Pre-adaptation, exaptation and technology speciation: a comment on Cattani (2006)

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Notes and Comments

Pre-adaptation, exaptation and technology speciation: a comment on Cattani (2006)*

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A recent article in this journal by Cattani (2006) pointed out that some part of a firm's technological knowledge base may be accumulated without anticipation of its subsequent uses but may later prove to have valuable applications. He called this technological *pre-adaptation*. This comment suggests that pre-adaptation is a confusing concept and offers an alternative term—exaptation—that might better describe the process Cattani refers to.

1. Problems with ''pre-adaptation''

In a recent article in *Industrial and Corporate Change*, Cattani (2006) advanced the idea of technological *pre-adaptation* to ''describe that part of a firm's technological knowledge base that is accumulated without anticipation of subsequent uses (foresight), but might later prove to be functionally ''pre-adapted'' (i.e., valuable) for alternative, as yet unknown, applications.'' (Cattani, 2006: 286). While I believe Mr Cattani's article makes an excellent contribution to the literature, I believe his choice of the term ''pre-adaptation'' is unfortunate. In this brief note, I want to explain why I think pre-adaptation is a confusing term and to tentatively offer what I believe is a less confusing alternative.

To begin, let me explain why pre-adaptation creates confusion. If one looks up the meaning of ''pre'' in the dictionary, one finds that it refers to *before, in front of, prior to, in advance of, an activity taking place before* . . . (Webster's, 1991). Therefore, if one speaks of a feature of an artifact (whether natural or man-made) being pre-adapted, an observer might ask what process pre-adapted it? In evolutionary biology, how the process of adaptation works is well-known, of course. At face value, prefixing ''pre'' to adaptation suggests that one is referring to an adaptive process *taking place before* . . . that is, that the adaptive process must have occurred *before* the fitness-value of the feature in question was in fact apparent. This suggests that some kind of

*Comments on Gino Cattani (2006), 'Technological pre-adaptation, speciation, and emergence of new technologies: how corning invented and developed fiber optics,' *Industrial and Corporate Change* **15**(2), 285–318.

foresightful adaptation is involved in pre-adaptation. But this notion contradicts one of the basic principles of evolutionary theory, that the process of natural selection involves no foresight. It also contradicts the intended meaning advocates want to give to pre-adaptation, as I understand it.

As a result of these contradictions, evolutionary biologists struggled for many years with confusion about the meaning of pre-adaptation. Lest it becomes too tempting to say this is all just a ''language game,'' let me quote one of the leading figures in modern evolutionary theory, S. J. Gould, who witnessed in his lifetime the conceptual confusion rendered in biological circles by pre-adaptation. Gould says, ''I cannot think of a more infelicitous term in our entire lexicon, *explicitly lamented and identified by scores of biologists*.'' (Gould, 2002: 1231, my italics). He went on to explain:

> 'What term in all our lexicon has ever come to us so inherently ''prepackaged'' for inevitable trouble and misunderstanding? . . . [W]e guarantee ourselves nothing but trouble when we invent a word with a ''plain meaning'' of foreordination as a description and definition of our best examples to illustrate the precisely opposite concepts of fortuity and contingency. The resulting, entirely predictable, confusions became legion in biology classrooms, and professors developed a tradition for explicating and apologizing in advance whenever they mentioned ''preadaptation''. Terms that automatically evoke such embarrassment must be fatally flawed . . .'
>
> I could present a catalog of such textbook apologies, but will cite only Frazzetta's lament (1975, p.212) to prove that my fulminations at least cannot be idiosyncratic: 'The association between the word ''preadaptation'' and dubious teleology still lingers, and I can often produce a wave of nausea in some evolutionary biologists when I use the word unless I am quick to say what I mean by it.' (Gould, 2002: 1232).

I have noted that Mr Cattani has taken great care to precisely define what *he* means by pre-adaptation. The problem is that many people will still make up their own minds about what they think pre-adaptation means, and casual reference to the meaning of ''pre'' in other contexts will inevitably lead some of them up the garden path, and into the same confusion that invaded the discipline of evolutionary biology for many years. Gould notes that the term has been fading from use in biology circles for the past 20 years, and that current graduate students are likely to encounter the term only rarely (Gould, 2002: f1231f.). This is good. Over the years, the discipline (of biology) has gradually selected-out the term. Of course, technology evolutionists are free to walk their own path and it will, of course, differ in many ways from the one walked by biologists. Our field is also free to observe the course of events in biology and not condemn itself to repeat the past.

So, if we accept for a moment the suggestion that the notion of pre-adaptation is not well-suited for describing technology evolution, what alternative term might work better?

2. ''Exaptation'': a better term?

Possibly a better term than pre-adaptation is *exaptation*, which is refers to a feature that is co-opted for its present role from some other origin (Gould and Vbra, 1982; Mokyr, 2000; Dew *et al.*, 2004). According to Wikipedia: ''The term has spread within literature on evolutionary biology. Hence: exapted used as a verb, where a biological function exapted an earlier function . . .'' This follows a 20-year period in which, ''[B]iologists have subjected the term to intense criticism and scrutiny, from which ''exaptation'' has emerged with strength and proven vigor.'' (Gould, 2002: 1234).

The term *exaptation* was originally coined in evolutionary biology, in an article addressing missing terminology in the science of form (Gould and Vrba, 1982). Gould and Vrba noticed that the concept of adaptation in fact subsumes two different criteria: *historical genesis* and *current use*. The first meaning of adaptation—historical genesis—refers to the dynamic process of evolutionary adaptation where an organism is ''designed'' by adaptation for fitness in a specific function, task or application. The key idea is that adaptation is the process of being designed to be fit *for* a task (Simon, 1996) whether that design occurs through variation–selection–retention processes (as in biological evolution) or Lemarkian processes (as in new product development, etc.). In biology, this led Williams (1966: 6)to define adaptation as occurring when we can, ''attribute the origin and perfection of this design to a long period of selection for its effectiveness in *this particular* role.'' (Emphasis added.)

