0333

The Wonder of Change:

Where do new things come from and how do they get here?

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1. So, where do new things come from?

First answer - from what is there already.

If we discard explanations based on special powers of creation from nothing, then anything new has to be based on what was there before.

A good example of this approach is provided by George Basalla (1988) who claims, "Any new thing that appears in the made world is based on some object already in existence." In support of this he tackles some tricky cases. The electric motor, for example, is based on two existing devices- the magnetic compass and the steam engine.

Basalla also discusses the transistor and shows that the first commercial transistors were regarded as improvements on the old style crystals which had preceded the thermionic valve. Literature from Bell in 1948 announced, "In the Transistor, two point contacts of the 'cat's whisker' or detector type, familiar to radio amateurs, are made to the semiconductor". The point contact transistor was soon replaced by the junction type but it provided an evolutionary link.

An essential part of Basalla's case is the continuity of all technology right back to the use of the first stones and flints.

> "Granted that every new artifact is based to some degree upon a related existing artefact we must next face the question of the first made thing. On what was it patterned? ..... a host of naturfacts could serve as models to initiate the process of technological evolution. There were rocks, stones, pebbles, sticks, twigs, branches, leaves, shells, bones, horns, and ..." p 50.

[He could have added birds' nests, suggested by Vitruvius as giving the idea of constructing shelters.]

Here I tend to agree; there are few counter examples. People like Usher (1929) have tried to argue that there are things called primary inventions which are really new. I find the case for the existence of primary inventions to be unconvincing. For example, Usher regards the railway as a primary invention. However, all the elements of the steam powered locomotive pulling trucks on metal rails have a previous existence. Stationary steam engines were used to pull trucks on rails before the steam engine was put on wheels. Rails have a long history. Steam engines evolved out of earlier hot air machines which were even known to the ancient Greeks (though they did not have much use for them).

I find it difficult to imagine something really 100% new. Whatever it is, it must be made of something and it must do something. If it did not look like anything that had ever been seen before and it did something that had not been done before, how would you know that it was an invention and not a heap of scrap? It was claimed by Francis Bacon that the ancient Greeks would not know what to make of a magnetic compass. However, they knew about navigation. They used the sun and the pole star to find the south by day and the north by night. Once they realised the the compass pointed towards the pole star, they would know what to do with it. There is a difficulty here, the evolutionary antecedents relate to use rather than hardware. This is one reason for treating evolutionary technology as part of human evolution rather than considering technology in isolation. New technology is sometimes linked to the past conceptually rather than mechanically. Thus electric fires are still called "fires" even though nothing is burning.

Basalla's continuity is of the strong variety. He is not talking about use or concepts. He is claiming that 'objects' provide the basis for new objects. This continuity is part of a four component evolutionary system consisting of 1. diversity, 2. continuity, 3. novelty and 4. selection.

In Basalla's four component system, the concept of continuity is the weak link. Just what does it mean to say that something is based on something else? Obviously, the intervention of a human mind is required; a mind capable of both imitation of what is there and of providing modifications to what is there in the hope of obtaining improvements.

Where do new things come from? 2nd answer - from what is there already by imitation and modification.

This answer divides into three, depending on the type of modification. Changes to what is there can be by accident, by design or by a combination of the two known as trial and error experimentation, 'suck it and see' or empirical testing. The possibility of accidental change due to errors in imitating is usually called Darwinian but it must be remembered that Charles Darwin did not know about genes and their mutation.

Long before 'mutation of the genes' had been thought of, some people appreciated that in Darwin's account there was an important role for accident as the source of 'modification'. The earliest attempt to transfer this idea that I have come across is by

Eilert Sundt, a Norwegian sociologist, who visited Darwin in 1862, three years after the publication of 'Origin' (Darwin 1859). Sundt then wrote an interesting paper but unfortunately for us, he wrote in Norwegian. Jon Elster (1983), a historian at the University of Oslo has translated Sundt and gives an account of what he describes as Sundt's 'quasi-Darwinian model of technical change'

Sundt's account of change in methods of building is -

> "Even when people who set up new buildings did not intend to deviate from custom in any way, it could easily happen that some small variation arose. This would then be *accidental*. What was not accidental, however is that inhabitants of the house and the neighbours should *perceive* the variations and form an opinion as to their advantages and inconveniences. And it is then not at all surprising that when someone later wanted to set up a new house, he would carefully *choose* that house to *imitate* which seemed to him most useful. And when the idea of improvement in a definite direction had first emerged, someone more clever could then take a further step and actually envisage and carry out another improvement." - from Elster (1983)

Sundt has a similar account of ship building, involving accidental changes, perceived improvements, choice etc. to which he adds the idea of experiment.

