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ABSTRACT

Three fundamental systems of communication are defined: information, explanation and imagination. Information is based on analytic distinctions between objects in the world. Explanatory communication provides knowledge through discourse, narration, logic, rhetoric and other forms of systemic elaboration. Intellectual discovery relies on a third system of communication, that of imagination. Rather than distinction or elaboration, imagination is rooted in intuition and analogy. The most powerful medium of the imagination is antonymous insight. The article discusses examples of the latter from warfare, politics and science.

Keywords: Information, Analysis, Knowledge, Discourse, Imagination, Antonym

Three Systems of Communications

There are three fundamental systems of communication: information, explanation and imagination (see Table A).[1] The first system of communication—*viz.*, information—is analytic in nature. It relies on the drawing of distinctions and the parsing of differences between objects in the world. This allows us to identify objects in the world and attribute characteristics to them. In doing so, we separate out elements of the world, and we isolate and define their specific features. Such analytic distinctions are very powerful. Yet their strength, which is their capacity to distinguish objects and attributes, is also their weakness. They are, by their nature, limited in their connective force. For what distinguishes does not connect. In analytic forms of communication, we are limited to connecting object and attribute, name and quality. That is more or less as far as it goes. It is rather the second system of communication that connects the propositions we make about the heterogeneous elements of the world. This system of communication takes the names and descriptions, the analytic reports and statements that we make, and weaves them together. This second system of communication is commensurate with knowledge in the full sense of that word. Knowledge as a system of communication involves more than information. This is true no matter how sophisticated the analytic distinctions we draw may be. Knowledge proper requires communicative operations such as inference, argument, explanation and narration. Knowledge is discursive. It involves the moving from one act of cognition to another in a systemic "chain" or "train". It involves our capacity to reason. However, just as information has its limits, so does reason. Whether we explain, argue, or narrate things, all discourse reaches a point of diminishing returns.

Discourse and reason knit observations, reports, analytic definitions, data and statements into lucid structures whose "chains" persuade us, but only ever up to a point. All kinds of discursive knowledge, including scientific, technological, legal, political, social, and aesthetic knowledge, reach a limit at which point they cease to satisfy us. We are left feeling that the explanation or narration is not adequate, however elaborate it may be. This is the point at which arguments run out and proofs appear to be unprovable. At this juncture, knowledge stagnates. How then, when faced with such conditions, is knowledge advanced, developed or kick-started? The invigoration of knowledge happens because of acts of imagination. Imagination is synthetic, not analytic.[2] It relies on intuition, analogy, and the ability of creating resemblances between things rather than drawing distinctions. Analogical-synthetic acts of imagination overcome the periodic stagnation of the discursive system of communication. Imagination plays the central role in audacious kinds of problem solving, visualisation, projection, anticipation, and creative thought.

System	**Information**	**Explanation**	**Imagination**
Cognitive Style	Analytic	Elaborative	Antonymic
Cognitive Media	Proposition	Argument	Analogy
Cognitive Method	Observation	Reason	Intuition
Cognitive Outcome	Differentiation	Inference	Resemblance
Communicative Form	Report	Discourse	Wit
Cognitive Function	Distinction	Knowledge	Creation
Table A			

Information, Explanation and Imagination

We all begin life in a blur. The most important thing a child learns is to distinguish things (objects, words, events, deeds). The child learns how to differentiate "mother", "father", "food", "toy", "flower", and "car" from the primordial smear into which we are all born. Our first communicative acts are also our first way of systematising the world for ourselves. These acts are principally acts of *distinction*. We use them to carve up the world, to differentiate and distinguish one thing from another. With the passage of time acts of distinction grow more sophisticated. The same occurs also on a social level. Immanuel Kant, in the *Critique of Pure Reason,* made the point that acts of distinction rely on a more fundamental cognitive unity.[3] Every object that is differentiated out from the experiential smudge of sensibility has its own spatial and temporal unity. Kant attributed that unity to the working of the human mind. The mind's synthesizing function gives every distinguishable thing its "object-ness". Consequently and paradoxically, analysis relies upon a prior synthesis. Conversely without the analytic capacity to differentiate, the world would appear to us as a blur of impressions, each swamping the other. To distinguish one impression from another, the mind differentiates impressions temporally and spatially, such that they cohere as objects.

In growing up, a child learns to recognise distinct spatiotemporal objects, to name them and characterise them. The child comes to recognize, name and characterise an innumerable number of such objects. Thus to make sense of the world, the child first has to make distinctions. Parents point to and name objects. Then those objects are given attributes. "The flower is red." The world in this way is broken up into discrete entities. Flowers are distinguished from cars, and cars from people. Qualities and characteristics of objects likewise are separable. Colour is distinguishable from shape. The child learns terms for the solidity, extension, motion, number, and figure of objects along with the names for their colour, taste, smell, and sound. Thus starts the child's long journey through the world of information. Names become ever more sophisticated, and attributes ever more abstract. The flower is broken down into stigma, style, stamen, filament, and petal; qualities are specified as beauty, symmetry, dynamism, and so on. The most sophisticated societies have specialised institutions that coin names and attribute qualities. Finer and finer distinctions are created. More and more terms, both arcane and popular, are generated. This coinage happens in laboratories and astronomical observatories, in newspapers and learned societies, and spontaneously in everyday conversations and discussions. Life is an endless process of naming and characterising. What occurs in and through this process is human judgment. When we name and describe things, we judge them. We judge their everyday significance, their moral import, their aesthetic nature, their utility, their hedonistic quality, and so on. In doing so, we identify the parts and qualities of the world that are important to us.

