Bimonthly' can mean twice a month (Fr: 'bimensuellement/deux fois par mois') or every two months (Fr: 'tous les deux mois').

Example 22: '*-oxyde*'
'Oxide' and 'dioxide' can sometimes, in French, be translated by 'anhydride', hence 'anhydride carbonique' for 'carbon dioxide' or 'anhydrique cuivrique' for 'copper (II) oxide'.

Example 23: '-phyte' and '*-phile*'
The suffixes '-phyte' and '-phile' exist in both French and English, and both can combine with the prefixes 'hydro-' 'meso-' and 'xero-'. But the preferred suffix in French is '-phile', hence 'hydrophile', 'mesophile', and 'endophile', while the preferred suffix in English is '-phyte', giving 'hydrophyte', 'mésophyte' and 'endophyte'.

But, '-phile' in French pertains to both plants and animals, the equivalent suffix in English, '-phyte', pertaining to plants only, not to organisms in general. The usage of '-phile' and '-phyte' is therefore different in French and English, though the core meaning is maintained: type of adaptation to the environment in terms of the need for water. To complicate matters, 'un hydrophile' is another word for 'an insect'.

Example 24: per-
In technical English an 'infusion' is a continuous slow introduction of a solution, especially into a vein, while a 'perfusion' is when liquids are forced through an organism or tissue. The prefix '-in' means 'within', 'into', 'towards', whereas '-per' means in this case 'through'. (Longman 1985).

In French the word 'perfusion' has both senses of 'infusion' and 'perfusion' in English. 'infusion' being restricted to the preparation of herbal tea drinks and has no medical meaning.

DISCUSSION

Faux amis exist in general language and are relatively well documented between English and French. Awareness of them leads people to be cautious in their expectation that similar words will transfer between languages. Similar caution is needed for the transfer of technical words.

A study of definitions has shown that there are some significant differences between French and English. If the basic sciences are largely "culture independent subject area where the rule is full equivalence between LSP terms" (Bergenholtz & Tarp 1995:53), then such differences in definitions, which are related to the two science cultures, ought not to exist.

The differences are particularly striking when mathematics is involve, supposedly the most culture-independent subject of all. That such basic concepts as a 'line', and an 'angle' should be different in French is an important finding. This is further evidence that even mathematics in French has fundamentally different qualities to that in English, which are rooted in the different cultures. As Frawley reminds us, "language plays a central role in mathematical problem-solving and the acquisition of mathematical knowledge...because mathematics is taught and understood via the *sub-language of mathematical discourse*" (1992:385 italics Frawley), a key element being the linkwords (Austin & Howson 1979).

Bergenholtz & Tarp make frequent reference to **the supposed culture-independence of science**. In the related field of ESP Widdowson (1974, 1979) and others have argued that this is particularly seen in the internationalness of the symbols and other non-verbal forms. I have already demonstrated that such an expectation is at best an oversimplification, and that there are cultural differences which are related to the differences which exist between French and English in the area of non- verbals (Lowe 1996). Non-scientists too easily assume that "the content, methods, and technical procedures are independent of social and cultural influences" (Tarantino 1991:56) as are the "cognitive processes underlying the discourse of science" (p57). Tarantino makes this assumption even for school level science, which, because of its closeness to the pre-science world view might be most expected to be subject to cultural influence. Tarantino does expect some textual variability, but is able to naively state that "Regardless of their primary culture, science students are trained according to the same principles, theories, and cognitive patterns (p57).

While science may be less culture-bound than for instance the different systems of law, there are nevertheless marked differences in the cultures of science which is reflected in the way science is taught in schools, and in the language of science. Anyone who has worked in British and French schools, and taught or observed science, will be quite convinced that there are major differences, which while hard to state objectively in an article, do actually exist and could be described as follows.

In France, mathematics is king. The preference dominates lessons in chemistry and physics. French teachers are routinely shocked to hear that in England I studied physics as a major subject in my baccalaureate, without using much calculus and that I studied mathematics as a subsidiary subject, to a level they achieve in their system three years before the baccalaureate. In England, mathematics in science can even be viewed as a hindrance to understanding the physical phenomena, and I well remember teaching physics to low ability 15 year olds, without anything more complicated than simple addition and subtraction.

The British concentrate much more on practical work, and the practical applications of the phenomena studied. If anything, chemistry is king in England, being seen as important for biology, physics, and geography, while in France it is devalued, being taught as part of physical science, with physics getting the lion's share of the time.

There are also other differences in approach in the school cultures. The French system over-emphasises hard study. School hours are long, with homework that is highly directed and monitored. British schools encourage wide reading round the subject, with time to think, and to pursue projects of independent study. This means that by the age of 18, a science student in Britain may well have already completed several projects: extended essays or pieces of research, as well as having passed a sophisticated series of examinations that involve a great variety of examination types and tested skills.