> "when the idea of new and improved forms had first been aroused, then a long series of prudent experiments, each involving extremely small changes, could lead to the happy result that from the boat constructor's shed there emerged a boat whose like all would desire."

This gradual series of changes comes to a stop when,

> "Each kind of improvement has progressed to the point where further developments would entail defects that would more than offset the advantage."

Elster describes this approach as leading to local maxima which have the problem that they can not be further improved without going through some kind of radical change or by becoming worse in order to become better in a different way. One answer to the problem of local maxima is the concept that evolution happens somewhere else. People who study fossils in cliff faces are sometimes surprised to note the absence of gradual change with transitions - a whatsit with two thingies is replaced by a whatsit with six thingies without any intermediaries - that's because evolution happens somewhere else and out of all the cliff faces in the world you are unlikely to be working on the one that has whatsits with four thingies. Once they had appeared somewhere, the six thingies variety were so superior that they spread round the world replacing the two thingies variety.

Another answer to this problem is the requirement for a change in the 'rules' of competition. People choose what to imitate and the reasons for their choice can often change. When this happens, a local maxima ceases to be the optimum and is replaced by something else.

Ideas about the importance of imitation accompanied by trial and error modification are not new. In fact, one of the earliest people known to have had such ideas was Vitruvius who wrote his "The Ten Books on Architecture" during the time of Augustus, the first Roman Emperor.

Vitruvius suggested that artificial places to keep out the rain must have started somehow. One possibility was that simple shelters in the woods were the first form of construction. In the words of one translation (Vitruvius 1914)

> "Some in the group began to make coverings of leaves, others to dig caves in the mountains. Many imitated the nest building of swallows and created places of mud and twigs where they might take cover."

These early people (Vitruvius called them 'the ancients') could have improved their shelters by experiment and by imitation. The first improvements could have been to strengthen those parts that failed in storms.
Vitruvius suggested that the ancients judged the success of their experiments on two criteria, the technical - did a building fall down in a gale; did it keep out the rain - and the aesthetic - was it beautiful or not; did people like it.

Trial and error led eventually to the discovery of something called 'the basic principles of architecture'. For example, Vitruvius claimed that the Doric order had emerged from the trial and error of carpenters leading to improvements in the use of wooden construction frames. In contrast, the Ionic order with its slenderness emerged through changes in taste leading to 'greater refinement and delicacy of feeling'.

Vitruvius added a third criteria- was it true to Nature? This seems to be a sort of test of its aesthetic value. Architectural historian, Mark Gelernter (1995), discusses a problem with using 'nature' as a yard stick for good form. This is the problem of which bit of nature do you pick. If you pick a well formed piece of nature then you have to have an idea of 'well formed' in advance of the selection.

For example, Vitruvius claimed that the 'ideal' human body fits into a circle with the navel at its centre (as popularised by Leonardo da Vinci.) This and other proportions were discovered by the 'ancients' who, according to Vitruvius, examined many examples of 'well shaped men'. The problem, as stated by Gelernter, is how did they know which men were well shaped and which weren't.