The most sophisticated descriptions assume that some part or element or quality of the world affects and changes some other part, element or quality. In some cases, this means that the part, element or quality A *causes* the part, element or quality B. The event "photosynthesis" for example causes the tree (object) to grow (quality). Most descriptions of this type though are not strictly causal. Rather they suppose some transformative correlation between A and B. In some degree, A affects B. A is an agent that changes in some respect, though not necessarily always, the qualities of patient B. A thus determines, influences, shapes, governs, establishes, disturbs, moves or otherwise has an effect on, either regularly or intermittently, B. We name B, we characterise A. Having drawn such distinctions, the instinct of reason is to bring together what has been set apart. Thus while the world is apprehended as a massive array of distinct names and features, the human mind seeks to establish patterns of connection between the parts, elements and qualities that it has teased apart.

The child that absorbs information, and learns to make judgments, is also the child who asks questions. The most important of all questions is "why?" Human beings not only name and describe the qualities of the world; they also search for explanations as to why the world is in the state that it is. "The tree has grown," the parent observes. "Why?" asks the child. Answers to "why" questions suppose that statements ("A *is* B" or "A *affects* B") can be woven together. We arrange statements into explanatory discourses. We give reasons for our statements. We do this when we reason, argue, and recount. We deploy logic, rhetoric or narration, depending on the circumstance. Discourses, whether in the arts and sciences or in everyday life, are shortcuts. If we assert that "all persons are mortal" and that "John is a person", then we conclude that "John is mortal" thereby avoiding the tiresome bother of considering every person individually and deciding on whether each one is mortal or immortal. But such short-circuits, helpful as they are, have first to come into being. There was a time when the statement "all persons are mortal" did not exist. For it to exist, human beings had to be able to imagine themselves as human beings. The statement "all persons are mortal" tacitly assumes that we can imagine a species. It supposes that we are not just part of a tribe (a genus) distinguishable from another tribe (a genus). Similarly it assumes that we are able to separate the species of human beings clearly from other animals and from the gods. This has not always been the case. To reach that point we had to doubly equate our being both with other human beings and with mortality. We are the creature who dies and yet who does not die. We share mortality with animals but possess a "soul" that is immortal. The term "soul" is not commonly used today, but the conception of being human invariably conveys a sense of human works or acts that outlive their creators. The point here is not to debate the nature of the human being or whether there is a common humanity. Rather it is simply to indicate that even seemingly commonplace principles of reasoning that allow us to draw rapid-fire conclusions from information to hand have their origins neither in reason nor description but in the imagination. The principles of reasoning interpolate complex equations and metaphors that neither descriptions nor explanations provide in their own right.

Descriptions and explanations of the world are very useful. We rely on them enormously. For many or most purposes, they work for us. But descriptions and explanations also fail us. It is then that we turn to that rarer cognitive faculty, the imagination. To understand the imagination, let us compare this faculty with the faculties of analysis and reason. The word "comparison" itself is telling. It points to the instinct of cognition to compare A and B. At the level of description, comparison serves the function of distinction. It lifts each of us out of the primal blur. The "cat" is distinguished from the "mat" when the parent says to the child "the cat is on the mat". In this manner, the child is taught how to relate things together by distinguishing or separating them. Like many of the operations of the human mind, this is paradoxical. When the parent says to the child, "the cat has destroyed the mat", a causal connection of a certain kind is made. The child learns that agents (a cat in this case) affect, influence or determine various patients in the world (a mat in this case). When the child hears this from the parent, it may very likely ask "why did the cat do this?" This will elicit all kinds of realistic and fanciful explanations from the harassed parents. We ascend from curt explanations to expansive rationales and elaborations. Stories, parables, justifications, defences, arguments and debates emerge from the explanatory impulse. With sophistication come formal characteristics and structures of explanation. Logic, rhetoric, and narration all have forms both strict and flexible. But the world is more complex than can be comprehended either by descriptions or explanations. A child growing up in a hypothetical world of pure description/explanation would be intellectually impoverished. Take for instance the case of emotional education. If the child has taken to bullying the cat, the parent steps in and says "stop treating the cat like a mat". In that kind of simple statement we can observe the origin of the arts and sciences, and the via media of the imagination. The parent intervenes to stop the child's cruelty by telling the child that it is treating the cat "*as if*" it was a mat. The child (in effect) is walking all over the cat, figuratively and literally.

The imagination detects unlikely resemblances. The faculty of observing "as if" is very powerful. We hear, see, taste, and feel "as if" A was B. In analysis, we separate in order then to connect, for example, the colour red and the shape of the automobile. In the most sophisticated descriptions, we observe that one thing analytically distinguished (A) changes another thing so distinguished (B). The ignition of fuel sets the automobile in motion. In contrast, the primary function of the imagination is not to distinguish A and B. Rather it is to connect A and B. The most potent acts of imagination occur where the distinction between A and B is ordinarily thought to forbid a connection between the two. Most imaginings fall short of this though. Take the case of the "red automobile". The colour red in many cultures is a signifier of aggression. To "see red" is a metaphor for anger. This probably has a part physiological basis. In the psychology of colour, red is a "hot" colour that "advances" toward us, rather than a "cool" colour that "retreats" from us. The string of metaphors, as distinct from the chain of reasoning, brings us to connect the vehicle that moves forward fast with the colour red. Even if there have been millions of red cars in existence, there was once the first red car. That paint job was imaginative, though only mildly so. The connection of red with speed, thrust, dash, momentum, and so on, has a long history, so that such a metaphor was hardly startling. The greatest metaphors, though, *are* startling. In and through them, the imagination draws together that which seems to be very far apart and yet somehow makes the connection plausible. Things that are thought unlikely to be connected (notably opposites) come, via the imagination, to have a probable or perceivable bond. Often this occurs in defiance of reason in the ordinary sense. It usually involves a tacit but nonetheless far-reaching re-description of the world.