The tentative nature of science will also be taught much more than in France. In French thought, school science is a largely a body of knowledge to be learned and repeated and applied in examinations. In British thought science is much more a series of concepts and skills to be applied to new situations. These skills include evaluation of evidence and competing theories.

French love of precision has already been reflected in some of the definitions and vocabulary studied above. The British attitude is more likely to leave implicit that which is assumed or need not be said. Measurements need only be as precise as they need to be to obtain a meaningful result, and the skill of estimation is taught and practiced.

One cannot get away from the impression that school science in England is more concrete, practical, visual, and applied quickly to everyday life, and not excessively concerned with precision. Common words are frequently used with a science specific meaning, either alongside technical terms, and sometimes even in preference to a technical term. In contrast, in France the technical term is more often preferred, as for instance with '*biosphère*', and the preference for '*biocénose* instead of '*communauté*', and '*biotope*' instead of '*habitat*'. In France there seems to be more emphasis on Cartesian, rational, unambiguous use of words and symbols, to the point where to British eyes it is pedantic, and states the obvious. The way internal evidence is described as <natural> ('*les preuves naturelles*') while external evidence is described as <artificial> ('*les preuves artificielles*') is no accident.

The subject matter of science does change significantly between the French and English cultures, and experienced science teachers will recognise a difference even within English between American and English textbooks, which reflect the culture of education and examinations as well as the differing science cultures. The differences are great enough to mean that the supposed culture-independence should not be presumed. It is simply not fair to say that "the frame of reference of the different users is the same" (Bergenholtz & Tarp 1995: 61) when the frames of reference, and the associated language, are not always the same. While it is arguable whether or not science is more or less culturally dependent than law, it is clear that both need encyclopedic information. A "comparative description of the dictionary subject-matter within the respective cultural areas" is required for science, in addition to a "culture-dependent presentation of the subject field" (p61).

It is important to consider the results from research done on teaching the language of science to native speakers of English. The work of Cassels & Johnstone (1985) for instance has shown that the problem words to students, even the native speakers, are not the new specialised technical words, but the so called sub-technical words, where a word in common use is extended and re-defined to give a very specific meaning in a science context. It is easier for students to learn a new word, than to change the meaning of a known word. New words also demand explanation, whereas it is easy to assume that old words are understood in new contexts, and not spend much time differentiating the common meaning from the specific meaning in science. Trimble came to similar conclusions in his research into ESP (1985:128-9). Lexicographers need to document semi- technical words very carefully, and highlight them.

Similarly, it can be argued that when changing languages, the difficult words are not likely to be the totally new ones, but similar words with different ranges of meaning, the false cognates or faux amis. The comment of Cassels & Johnstone that, "Things are at their most dangerous stage when both learner and teacher know the meaning of a word and each assumes the other shares the same meaning" (1985:15), originally meant for common words given a specific meaning in science, could apply equally well to the faux amis and technical words in a bilingual context.

There is **another problem facing lexicographers which reinforces the need to concentrate on semi-technical words**. Despite the findings of Cassels and Johnstone (1984, 1985) **the trend in science teaching in Britain, is to avoid technical words and use if possible an everyday English equivalent** (IOB, 1989:29; Barrass, 1979:191). In other words, to use the semi-technical word. The motivation behind those arguing for the use of everyday words instead of specialist words is to reduce the vocabulary load of science lessons. We know that it is probably harder to learn a new meaning to an existing word than to learn a new word for a new concept. But the favoured approach in Britain is against such an idea. What concerns us more though, is that because everyday words used in science may well be less constant than the technical words, this trend adds yet more vocabulary to be learned by the non-native speaker of English. Learners of the language of science in English are going to need the semi-technical language and the technical language.

It might be thought that research articles in English do not use semi-technical words, and if they do, they avoid using synonyms in the same article. This may be a valid point for some journals. The evidence I have seen (which I cannot find at the time of writing) suggests that in an article, for the sake of a varied style perhaps, synonyms, both technical and semi-technical are used.

The task of working from English into French is though probably much simpler, since it is likely that popular and semi-technical vocabulary will have only one equivalent in French. The extent of this trend at university level and higher has yet to be studied.

Finally, lexicographers nowadays are increasingly relying on data bases of words in context, both written and spoken. But there is plenty of room for informed judgement within the technical arena. Infrequent words are not necessarily the least important or least used. One would expect broadly based, multi- disciplinary dictionaries to cover the most significant words. As a case in point, one of the most significant in biology, upon which the whole subject is based, is the word 'homeostasis' (New Scientist 2000:62). Yet it is not listed in mono-lingual dictionaries such as Collins Cobuild (1987) and the bilingual Harrap's shorter dictionary (1993) or Harrap's Science dictionary (1985).