The theory of Vitruvius is very sophisticated and contains the basic elements of a modern evolutionary theory. According to Richard Dawkins (1976), an evolutionary system needs a replicator. In biology, the replicator is the gene, a stretch of DNA, which enables copies of itself to be made. The gene is not the only replicator; Dawkins points out that there must have been replicators before DNA - it did not appear from nowhere - and humans have a new replicator, the meme, an idea that is capable of being copied. Dawkins extends his discussion of memes and memetics in The Blind Watchmaker (1988)

My own version of memetic theory (Langrish 1999) has three different kinds of memes, recipemes, selectemes and explanemes and these three kinds of idea patterns can be seen in Vitruvius

First, we have recipemes - patterns of ideas about how to make things (in Vitruvius' case - buildings). These ideas are transmitted by imitation, starting with imitating nature. Then we have selectemes - ideas about what is a better building. Selectemes include not just criteria of efficiency but also what do we fancy. Darwin was aware that there was more going on than just improved efficiency. Hence his interest in things like peacocks tails which prevented the peacock from flying away from a predator but were 'fancied' by the females. The selectemes themselves are part of a changing system as Vitruvius noted with his suggestion that there had been changes in taste.

Recipemes tell you *how* to construct a building. Selectemes tell you *what* sort of building you want. Finally we have explanemes. Vitruvius attempted to explain *why* some things were better. His explanations of resemblance to nature and ideal proportions have been discarded showing that explanemes are also part of a system of change. Explanemes need a language for transmission. The ideas of Vitruvius were rediscovered at the time of the Italian Renaissance. This would not have been possible without a written language.

The memes - recipemes, selectemes and explanemes - all change over time. They also combine with other memes producing the new variety that is needed to fuel a natural selection system. The human abilities to experiment and learn from trial and error speed up the process of change but the focus of attention then moves to the selectemes. How do we know that the results of a particular experiment offer an improvement? Because we have an idea pattern of what we are looking for. This idea may turn out to be wrong as with the idea that faster air travel meant better which had to be modified after the Concorde turned out not to be better.

In the period before 1859 when Darwin published his 'Origin', many writers had ideas similar to those of Vitruvius. Some of these have been summarised by Steadman (1979). New things come from trial and error but where do the subjects of the trial come from? Imitation is one answer but that just moves the question further back in time.

Another source of new things is the sticking together of two previously separate recipeme streams. This may be by accident or by deliberate choice. In biology, this is known as symbiosis.

Where do new things come from? 3rd answer - from the union of two different bits of what is there already ie symbiosis - sticking things together to make something new.

The importance of symbiosis in biology has only been recognised fairly recently. The orthodox view of the origin of biological species is a branching phenomenon. A single species slowly becomes changed over time and if part of the species becomes separated from the main body, then again over time the separate group can become its own new species. This way of changing things is not appropriate for a general model.

Technological change and many other kinds of human change, such as language, do not form disconnected branches. A more frequently observable phenomenon is things joining together rather than splitting apart. This is why there are no technological 'species'.

After years of fighting the biological establishment, Lynn Margulis (1998) has popularised the idea that new forms of life can come into being by a combination of existing forms. This is not branching; this is symbiosis of two different life forms producing a new form. In her own words

> "That animal and plant cells originated through symbiosis is no longer controversial. Molecular biology, including gene sequencing, has vindicated this aspect of my theory of cell symbiosis. The permanent incorporation of bacteria inside plant and animal cells as plastids and mitochondria is the part of my serial endosymbiosis theory that now appears in high school textbooks. But the full impact of the symbiotic view of evolution has yet to be felt. And the idea that new species arise from symbiotic mergers among members of old ones is still not even discussed in polite scientific society." (Margulis 1998 p9.)

Her serial endosymbiosis theory suggests a four step origin of plant and animal cells with each step involving a different symbiotic merger. The details do not matter here; the point is that a form of evolution involving things combining instead of branching is now accepted as a possibility. Such events, of course, are quite common in the design of technology. Numerically controlled machine tools are an obvious merger of computers and lathes, each with their own histories. New sources of power tend to work through the available technology forming mergers with things that were there already. For example, power sockets in the home merged with both radios and clocks then someone put the clock and the radio together in one container. However, people did not seem to fancy clocks and radios in one box so they went their separate ways until very cheap digital time keepers found themselves stuck on to nearly everything. There are also less obvious cases of the mutual benefit of two separate histories coming together. Sky scrapers would not have been built without lifts (US elevators) but modern lift technology was developed in response to the new demand for fast reliable elevators capable of supplying a building of 60 or more stories.