The most powerful descriptions of the world are metaphors. Conversely, every description or re-description of the world is also, potentially, a practical intervention in the world. Description and action share two things in common. One is susceptibility to reason; the second is susceptibility to metaphor. Susceptibility is not the same as actuality. That means that reason and metaphor can transform what we say and do, but do not automatically do so. Reason and imagination are acts performed on propositions and deeds. Thus when we devise or decide our deeds, we are able to use practical reasoning to appraise what we are about to do. We do not always do this, but we sometimes do it. In operational decision making, we reason "if, then". If we do A, organize B, and follow step C, then we can achieve X or Y. Underpinning this are tacit syllogisms about the world. Yet what we plan rationally does not always happen in reality. When it doesn't, we can refine the inferential calculus of both our plans and our syllogisms. Notwithstanding that, all reasoning has a limit. We can go so far and no further when we reason practically. This is not just because the world is more complicated than we can comprehend in either our plans or our deductions, though that is partially true. It is also because operational "if, then" reasoning depends tacitly on syllogisms whose major ("all birds have feathers") and minor premises ("penguins are birds") are also descriptions of the world and these descriptions can fail us. They can fail us in a variety of ways. Sometimes they cannot pass the test of induction. That all birds can fly is not true, nor is it true that all flying animals are birds. The ostrich and the penguin cannot fly. Bats are flying mammals.

But the human world is not only empirical; it is also metaphorical and symbolic. Thus we act and intervene and organize not only on the basis that A *is* B but also that A *is like* B. In such cases, B is not simply a description of A. Rather B resembles A. Such resemblances are paradoxical. They are most compelling not where A is most similar to B but where subject A and predicate B are most dissimilar and yet are still undeniably like each other. Thus, in this manner, human beings can have avian characteristics. From the Penguin character in the *Batman* cartoon to the Crow people, the American Indian Nation, to various basketball, skateboard and football players, to the participants in competitions for home-made gliders and human-powered air-craft, bird-men abound. This is not an exception nor is it unusual. The capacity for distinct entities to be both similar and antithetical lies at the core of human culture. It is the protean basis of mythology. Innumerable kinds of angel-horse, ape-man, human-demon, human-horse, dog-bird, bird-mammal, human-lizard, crocodile-fish, dog-wolf, fairy-dog hybrid creatures exist in mythologies undergirded by elementary antonymic thinking. Comparable thought structures are found in philosophy, literature and science. The antonymic structure is the latent structure of imaginative thought and is a common thread in all acts of human creation. It is a durable structure that insinuates a specific kind of change at its heart, the *switch,* as for example between human and demon.[4]

Practical Reason: From "If, Then" to "As If"

Our most powerful descriptions thus do not simply characterise something but rather they indicate that one thing shares in the characteristics of another thing. It is not only that she smiles but that in addition her smile is like sunshine. The further apart and more dissimilar two things are, such as smiling and sunshine, the more evocative and compelling is the metaphor that draws attention to the way in which those two distant things resemble each other. The most interesting metaphors and symbols are those that make similar what is dissimilar. Like everything else in the world, attempts at metaphors and symbols can go awry or prove inadequate—just as our deductions, inductions, and plans do. All play a part in practical reason and each can fail.

Warfare is a good example of the limits of practical reason. While in hindsight there was evidence that it was coming, no government predicted the attack on Pearl Harbour in December 1941. Even the preternaturally foresighted Winston Churchill told his Defence Committee as late as October 12 of that year that he "did not believe that the Japanese would go to war with the United States..." This was a rational assessment. It was based on the rational maxim that *if* Japan went to war with the United States, *then* Japan would be defeated. That maxim proved in deed to be true. The problem with rational maxims in war, though, is that an enemy may not be rational or may not observe the same rational maxim. In the case of Pearl Harbour, as one historian of World War Two has put it, the views of the British and American governments in their assessments of Japan's war plans were "distorted by logic".[5] Both governments "possessed strong intelligence of an impending Japanese assault. Yet it remained hard to believe that the Tokyo regime would start a war with the United States that it could not rationally hope to win" (Hastings: 205). Logic is very serviceable in practical matters. But it has its limits, all the same. It is at the limits of logic that the imagination comes into play. Imagination allows us to see that in a logical game an opponent may behave illogically.

Churchill was an exceptional war leader precisely because he could, and frequently did, qualify logic with acts of imagination. He possessed a remarkable imagination evident in his inexhaustible wit and literary facility.[6] Churchill was a master of the antonymous political phrase. Endless numbers of these pepper the fifteen million words he composed in his lifetime. These voice everything from existential irony ("The glory of light cannot exist without its shadows") to military realism ("To try to be safe everywhere is to be strong nowhere") to historical paradox ("The longer you look back, the further you can look forward").[7] Some of those who worked with Churchill at high levels in the hot-house of war-time government complained in their private diaries of Churchill's flights of fancy. Yet precisely fancy, Churchill's "jets and gusts of image and association" (Nicholson, 1940), accounts for why he became possibly the greatest political leader of the modern age. He is certainly in a tiny class of remarkable leaders of enduring importance such that though he roused and led a nation, his example is universal.[8] While he was at the helm of Britain at war, he acted on the stage of world history and ultimately became a model that transcended both his own nationality and his own era.