CONCLUSIONS

This paper has described in detail some of the many differences in the vocabulary of science between French and English, and begun the task of studying them in their cultural context. The word studies illustrate the depth of detail required not just in the linguistics, but also in the knowledge of science, science cultures and science education. Lexicographers need to take such information into account and make it available in usable form in their published texts. In this way the material should be useful to science students learning English, to their teachers who are rarely qualified in science, and to bi-lingual scientists.

In view of the importance of mathematics to science, and the differences that do exist, it is a matter of some urgency that a bi-lingual mathematician is persuaded to compare mathematics in English and French. The work now needs extending beyond school level into subject disciplines at university, and within each discipline to identify and study all the definitions, faux amis, eponyms, and collocations, and seek definitive work that for a given subject identifies and explains all the major differences. Alternative methods of presenting encyclopedic information also deserve consideration, such as parallel sentences (Van Roey *et al* 1988), or discussion of key words, as in Thody & Evans (1985) and in this article. The work also needs extending to language pairs other than English and French.

NOTES

1. The Association for Science Education, referred to in the text as a source of authoritative information on school science in Britain, can be contacted at: ASE, College Lane, Hatfield, Herts, AL10 9AA.

2. This use of "evidence for" was originally unintentioned, but in the light of the discussion above on 'evidence' and 'proof', gives another apt example, for here it means 'signe de la nature supranationale de la science'.

APPENDIX 1: FAUX AMIS

See Maillot (1981:15,32), Défourneaux (1980, 1983) and Van Roey *et al* (1988).

English	French
BIOLOGY	
1. wild	sauvage
2. tonsillitis	angine (f)
	amygdalite (f)
angina (pectoris)	angine de poitrine
3. (repeating) unit CH_2CH_2...	*Le motif (qui se répète)* CH_2CH_2...
4. preservative	agent (m) de conservation
condom	préservatif (m)
5. respiration/breathing	respiration (f)

6. "Some drugs tend to accumulate in the *body* (plus rarement: *organism'*)." "Certains médicaments tendent à s'accumuler dans l'*organisme*'." "Unbalanced slimming diets like these are bad for the *system*'." "Ces régimes amaigrissants mal équilibrés sont néfastes pour l'*organisme*." (Van Roey *et al* 1988:489)

PHYSICS

English	French
7. speed,	*vitesse*, (f)
velocity,	*vecteur vitesse* (Défourneaux 1980:122)
8. conductor	l'âme (conductrice) (f)
to insulate, to isolate	isoler
9. insulation	isolement, isolation
10. switch (and compounds of)	commutateur (m)
commutator (of a motor)	collecteur (m)
11. field magnet	inducteur (m)
inductor	inductance(f), bobine de
12. resistance (size)	résistance (f)
resistor (object)	

13. generator	génératrice (f) (for DC) alternateur (m) (for AC)
alternator	alternateur synchrone
alternative	optionnel, alternative (périodique), successif
alternating	alternatif
14. to annulate, to zero	anneler, annuler
15. magnetic, magnet	magnétique, aimant (m)
16. aerial	antenne (f)
17. electron microscope	microscope (m) électronique

<u>CHEMISTRY</u>

18. competing reactions, — réactions concurrentes (f pl)

The primary sense in French is of competition. If the sense of 'concurrent' ie 'at the same time' is needed, then other adjectives such as '*associative, co-operative*' or '*concomitante*' would be used.

19. product — produit (m)

The English 'product' has a narrower sense than the French and means in the context of chemistry, the end substance(s) of a chemical reaction. The French '*produit*' can mean simply 'substance' or 'result'.

20. chloration (-Cl)	chloratation (f)
chlorination ($-Cl0_3$)	chloration (f)
to nitrate; nitration	nitrer; nitration (f)($-NO_2$) nitrater; nitratation (f) ($-NO_3$)

Defournéaux (1983:87) points out the problem is the contraction in English of -atation to -ation, which gives ambiguity in English.

21. fluorine (halogen)	fluor (m)
fluor [spar] (mineral)	fluorure (m) [de calcium naturel, alias 'spath'(m) or 'fluor']

Note, Maillot (1981:37-8) says such a confusion is destined to disappear as minerologists in both languages are agreed to use the term "fluorite".

22. ignition	inflammation (f)
combustion (state of)	ignition (f) (en)
23. phenol = versatile reagent	phénol (m) = corps susceptible de plusieurs réactions
inconstant	versatile

24. non-metal	métalloïde
metalloid	métalloïde

The French *'métalloïde'* covers the non-metal and the half metal (=metalloid) definitions in English.