One can even go back to Vitruvius for a possible example. Building construction might have started by the imitation of swallows nests but in practical terms this involved two separate lines of practice coming together. People used both wood and mud as building materials before they put the two together. A half way house involved strengthening the mud with straw to give a plastic material which hardens in the sun (used to make bricks in ancient Egypt, as described in Exodus 5.)

The results of such mergers still have to pass through the sieve of natural selection; they need selectemes in their favour. The process is still Darwinian and a Darwinian theory of change in design has room for new things emerging from mergers of existing things.

Where do new things come from?

Fourth Answer: From humans using their special powers of organisation, creativity, foresight and scientific understanding.

This answer divides into three - 4.1 In response to a need; necessity is the mother of invention. 4.2 From 'discoveries' made by creative individuals - scientists, inventors, designers or people like Leonardo who defy classification. 4.3 From organised human activity, 'organised' being used in the widest sense to include notions like innovation being the output of capitalism or the free market as well as the belief that new things come from the activities of design management, science policy, marketing or some other over-optimistic belief in the powers of human foresight, rationality and intentionality.

The next part of this paper examines some evidence relating to the credibility of the above answers.

Part TWO. Some Evidence

2.1 Evidence from case studies.

In the early 1970s, James Utterback (1974) reviewed eight different studies of successful technological innovation in different industries and countries. These included the Manchester 'Wealth from Knowledge' study (Langrish et al. 1972). Utterback's summary, Table 1, seems to show a remarkable consensus in that all the studies had a majority of cases stemming from organised attempts to meet a 'need', these needs being market need - the need of a customer, production need - the internal need of an organisation or mission need - the special case of Government deciding what is needed. The smaller proportion of cases, described as originating in technical opportunity, represent the discovery of something new, followed by attempts to find some use for it.

Table 1

Case Studies of Innovation - Utterback 1974.

Study	Proportion of cases, % from market, mission or production needs.	Proportion of cases, % originating in technical opportunity.
Baker et al	77	23
Carter & Williams	73	27
Goldhar	69	31
Sherwin & Isenson	66	34
Langrish et al	66	34
Myers & Marquis	78	22
Tannebaum	90	10
Utterback	75	25

At first glance, Table 1 looks like very strong evidence for the claim that new things stem mainly from intentional organisation of resources to meet a target. However, there are problems with this apparent conclusion. First, the figures are Utterback's own interpretation of the results of the eight studies and secondly they rest on the assumption that it is possible to identify a single starting point as the 'origin'. In fact, it is more realistic to say that all innovation needs both a technical opportunity (otherwise it would not be new technology) and a 'need' (otherwise it would not be 'successful').

Many of the cases included in the Manchester study (Langrish et al 1972 - 84 examples of technological change represented by innovating organisations that had gained the Queens Award to Industry for a named innovation) could not be accurately described as linear changes through time. In most cases, the history of the innovation could be seen as a coming together of different strands of technical development in a commercial environment that itself had different and changing strands. The 84 examples involved 158 key technical ideas of which 56 originated within the innovating firms and 102 from outside. The fact that nearly two key technical ideas per innovation were identified is evidence for the symbiotic view of change. New things emerge from a complex mixture of factors and the results of newness radiate in ripples, leading to further changes. Any simple lines of development or technological trajectories are in the eye of the beholder and not in reality.
The 102 external technical ideas were examined to look for evidence of British University input into British technological innovation. In fact, of the 102 ideas only 7 came from a British university and 17 from a British government laboratory (including Research Associations). (See the first column of Table 2.)

Table 2. Institutional Origins of Knowledge Inputs to British Industry.

Origins	% of 102 ideas	% of 396 references	% of 452 abstracts
UK Industry	22	10	19
UK University	7	6	1
UK Government	19	11	1
Other Industry	40	40	68
Other University	3	21	5
Other Government	9	12	6

The apparent conclusion that ideas from British Universities had little effect on British industrial innovation was challenged in a variety of ways. One of these was the claim that although industrial innovation may be based on industrial research, the day to day progress of industrial research depended on university research in lots of small ways rather than in the 'big' ideas. For example, industrial chemists spend time reading the results of university chemistry.