As a war-time leader, Churchill was always careful to balance and check his fancy with the rationality of government. He had pet projects, but he made no major strategic decision during the war without the approval of his generals. Yet he did wear out his subordinates with an endless stream of ideas, which accounts for much of their grumbling. That in itself is striking. It suggests that compared with more prosaic reason, imagination has a greater wear and tear on the mind. Its aerial "leaps", to use the common metaphor, have a gut-turning quality that seems as much as anything to elicit irritation in those contemplating the raw output of the imagination. In its tidy version, wrapped up as the history of great ideas, it is domesticated and safe. The historian places the imagination at a comfortable distance. Up close and personal, it is much more intimidating and confronting.

Imagination comes into its own when reason fails. Reason most often falters in times of emergency. By all of the dictates of reason and logic, Britain should have been defeated by Germany before the United States entered the war in late 1941. Britain's land armies were inferior to those of Germany. Its air force was smaller. British production of war materials lagged behind Germany's industrial power-house. Yet Britain was not defeated. This was because of Churchill's mystical faith in the destiny of the island nation. Such faith was not irrational, but neither was it just another species of rationality. Churchill was not a visibly religious person. Puritans and dogmatists irritated him. All the same his writings are filled with a subtle kind of deist imagery. The appeal he made in one of his great speeches in 1940 to the "sunlit uplands" is typical of this.[9] The image is domestic and majestic at the same time. Churchill's strategy to resist invasion successfully until America could be induced to enter the war was rational. But the faith he embodied, his faith in the fortitude of a people to resist and survive, trumped the even more daunting logical reality that Britain could not withstand invasion by a more powerful enemy. Churchill told the British public that faith "is given to help us and comfort us when we stand in awe before the unfurling scroll of human destiny."[10] In the abyssal years, from 1940 to 1942, faith defied what reason supposed—that defeat or surrender was in the offing. It is not the case that the Battle of Britain, the struggle for supremacy in British air space, was won by faith and not reason.[11] Rather it was won by a collective imagination that united faith and reason. Churchill, the personification of that imagination, paid scrupulous attention to the most practical and intimate details of war planning. He was a gifted organizer of systems, and was able to shake recalcitrant government ministries into action. Before the First World War as First Lord of the Admiralty, he gave the British navy a general staff planning capacity for the first time in its history. As Minister of Munitions in World War One he radically overhauled the production logistics for provisioning the allied armies. He pioneered the idea of an air force and agitated for the development of the tank. All these efforts, like his later war prime ministership, relied on a mastery of operational logic. Yet they equally required imagination.

The invention of the tank neatly illustrates the relation between "if, then" (logic) and "as if" (imagination). As the nineteenth century advanced it became clearer that *if* science could be applied to the battlefield *then* warfare could be industrialised. That logical-operational frame was easy enough to state. Bringing it into reality, however, required imagination. Where logic is sequential or methodical in nature, imagination is antonymic. Accordingly the tank was an "armoured tractor". It combined or hybridised the agricultural machine and the military function. Various conceptual and production prototypes of the tank appeared in the nineteenth and early twentieth century. James Cowen proposed the idea of a "steam tractor with cannon" at the time of the Crimean War. The British government rejected it as impractical. The British engineer David Roberts in 1904 through 1909 developed various prototypes for the British army of a "tractor on caterpillar track" though never included artillery with it. The Austrian engineer Gunther Burnstyn took Roberts' idea a step further and in 1911 designed an "armoured tracked vehicle". The Austrian government declined to offer him a contract to put the machine into production. The Australian Lancelot De Mole proposed a "chain rail vehicle" to the British War Office repeatedly through 1912-1917. The French Colonel Jean-Baptiste Eugène Estienne in 1914 advocated for the "armoured car" idea, the militarization of the automobile, which proved unsuitable for rough terrain. In 1914 Major Ernest Swinton, Britain's official war correspondent, argued an idea for an "armoured tractor" first suggested to him by his friend the South African engineer Hugh Merriot. Swinton's proposal for the armed tracked vehicle was made to Lieutenant-Colonel Maurice Hankey, Secretary to Britain's War Council. Failing to interest the Army in it, Hankey sent a memorandum to the Committee of Imperial Defence, on which he also served as Secretary, where it caught the attention of the First Lord of the Admiralty, Winston Churchill.

Churchill, who spent a life-time ignoring departmental boundaries, convinced the Prime Minister of the day, H.H. Asquith, of the merits of the idea. In the face of the continuing disinterest of the Army, Churchill created a "Landships Committee" in his own department that set the practical development of the tank in motion. Churchill's antonymic coinage, the "landship", was yet another classic antinomy on the road to the practical invention of the tank. Churchill's proposal to Asquith contained the core conceptual elements of the tank as a working artefact: an industrial tractor using the caterpillar system and incorporating an armoured bullet proof shelter and guns.[12] In February 1915 Churchill commissioned the Director of Naval Construction, Eustace D'Eyncourt, to design a land-ship, dubbed for secrecy purposes a "water-closet" and then a "water-tank". While Churchill was not responsible for the genesis of the tank-idea, he was responsible for its final development. After the war, the Royal Commission on War Inventions concluded that "it was primarily due to the receptivity, courage and driving force" of Churchill that the idea of using the tank as an instrument of war "was converted into a practical shape".[13] Churchill's receptivity and drive were a function of his imagination. He had no difficulty in the slightest picturing the combination of military weaponry and industrialised agricultural machinery, or in imagining the usefulness of such a machine in crossing rough terrain and trenches. In a memorandum to the British Cabinet late in 1916, while he was serving as an officer on the Western Front, Churchill wrote memorably (with allusions to Homer) of a "collective metal shield" pushed along on a caterpillar capable of traversing obstacles, ditches and trenches. That same period, keen to discover any way he could of shortening the war, found him also speculating about "torpedoes fired from seaplanes".[14]