The second meaning of adaptation—current utility—defines adaptation in a static *ex post* sense. In this conception, an adaptation is any feature that currently enhances fitness, regardless of the evolutionary process by which it developed. However, strictly speaking, this concept is actually better described by the term ''aptation'' rather than adaptation, since the etymology of ''aptus'' is ''fit,'' whereas ''adaptus'' refers to the process of increasing fitness by designing for a particular function.

In contrast, the term ''exaptation'' refers to an operation, a process, of changing the function of a feature—what Gould refers to as a ''quirky functional shift'' (2002: 1217). As Mokyr describes it, ''The basic idea is that a technique that was originally selected for one trait owes its later success and survival to another trait which it happens to possess.'' (Mokyr, 2000: 57). The importance of the idea of exaptation is that features of organisms—or technologies—can have *non-adaptive origins*, that is, they might evolve for one reason, or for no apparent reason, and then later be co-opted for a new role, that is, be ''exapted.'' It is this notion that new technologies might emerge out of non-adaptive origins that appears to be Mr Cattani's point

about Corning's fiber optics: a case where ''firms accumulate knowledge without anticipating its subsequent applications.'' (Cattani, 2006: 290). The point seems to be that R&D labs often seem to accumulate a lot of ''stuff'' laying around: R&D rubbish. I have found that the analogy with rubbish DNA is very helpful here. According to Brenner (1998: R669):

> Some years ago I noticed there are two kinds of rubbish in the world and that most languages have different words to distinguish them. There is the rubbish we keep, which is junk, and the rubbish we throw away, which is garbage. The excess DNA in our genomes is junk, and it is there because it is harmless, as well as being useless, and because the molecular processes generating extra DNA outpace those getting rid of it. Were the extra DNA to become disadvantageous, it would become subject to selection, just as junk that takes up too much space, or is beginning to smell, is instantly converted to garbage.

The point here is that Corning, like a lot of other firms, had R&D ''stuff'' laying around—call it knowledge, original research, whatever. Some of this stuff turned out to be junk that was exapted; this is the topic of Mr Cattani's article. The rest, presumably, turned out to be garbage. Of course, at the time, no one could know which knowledge might turn out to be useful or not, which is precisely why pre-adaptation is a bad term to use: one can't tell, *ex ante*, what's pre-adapted from what's not, that is, one can not tell junk from garbage. This difficulty favors using the term exaptation, which does not invoke the specter of foresight, or of anything ''pre.'' Therefore, I conjecture that the term exaptation might be much better suited for use in describing the particular processes of technological evolution that Mr Cattani wishes to highlight, than the term pre-adaptation. For clarity, the terms are laid out in Table 1, below.

Given that exaptation appears to be such a better term than pre-adaptation, I confess to being somewhat perplexed by the apparent criticism Mr Cattani makes of

Table 1 Taxonomy of fitness (Gould and Vrba, 1982: 5)

Process	Definition			Usage
Natural selection processes shape a characteristic for current use	Adaptation	Adaptation	Function	
A characteristic previously shaped for another function is co-opted for a new use	Exaptation			
A character whose origin cannot be ascribed to selection processes is co-opted for use				Effect

the concept of exaptation in a footnote in his paper (p. 290f.2; as well as Cattani, 2005) where he says:

> For Gould and Vrba (1982), pre-adaptation refers solely to features that promote fitness and were built by selection to perform the same function for which they originally evolved, while features that evolved for other usages or for no function at all and were co-opted for their current role at a later point in time are ''exaptations.'' *The usefulness of establishing whether existing features were from the outset ''optimally designed by natural selection for their functions'' (Gould and Lewontin, 1979: 585) is questionable.* (My italics.)

Leaving aside my confusion about what Mr Cattani means by a feature that ''was built by selection to perform the same function for which they originally evolved,'' the key issue seems rather clear cut: the question of the usefulness of establishing whether a feature originated through an adaptive process, or not. Here I find Mr Cattani's perspective very puzzling because it appears to me that his work is an excellent example of establishing the origins of a technology, and finding that these origins were ''non-adaptive,'' that is, not a product of foresighted design, but instead a case where ''firms accumulate knowledge without anticipating its subsequent applications.'' (2006: 290). As far as I can see, Mr Cattani has done an admirable job of tracing the origins of fiber optics in this regard; indeed, I wish there were more studies like his.

As for biologists, they doubtless have their own mission in mind when they perform what appears to me to be *exactly the same kind of analysis* of the origins of biological organisms. A biologist might classify a feature as initially having no use or a different use, just like Cattani classified Corning's initial R&D in fiber optics. The methods of investigation used by technology historians and evolutionary biologists might be different and the investigation may be more or less trying, but it appears to me that whether they are aware of it or not, Mr Cattani's purpose, and Mr Gould's, are almost entirely the same.

In my view, the real value of Mr Cattani's article is that it points to an important pool of R&D that might have no initial purpose, or whose purposes initially lay elsewhere, but later provides the raw material for technology evolution. For scholars interested in the idea of technology speciation (Levinthal, 1998; Adner and Levinthal, 2002), this is an important issue because it helps us understand the process by which new technologies emerge. In Gould's language, this amounts to the concept of the ''exaptive pool,'' that is, that new species of technology sometimes emerge from a pool of unlikely origin. To see this, we need the kind of fine-grained investigation of the factors underlying technological speciation, of which Mr Cattani's article is an exemplar. It would be a loss for all of us if such excellent ideas were obscured by an unfortunate choice of words.

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