In order to test this 'small ideas' claim, seven review articles written by British industrial chemists were examined (Langrish 1972). These reviews contained 567 references to other publications (including patents). The institutional origins of 396 of the references were identified (references do not state where the authors come from; this requires finding the original publication.)

The second column of Table 2 gives the percentage breakdown of the institutional origins of the 'small' ideas, considered worthy of mention by industrial chemists writing a review. The figures are very similar to those in column 1, representing the 'big ideas'.

Column three of Table 2 gives the figures for a study of abstracts published by the Journal of the Society of Chemical Industry which showed even less attention being paid to the output of universities (Langrish 1978)
In other words the claim often made by university scientists that industrial advance rests on the back of university research is not supported by the evidence.

The route taken by the 102 technical concepts from outside to being used within the Award winning firm was examined. Conferences, visits abroad, reading all played a part but the most frequent route for successful transfer was inside the head of a transferring person. Useful technical concepts are not units like atoms; they are patterns and they are associated with other concepts. The successful transplanting of a technical concept requires some of its environment to be moved with it, rather like transplanting a seedling along with some earth.

So far, the discussion has centred on the origins of change. Looking at the effects of change can also offer an insight. If change is a rational process capable of being planned, then the outcomes of change should be predictable. If, however, innovations lead to many surprises then change might be more 'biological' since biological evolution is essentially unpredictable.

Carol S Goldstone (1976) looked at what happens some years after innovation. She used ten case studies, examples of technological change that had been awarded the Queen's Award for Innovation and previously studied as part of the 'Wealth from Knowledge" Study. Returning to examples of technological change, nearly ten years after they had been previously studied, enabled the outcomes to be compared with what had been anticipated. For example, the Procion Dyes, discovered and developed at ICI Dyestuffs Division had been one of the cases published in the Wealth from Knowledge Study. These new chemically reactive dyes for Cotton were discovered by Stephen and Rattee and Rattee's views were recorded in his inaugural lecture as Professor of Colour Chemistry at Leeds University. In this lecture, he claimed that the main effect of these new dyes would be to make it much easier to use continuous dying of large quantities of fabric. In fact, one of the effects was the exact opposite of this; it became much more economical for fashion conscious manufacturers to produce small quantities of brightly coloured cotton fabrics.

It therefore seemed possible to examine the outcomes of innovation in terms of anticipated and unanticipated outcomes. The outcomes could also be categorised in terms of desirable and undesirable.

Carol Goldstone's ten examples of change produced eighty effects, with a range from 4 effects for Doulton's innovation of ETC (English Translucent China) to ten effects for Plasticiser's development of fibrillation as a new way of processing polypropylene without infringing the ICI, Montecatini patents.

Of these 80 effects, 47 were classified as predictable and 33 as unpredictable. The effects were also classified as desirable, undesirable or neutral from the different perspectives of desirability to the innovating organisation and desirability to the rest of the world. Table 3 shows the results.

Table 3a . 80 effects of 10 innovations.

Desirability from company perspective.

	Desirable	undesirable	neutral	Total
Predictable	25	7	15	47
Unpredictable	14	7	12	33
Total	39	14	27	80

Table 3b . 80 effects.

Desirability from viewpoint of society.

Predictable	26	4	17	47
Unpredictable	8	4	21	33
Total	34	8	38	80

Such classifications are, of course, not easy to accomplish; the complex world of innovation does not like being divided into simple boxes marked desirable, undesirable or neutral. A further complication is that classification is time dependent. Innovations can move from being successful and desirable to being the opposite. For example, the Plasticisers innovation was commercially successful but the small family firm then over-expanded leading to cash flow problems and eventual take-over by another firm. However, the three Slack brothers who were Plasticisers Ltd, really liked inventing things and were presumably not too unhappy at having to sell. Over a much longer time scale, the desirability of effects may be seen in a different light. For example, at the time of the study, global warming was not an issue. Nonetheless, there is a pattern to these results which suggests:

1. More than 40% of the recorded effects of technological change were unpredicted
2. The unpredicted effects were twice as likely to be 'nice' effects as 'nasty', both from the perspective of the innovating firm and from wider society. (Though it must be noted that no attempt at quantification was made. In principle, one very large unpredicted result could outweigh 20 minor ones)
3. For the present paper, the most important point about this study is that it offers no support for the view that technological innovation is, or even could be, a 'rational' process with decisions being made on some kind of cost benefit analysis of the future.