The Antonymous Imagination

The imagination at its peak is antonymous. It embraces microscopic intimacy and macroscopic publicity. It interpolates opposites. It forges connections and analogies, bonds and metaphors between things like reason and faith that seem on face value so far apart. If one looks at the great period of twentieth century science, dating from 1900 to 1930, it is one of the notable characteristics of the period that the antonymous imagination is given free reign. This reminds us of the similarly antonymous era of the High Renaissance, even though its twentieth-century counterpart was much shorter lived. European science between 1900 and 1930 is filled with marvellous antonymous ideas about space-time (Einstein), matter-energy (Einstein), position-momentum (Heisenberg), and wave-particle (Bohr). This distantly mirrors the flood of paradoxical imagery that courses through Shakespeare's writings. Whether it is reflecting on the "heavenly comforts of despair" or observing that "in poison there is physic", Shakespeare repeatedly, doggedly, and seemingly effortlessly, draws on the quantum nature of the imagination.[15] Particular historical epochs encourage such thinking. Shakespeare lived in a time of fierce imaginative contrariety. Donne, Montaigne, Paracelsus, Pico, Bacon, Castiglione and many others approached the world in a similar manner. To assert that by human deeds "sweetest things turn sourest" was natural.[16] In such locutions we reach the limits of language. We communicate what is beyond communication. In doing so, we arrive at the ultimate vocation of communication.

Understandably what is ultimate in communication is rare. Certainly it is rare for communicative contrariety to become a pervasive feature in art and science. This is what makes the late Renaissance so creative. We see a short burst of the same in the early twentieth century. Then it peters out. The antonymous imagination retreats after 1930. The tyrannies of the 1930s signal this retreat rather sharply. It is striking that the final entry in Alan Lightman's collection of outstanding twentieth-century science documents dates from 1972. Even allowing for a certain passage of time before great ideas are broadly recognized, the record of the latter two-thirds of the twentieth century is thin. Lightman's collection includes 25 papers.[17] Four are from the first decade of the century, four from the second decade, and five from the 1920s. Then the numbers decline: three from the 1930s, one from the 1940s, two from the 1950s, five from the 1960s, one from 1970s, and none after that.[18] We have reaped the harvest of the seeds that we have sewn. Despite its omnipresence, information technology failed to match the depth of innovation on the Promethean scale of electricity or the automobile (Cowen, 2011; Murphy, 2010a, 2010b). Over the past twenty years, in real terms the returns on each research investment dollar have shrunk. Telecommunications, pharmaceuticals, advanced materials, alternate energy and bio-technology are all yet to fulfil their 1990s promises.[19] Without the impetus of antonymous discovery, team-based big science suffered as much as individualistic fine art did in the dismal post-modern era.

The economist Tyler Cowen (2011) suggests that this declining rate of return is of an even longer historical nature. He argues that "it was easier for the average person to produce an important innovation in the nineteenth century than in the twentieth century... Meaningful innovation has become harder, and so we must spend more money to accomplish real innovations, which means a lower and declining rate of return on technology." This is consistent with the observation in Murphy 2010a and 2010b that the peak of European science and technology (and also the arts and humanities) is 1870, a point made separately for science and technology by Cowen. Cowen is correct when he observes that major technology gains were made in nineteenth century principally by amateurs while increasingly smaller gains are made today by institutionalised experts. Even then, Cowen further notes that we have exhausted the mid-range gains made by expanding the education systems that produced the first generations of highly-qualified scientists and technologists. Underlying this is the more basic fact elucidated by Cowen that most contemporary innovations bring only slight additional benefits to the majority of the population quite in contrast to the waves of innovations from the 1880s to the 1940s such as electricity, electric lights, automobiles, aeroplanes, pharmaceuticals, mass productions, the phonograph, tape recorder and radio. It might be concluded from this that after the creative peak of 1870 a series of applications and elaborations of creative science occurred through the 1940s. Beyond that point the long-term effects of a declining collective imagination begin to become clearer to the observer. Both the rationalism and the irrationalism of the twentieth century play a part in the drying up of innovation. The innovation lobby also plays its part, because it believes it can detach innovation from basic discovery. Once creation falters innovation then declines or else it becomes directed to frivolous ends. Once this happens, income and wealth creation, which is dependent on ever-more inventive waves of industrialisation, begins in a relative sense to shrink.

The title of the most famous twentieth-century work on the method of science, Karl Popper's *Logic of Scientific Discovery*, signifies part of what went wrong. It was first published in 1934 as the *Logik der Forschung* at the very turning point as the short period of titanic twentieth century science ebbs. This book, along with the rest of Popper's works, is a brilliant statement of the power of discursive rationality set against the tacit background of tyranny. However, discovery is not discourse. It does not matter whether discourse is conceived as refutation or as justification. Either way, discovery cannot be explained in terms of explanation. A discovery precedes logic. It comes before argument. It is an artefact of intuition or insight. It is not communicated through explanatory forms, irrespective of whether those forms either serve to defend the truth of propositions or criticise their fallibility. The propositions of discovery are ingenious contradictions more than anything. They are true and false, positive and negative, affirmative and critical in the same instance. They are, as Neils Bohr put it, "complementary", or, as Bohr's sometime assistant Heisenberg conceived it, "uncertain". In a word, they are antonymous.