<u>MATHEMATICS and GENERAL</u>

25. compound	corps composé (m)
pure, acidic, basic substance	corps pur, acides, basiques tracer
(substance)	corps marqué
the human body.	le corps humain
26. to terminate, termination	mettre fin à arrêt (not '*terminer*')
to complete, completion	mener à son terme achèvement (not '*compléter*')
to end; end-point; completeness	se terminer; fin; plénitude
27. to parallel	se comparer à; NOT: se dérouler en parallèle avec
28. solution (liquid)	solution (f)
(of a problem)	résolution (f)
(in)solvable problem	(in)soluble
29. single (unit)	simple
30. datum pl: data	donnée(s) (f) (not 'dates')
31. approximate/approached	approché
to approach	tendre vers
32. to summarise	résumer
to resume	recommencer, reprendre
33. a pair of scales,	balance (f)
"The tightrope walker lost his <u>balance</u>" Van Roey *et al* (1988:73)	"Le funambule perdit l'<u>équilibre</u>"

[underlined here indicates bold in the original, also in examples 36, 37, 38]

34. diamond (shape of)	losange (m) (form de)
35. even (level, steady)	égal
36. "Could you <u>adjust</u> the aerial?" Van Roey et al (1988:490)	"pourrais-tu <u>orienter</u> l'antenne?"

37. limited knowledge	connaissances primaires
primary concern	but (m) principal
"Research is a matter of primary	"Nous attachons une importance to us".
	importance primordiale à la recherche".

Van Roey *et al* (1988:545)

38. process of digestion	le processus de la digestion
trial/lawsuit	procès
39. experiment, experience	expérience(f)
experimented, experienced	expérimenté
experienced	qui a de l'expérience du métier, (observateur) averti
experienced in	(oeil) exercé à
experienced in business	rompu aux affaires
experience	épreuve personelle
to experience	éprouver, faire l'expérience de, il m'est arrivé
practical experience	la pratique
facts within my experience	faits à ma connaissance
have you had any previous experience?	avez-vous déjà travaillé dans le métier?
to carry out an experiment	réaliser une expérience
40. chronometer, stop watch	chronomètre(m)
41. humid	humide

Humidity is the degree of water vapour in the air. '*Humide*' is a wider word, covering English words such as damp and moist.

42. lens (in general)	lentille (f)
lens of the eye	cristallin (m)
43. sensible	sage, raisonnable, sensé
sensitive	sensible
sensitivity of the oscilloscope	La sensibilité de l'oscilloscope
44. order of magnitude	ordre (m) de grandeur

45. The English 'alkene' (carbon with double bond) can sound like the French '*alcyne*' (carbon with triple bond).

APPENDIX 2: SOME EXAMPLES OF DIFFERENCES DUE TO AFFIXES

1. *-ure* and -ide. *Chlorure de Sodium* becomes sodium chloride, the -ure becoming -ide.

2. *-trice*. The suffix *-trice* is the feminine of *-teur* . Words with this ending are sometimes translated by -trix, sometimes by -tor and other times indifferently, -trix or -tor. Examples are:

directrix	=*directrice*
generator	=*génértrice*
bisectrix or bisector	=*bissetrice*

3. *-able, -ible*. There is no rule for the correspondence between French and English, and all four possible variants exist:

-able	= *-able*	eg	measurable	=	*mesurable*
-ible	= *-able*	eg	negligible	=	*négligeable*
-ible	= *-ible*	eg	divisible	=	*divisible*
-able	= *-ible*	eg	expandable	=	*expansible*

4. *sous-* and *sur-*.These common French prefixes with science specific meaning have different translations in English.

sous-= under-	eg	*sous-développé* = under-developed
= sub-	eg	soustraction = subtraction
sur-= over-	eg	*suralimentation* = overfeeding (nutrition)
= super-	eg	*suralimentation* = supercharger (engines)

5. con-, in-

Toute affirmation pourra être confirmée ou infirmée Every statement can be confirmed or refuted (not 'infirmed').

6. *auto-*. The French *auto=* is often translated by 'self' in English, thus:

autofecondation	=	self fertilisation
autoportrait	=	self portrait
autopunition	=	self punishment
BUT autocentré	=	egocentric

7. oligo-élément = trace element

8. *bio-*. In English the prefix meaning life (bio-) can be replaced in French with the prefix (*syn-*), or with the adjectives *physique* or *organique*.

biological clock	=	horloge physique biofuel
	=	combustible organique
bioecology	=	synécologie

9. *anti-*

antichoc	=	shock proof, but anti-shock treatment
anti-déflagrant	=	explosion proof, flame proof *anti-mite*
	=	moth proof
anti-vol	=	thief proof
anti-conceptionnel(le)	=	*contraceptive* anti-hygiénique

= *unhygienic*

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