2.2 Evidence from a study of how designers make decisions.

The individual designer is more than just a maker of accidents. Changes in recipemes are not just random mutations; they have intentionality but the intentions have to fit into the changing complexity of everything else. Today's sensible decision can be tomorrow's disaster but designers have to make a living by making decisions.

Maria Abu-Risha (1999) observed and talked to designers at work, asking them question like 'why did you choose this particular picture to go on the cover of the brochure?' The answers were of the form, 'Well, it felt right" or 'its intuitive" or "I just knew". At the same time, the designers were very well informed about their clients preferences, the state of the market, what other designers were producing and so on. These ideas are not worked out like a physics equation; they form a 'pattern' in the mind, what Maria Abu-Risha calls a 'pattern of need'. In my thinking this a pattern of selectemes.

At the same time, decision makers have other ideas, concerning things that are possible, ideas about how to do things - recipemes. These form a pattern of possibilities which is compared with the pattern of need until there is a 'click' - a fit between the selectemes and the recipemes (see explanation of terms in answer 2 above). Maria Abu-Risha calls this 'click' Purposive Pattern Recognition, PPR. It is purposive because once the 'click' has been obtained, the decision maker knows what to do next.

The long sweep of design history is the result of countless individual decisions about what to make, how to make it, what to buy etc but at the same time these decisions are influenced by the long sweep. A similar problem exists in economics, traditionally divided into micro and macro economics; both are concerned with the flow of money; both affect each other giving rise to complexity which defeats attempts at forecasting. I f economics is complex, when we add other systems - political, social, fashion etc the result is so complex that it seems to defy description. And yet, individual designers, manufacturers, purchasers etc still seem to be able to make decisions.

2.3 Evidence from a mail order catalogue.

Erica Wright (2005) used the images and words in the Littlewood's mail order catalogue to provide data for investigating change in the appearance of mass produced objects between 1932 and 1980. This provided a quite different perspective. Individual designers and innovating firms are hidden from view beneath the relentless publication of pictures of objects for sale. These pictures change over time and a careful analysis revealed some interesting features:

a) There was evidence of a cyclical pattern of change. An earlier study of adverts (Langrish 1982) had shown that changes in design mirrored the stages of the Kondratiev 55 year cycle with its four stages of recovery, prosperity, decline and depression. This same pattern was revealed in the mail order catalogue. This may be interpreted as a cycle of selectemes with a period of economic prosperity favouring streamlining, reduced decoration etc and a period of decline favouring reproductions of older more decorative fashions.

b) Erica Wright claimed to see evidence for an evolutionary pattern in the catalogue. There was no evidence for 'progress'. Some designs survived in the catalogue and some vanished.

c) Support was claimed for the Zhavis' (1997) handicap principal which explains why some surviving designs can be described as 'sexy' rather than efficient or functional. (As noted above, Vitruvius had similar ideas)

d) Both cyclical change and natural selection can be incorporated into a model in which designs compete within a cyclical socio-economic climate.

3. Conclusions.

There is little evidence to favour some well known assumptions. The wondrous process of change is not reducible to some simple linear process, capable of planning, forecasting and management (though humans being human, they will continue to try).

Technological innovations are not applications of discoveries made in university science departments. Nor are they things that appear from nowhere as a result of individual genius.

The emergence of new things from what is there already happens in a way best described as a memetic process of Darwinian change. This is explained more fully in a recent paper (Langrish 2004)

We need to be much more modest in our beliefs that intentionality, rationality, reason, scientific understanding, good design and so on can lead to better things but we have to keep trying. Faced with the twin uncertainties of knowing what might be better and how to get it, future work will look at ways of providing some guidance to those who have to make decisions. One line to be explored is the importance of emotion in the workings of the brain. The work of neuro scientist, Antonio Damasio (1994) and others could help us to do a little better than saying, 'we just knew it was right'.

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