The crises of the early 1930s and the rise of the European dictators were part of a larger crisis of collective imagination. The tyrannies caused a fierce effacing of imagination. But once their paroxysm was expended, other duller sanitizations occurred. Reason recovered its faculties after the totalitarian era but less so did the imagination. The embarrassing epistemologies of the post-modern decades (1970-2000) signalled both a widespread unease that reason was not enough and a simultaneous failure to specify the other of reason in other than irrational terms. The net consequence of this was an over reliance on pedestrian reason. This proved perfectly proficient for many purposes excepting when insights of imagination were required. This begs the question, though, of why is it that reason is not enough? The answer, simply put, is that reason supports or refutes conjectures but it does not produce them. If profound conjectures that touch on the ambidexterity of reality are not generated, then, although science will continue to rationally extrapolate from known premises, the production of new constructive axioms and thus new rich prolific fields of inquiry will elude it.

There is a second reason that reason is not enough. This second consideration points to reason's self-contradictory propensity to undermine itself. The voice of reason is normally accompanied by an implicit claim of universal validity.[20] In practice, there is almost always a second and dissenting voice of reason in any discursive situation that in response says "Not me, I disagree". The philosophical character of reason has great difficulty reconciling the fact that whatever courts assent encounters dissent and whatever begins in dissent invariably makes statements that demand assent. The demand for assent has many overtones. Some of those overtones are distinctly domineering. However it is articulated, reason always makes a truth claim upon others, and, as a claim, it bears the unmistakable character of an "ought, should or must". It is difficult to ignore even the most courteous claim to truth. A claim demands something of others. Even the politest request to assent is a type of pressure. Other kinds of insistence on “what is reasonable” can be overbearing.[21] Conversely, though, the dissenter who dissents against this imperious assent in the name of some kind of standpoint outside of universal reason (usually some kind of irrationalism, however it may be dressed up) simply inverts the game of pressure without eliminating it. The voice of what is “not universal” either presumes the assent of others or else dismisses such assent as irrelevant: either way this is an arrogation that is the first step on the royal road to dictatorship. Under these conditions, criticism and critique end up generating the most despicable kinds of punitive orthodoxies.

The philosophical character of the imagination in contrast to that of reason assumes an ironic standpoint. Imagination treats assent and dissent as equipollent. Conceived from the always incongruous standpoint of the imagination, dissent generates assent and assent creates dissent. From a certain perspective, these opposites are identical. The imagination is antonymous. It makes a side-step around the often suffocating pressures of reason, irrespective of whether reason is confirmatory or critical. The imagination conjectures. It does so by conjecturing a paradoxical union of opposites. This might take the form of mythological bird-men, technological land-ships or the time-space and position-momentum of the physicist. At the point when the cognitive capacity to make opposites identical dries up, the sciences, as much as the arts, begin to falter. That is what in retrospect we see happens in the latter two-thirds of the twentieth century. The tyrannical era of the 1930s in Europe is a visible turning point. The restoration of reason after the defeat of the tyrannies though proves to be no augury of the imagination. The slackening of imagination becomes apparent by 1970. The post-modern era lasting from 1970 to 2000 is lacklustre in both the arts and the sciences.

A small resurgence of intellectual energy took place in the 1980s (Murphy, 2010a; 2010b). But this exhausted itself quickly by the end of the decade. One, somewhat comical, sign of this exhaustion was the subsequent rise of national research management schemes in the United Kingdom and Australia.[22] These schemes were an unconscious response to falling real levels of discovery. It is as if the bureaucratic auditing of research performance became a substitute for audacious research and a palliative for latent national anxieties that high-level discovery in the arts and sciences was faltering. The audits contrived various measures of quality and quantity of current research produced in preceding five or seven year spans. This was a meaningless exercise as long as the current output was not compared with historic output. The drill functioned simultaneously as amnesia about the past and a lightning rod of national anxiety that the overall quality of inquiry of the present, and the per capita quantity of that inquiry, was worse than that of the past. A sober look in the long rear view mirror suggests that indeed it was.

In the sciences the last truly remarkable leap in the twentieth century was the discovery of the significance of DNA. The story of this discovery begins in 1944 at the Rockefeller Institute for Medical Research when Oswald Avery with Colin MacLeod and Maclyn McCarty drew the connection between Deoxyribonucleic acid (DNA) and genes. The researchers asked and answered what was the chemical means of inducing "changes" in organisms that could be transmitted as "hereditary characters". The key presupposition was the following: "Biologists have long attempted by chemical means to induce in higher organisms predictable and specific changes which thereafter could be transmitted in a series as hereditary characters" (Avery, MacLeod, McCarty: 137). What this encapsulated was the antonymic idea that in *constancy* (hereditary transmission) lay *change* (variable traits). The constancy-change antinomy was later flattened out in various ways. Notably it was over-determined by the then-popular mid-twentieth century metaphors of language and grammar. The Columbia University biochemist Erwin Chargaff much later recalled that, when he read Avery's experimental results, he concluded that these were "the beginning of the grammar of biology". This was "the first text of a new language" (Chargaff: 639). A language can be decoded and thus understood if one knows its structural characteristics such as its grammar.

The structural form of the chemical media for transmitting inherited characteristics was deciphered in 1953 when James Watson and Francis Crick in the Cavendish Laboratory at Cambridge isolated the double helix structure of DNA.[23] This would permit what subsequently became known as "decoding" the genetic information "encoded" in DNA. What caused the emergence of the "information-life" metaphor is difficult to say with any precision. The key role that message decoding (cryptography) played in the modern warfare may have created a tacit frame of mind for such an equation. The popularity of language as a model for philosophy may also have played a background role. Interestingly though, the metaphor of the semiotic code does not appear in Avery's or Crick and Watson's original papers.[24] The analogy with code-cracking is a later addition. Rather at the heart of the two pioneering papers is a much more interesting intellectual contrariety. This is the paradox of bio-chemical changes that transmit structure (characteristics) and conversely a bio-chemical (helix) structure that causes alterations.

Beware of metaphors. They mislead as much as they lead. Avery and Watson-Crick's paradox of structure-alteration is profound. It plumbed the mystery of life. Less can be said for the equation of life with an information code. The twentieth century was addicted to linguistic analogies. The idea of the "information society" became wildly popular at the close of the century. But in truth semiotic-information metaphors are rather lame. They betray the diminished aspirations of a less than fertile age. That age was more often prosaic than creative. Creation is ineffable. While its metaphors are of necessity an artefact of language, they are also of necessity an artefact that points *beyond* language. In symbols or words they must paradoxically hint at what we cannot say. Thus if effective they are not metaphors of information. On the contrary they must intimate that which cannot be stated, whether in description, analysis or rational elaboration. In many ways an act of intellectual creation will always be elusive. This is not because it is irrational but rather because it happens so swiftly, in a flash. It is never explained. Often it is barely stated. The imagination lies on the border between the discursive and the non-discursive regions of human understanding. Some understandings we state. Some we elaborate. The deepest understanding is the most difficult to put into words or symbols. Not everyone is a Churchill or a Heisenberg. They are rarities. But the imagination and its means of communication are not rare. Wit, irony and paradox are the common possession of the species. They are not late arriving. What makes human beings "human" is their capacity to think ambidextrously through an endless series of couplets that compound reality and fiction, experience and anticipation, and so on. Because of this ability for contrary cognition, for thought that productively interpolates contradiction, incongruity, and irony, we are able to reflect, dissemble, satirize, strategize, and parody, in short, we are able to imagine. In and through this lies the path to invention and discovery.

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ENDNOTES

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[1] The rationale for this systems model is developed in Murphy, 2011 and Murphy, 2009, chapter 6. The philosophical roots of the model lie in Aristotle, Hobbes and Locke. Aristotle sets out the model of discursive knowledge variously in Book Alpha of *The Metaphysics*, Book Six of *The Nicomachean Ethics*, and Section Eight of *The Art of Rhetoric* in standard modern editions. The distinction between analytic knowledge and the imagination is introduced by Thomas Hobbes' *Leviathan* in 1651 and John Locke's *Essay Concerning Human Understanding* in 1690. See in particular *Leviathan*, Chapter VIII and the *Essay Concerning Human Understanding*, Chapter XI. The distinction is drawn in terms of the difference between (imaginative) wit and (analytic) judgment. Wit is a faculty of wit for pointing out the similitude or resemblance of ideas, whilst judgment dwells on their separation. Section Nine of Aristotle's *The Art of Rhetoric* includes topics such as simile, wit and metaphor, each of which are key media of the imagination.

[2] The synthetic nature of the imagination is hammered home by both Hobbes and Locke in *Leviathan*, Chapter VIII and the *Essay Concerning Human Understanding*, Chapter XI. The synthetic nature of intuition, imagination and conceptual understanding is also

emphasised by Kant in the *Critique of Pure Reason*. Kant states the matter thus in Book 1 Section 2 of the Transcendental Analytic: "Space and time contain a manifold of pure a priori intuition, but at the same time are conditions of the receptivity of our mind—conditions under which alone it can receive representations of objects, and which therefore must also always affect the concept of these objects. But if this manifold is to be known, the spontaneity of our thought requires that it be gone through in a certain way, taken up, and connected. This act I name synthesis. By synthesis, in its most general sense, I understand the act of putting different representations together, and of grasping what is manifold in them in one [act of] knowledge. Such a synthesis is pure, if the manifold is not empirical but is given a priori, as is the manifold in space and time. Before we can analyse our representations, the representations must themselves be given, and therefore as regards content no concepts can first arise by way of analysis. Synthesis of a manifold (be it given empirically or a priori) is what first gives rise to knowledge. This knowledge may, indeed, at first, be crude and confused, and therefore in need of analysis. Still the synthesis is that which gathers the elements for knowledge, and unites them to [form] a certain content. It is to synthesis, therefore, that we must first direct our attention, if we would determine the first origin of our knowledge. Synthesis in general, as we shall hereafter see, is the mere result of the power of imagination, a blind but indispensable function of the soul, without which we should have no knowledge whatsoever, but of which we are scarcely ever conscious. To bring this synthesis to concepts is a function which belongs to the understanding, and it is through this function of the understanding that we first obtain knowledge properly so called."

[3] Kant, *Critique of Pure Reason*, A108-109.

[4] The role of the switch in the literary imagination, specifically in the Shakespearean imagination, is discussed by Murphy (2009) and Davis (2007).

[5] In a different context, Churchill himself remarked: "We must beware of needless innovation, especially when guided by logic". House of Commons, December 1942.

[6] His close friend, the Oxford physicist, Professor Frederick Lindemann (Viscount Cherwell), observed of Churchill: "All the qualities... of the scientist are manifested in him. The readiness to face realities, even though they contradict a favourite hypothesis; the recognition that theories are made to fit facts not facts to fit theories; the interest in phenomena and the desire to explore them; and above all the underlying conviction that the world is not just a jumble of events but there must be some higher unity, that the facts fit together. He has pre-eminently the synthetic mind which makes every new piece of knowledge fall into place and interlock with previous knowledge; where the ordinary brain is content to add each new experience to the scrap-heap, he insists on fitting it into the structure of the cantilever jutting out from the abyss of ignorance." (Jones in Blake and Louis: 432).

[7] 1. Churchill, 1932: 8, 2. Churchill to Australian Prime Minister John Curtin, 19 January, 1942, 3. Address to the Royal College of Physicians, London, 2 March 1944.

[8] Standard contemporary studies of Churchill include Jenkins (2001), Rose (2009), Johnson (2009), Keegan (2002), and Gilbert (1991).

[9] "Hitler knows that he will have to break us in this Island or lose the war. If we can stand up to him, all Europe may be free and the life of the world may move forward into broad, sunlit uplands. But if we fail, then the whole world, including the United States, including all that we have known and cared for, will sink into the abyss of a new Dark Age made more sinister, and perhaps more protracted, by the lights of perverted science." Winston Churchill, "This was their finest hour", House of Commons, 18 June 1940 in Winston S. Churchill: 229.

[10] Winston Churchill, "The War of the Unknown Warriors", Broadcast, 14 July 1940 in Winston S. Churchill: 234.

[11] The Battle of Britain took place in the summer and autumn of 1940.

[12] Martin Gilbert, *Churchill: A Life* (New York: Henry Holt, 1991), 293.

[13] Martin Gilbert, *Churchill: A Life* (New York: Henry Holt, 1991), 299.

[14] Martin Gilbert, *Churchill: A Life* (New York: Henry Holt, 1991), 336.

[15] *Measure for Measure*, IV.iii, 109-111; *Henry IV.2*, I.i, 137.

[16] Shakespeare, Sonnet 94.

[17] One of the visible loses occasioned by the age of the dictators was the decline of German-language science. In Lightman's collection of leading science papers, there are 25 papers in total including 7 originally published in German. All but one of the German language papers dates from the period 1900 to 1927 (xv).

[18] Further evidence of the long-term decline of the arts and sciences after 1930 is discussed in Murphy, Marginson, Peters: 87-138.

[19] "Think back to 1998, the early days of the dot-com bubble. At the time, the news was filled with reports of startling breakthroughs in science and medicine, from new cancer treatments and gene therapies that promised to cure intractable diseases to high-speed satellite Internet, cars powered by fuel cells, micromachines on chips, and even cloning. These technologies seemed to be commercializing at 'Internet speed', creating companies and drawing in enormous investments from profit-seeking venture capitalists—and ordinarily cautious corporate giants. Federal Reserve Chairman Alan Greenspan summed it up in a 2000 speech: 'We appear to be in the midst of a period of rapid innovation that is bringing with it substantial and lasting benefits to our economy.'... With the hindsight of a decade, one thing is abundantly clear: The commercial impact of most of those breakthroughs fell far short of expectations—not just in the U.S. but around the world. No gene therapy has yet been approved for sale in the U.S. Rural dwellers can get satellite Internet, but it's far slower, with longer lag times, than the ambitious satellite services that were being developed a decade ago. The economics of alternative energy haven't changed much. And while the biotech industry has continued to grow and produce important drugs—such as Avastin and Gleevec, which are used to fight cancer—the gains in health as a whole have been disappointing, given the enormous sums invested in research. As Gary P. Pisano, a Harvard Business School expert on the biotech business, observes: 'It was a much harder road commercially than anyone believed.... There's no government-constructed 'innovation index' that would allow us to conclude unambiguously that we've been experiencing an innovation shortfall. Still, plenty of clues point in that direction. Start with the stock market. If an innovation boom were truly happening, it would likely push up stock prices for companies in such leading-edge sectors as pharmaceuticals and information technology. Instead, the stock index that tracks the pharmaceutical, biotech, and life sciences companies in the Standard & Poor's 500-stock index dropped 32% from the end of 1998 to the end of 2007, after adjusting for inflation. The information technology index fell 29%. To pick out two major companies: The stock price of Merck declined 35% between the end of 1998 and the end of 2007, after adjusting for inflation, while the stock price of Cisco Systems was down 9%. Consider another indicator of commercially important innovation: the trade balance in advanced technology products. The Census Bureau tracks imports and exports of goods in 10 high-tech areas, including life sciences, biotech, advanced materials, and aerospace. In 1998 the U.S. had a $30 billion trade surplus in these advanced technology products; by 2007 that had flipped to a $53 billion deficit. Surprisingly, the U.S. was running a trade deficit in life sciences, an area where it is supposed to be a leader." (Mandel, 2009)

[20] This is a point elaborated by an epistemological tradition that runs from Kant's *Critique of Judgement* to Habermas' *Theory of Communicative Action*.

[21] A classic example of this is the post-modern science of "global warming" and its claim in the face of many well-informed and serious critics that it is a "settled science" underpinned by an unimpeachable "consensus" of views. Such rhetorical tactics neatly illustrate the way in which reason so readily becomes imperious.

[22] These included Britain's Research Assessment Exercise (RAE) and Research Excellence Framework (REF) and Australia's Research Quality Framework (RQF) and Excellence in Research for Australia (ERA) schemes. New Zealand's Performance Based Research Fund was an analogous example.

[23] "We wish to suggest a structure..." are the opening words and thematic focus of Watson and Crick's historic article "A Structure for Deoxyribose Nucleic Acid" (1953).

[24] The Coldspring reprint of the original Crick and Watson *Nature* paper has much later annotations that introduce the terms information and code. See: http://www.exploratorium.edu/origins/coldspring/ideas/printit.html