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## **‘Good Death’: a Common Pattern in the Evolution of Mathematics, Science and Biological Organisms<sup>1</sup>**

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*Drawing from experience of pure mathematical and historical research, this paper investigates the formation and development of mathematical concepts, and explores the way such a communal creative enterprise evolves. These insights are used to look again at biological evolution and scientific theory-selection. On turning round the metaphor ‘red in tooth and claw’ that is sometimes applied to nature and to competing scientific theories and contrasting the two images, compost heap and scrap heap, a common pattern emerges of forms of ‘self-giving’ operating within a framework of co-creative competition. Images of ‘self-giving’, and even of ‘sacrifice’, are found in the evolution of the cosmos, of living organisms, of scientific theories, of mathematical concepts. In each there is the passing, or ‘death’, of the old, not just to make way but to prepare the way for, and to be subsumed into, the ‘life’ of the new. Use is made of Austin Farrer’s theology of ‘a world made to make itself’, and his insistence on the centrality of self-giving in the economy of God’s world.*

**Key words:** mathematics, concept-formation, theory-selection, evolution, death, self-giving, sacrifice

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### **Life and death of organisms and scientific theories**

Perhaps the hardest question posed for Christians, and indeed for theists more generally, by biological evolution arises from the perception of nature as ‘red in tooth and claw’. This phrase of Tennyson’s evokes all the pain, suffering, competition, apparent futility and waste entailed by natural selection. Even if we are careful to avoid moral categories in viewing the non-human world, those bloody teeth and claws, depicted so vividly by the art and technology of the wildlife photographer, may haunt us. The inevitable selection of brief moments

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<sup>1</sup> A summary of these ideas was given at the Science & Religion Forum Conference at St John’s College, Durham, in September 1999, while this paper is a much expanded version of a short talk: *Good Death, Communal Creativity and Eucharistic Science*, given at the Austin Farrer Centenary Conference, Oriel College, Oxford, 6–9 September 2004, for which I acknowledge the encouragement of Margaret Yee. I thank Ray Slade for some helpful comments, and Michael Stephenson for some pertinent references. I acknowledge the hospitality of the librarians and archivists of Trinity College Library, Cambridge, and University College, London, and I thank the anonymous referees for remarks which contributed to refining and clarifying some analogies in this paper. Finally I wish to thank my wife Rachel for her constant encouragement.

of violence to the exclusion of the peaceful days of grooming, courting, sleep and play, naturally results in caricature. Prolonged experience of the wild tends to engender a respectful perception of its ways that is at odds with the distasteful presentation of some wildlife films. Biologists also play down the idea of struggle, as for example in the words of G. G. Simpson:

To generalize... that natural selection is over-all and even in a figurative sense the outcome of struggle is quite unjustified under the modern understanding of the process... Struggle is sometimes involved, but usually it is not, and when it is, it may even work against rather than toward natural selection. Advantage in differential reproduction is usually a peaceful process in which the concept of struggle is really irrelevant. It more often involves such things as better integration into the ecological situation, maintenance of a better balance of nature, more efficient utilization of available food, better care of the young, elimination of intragroup discords (struggles) that might hamper reproduction, exploitation of environmental possibilities that are not the objects of competition or are less effectively exploited by others.<sup>2</sup>

However, we are still faced, if not with grim struggle, then at least with fierce competition for existence, for food or for a mate, and this seems incompatible with the spirit of the Sermon on the Mount, as if the ‘two Books’ of God’s self-revelation – the Bible and Nature – derive from two very different authors. The problem is posed no less starkly by the sperm-meets-egg saga in a single human conception, or by the very existence today of spiders and crocodiles. That the issue is not so much with Darwinian evolution as with all of the processes and interactions of the natural world (Tennyson’s phrase was written before the publication of *On the Origin of Species*), seems not to be widely recognised by Christian believers, in spite of considerable scholarly theological reflection over the past decade.<sup>3</sup> Popular writing often affirms that nature’s intricate order, variety and fecundity is a direct indication of God’s character and purposes. For example, Rick Warren, in his enormously influential book *The Purpose-Driven Life*, writes: ‘God formed every creature on this planet with a special area of expertise. Some animals run, some hop, some swim, some burrow and some fly. Each has a particular role to play, based on the way they were shaped by God.’<sup>4</sup>

But the reader’s attention sometimes seems deliberately shielded, in such popular writings or sermons, from the less appealing aspects of nature – the facts about just why this animal is running or burrowing (shrieking the while),

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2 Simpson, G.G. *The Meaning of Evolution*, New Haven: Yale University Press (1971), p. 201.

3 e.g. Murray, M. *Nature Red in Tooth and Claw: Theism and the Problem of Animal Suffering*, Oxford: Oxford University Press (2008), and Southgate, C. *The Groaning of Creation: God, Evolution and the Problem of Evil*, Louisville: Westminster John Knox Press (2008).

4 Warren, R. *The Purpose-Driven Life*, Lake Forest, CA: Purpose Driven Ministries (2002), p. 234.

and how perfectly the peculiar shape of the pursuing animal is designed for predation, and that of the pursued for escape. Challenged with these uncomfortable facts, many Christians display unease and anxiety, and murmur something about sin being at the root of it. Selwyn Hughes, the well-known contemporary devotional writer, exemplifies this response:

But is everything in creation ‘bright and beautiful’? Honesty compels us to face the fact that while this is wholly true, it is not the whole truth. Those who look out at creation and see nothing but things that are ‘bright and beautiful’ are not looking at the whole world. I once saw a documentary, for example, which showed the soldier ants of South America. Those amazing creatures, nearly an inch long, move in their millions, fall upon their prey like tar, and with their enormous pincer-like jaws, pull their victims apart. I remember recoiling in horror as I watched.

The same programme showed viewers how those strange creatures the lampreys live: how with their scaleless bodies and sucker mouths they tear off the scales of living fish and eat them alive. I shudder with horror at the very recollection of it. When one looks at the other side of creation, one can’t help wondering if this is really God’s world or whether He has been excluded from it and some malignant enemy has taken over. What is the truth about this?

The truth is that we live in a *fallen* world – a creation originally made by God, but blighted by sin. When Adam and Eve rebelled against God in the Garden of Eden, their action had repercussions that penetrated to every corner of the Universe. Sin upset the balance of the universe and affected not only the world of humanity, but the whole of the material creation also. I don’t think there is any way we can fully understand this. We can only view in amazement the wonder of a creation that unfolds the most glorious sunsets and then at the same time shows us a more horrifying side – the side that Tennyson described as ‘Nature, red in tooth and claw’.<sup>5</sup>

Hughes’s apparent ascription of animal pain and predation to the effects of a cosmic fall was not shared by the writers of the passionate but unsentimental nature poetry of the Psalms who (uniquely among ancient nature-poets) take all creatures as designed by a good and beneficent God to be what they are (e.g. Ps. 104: 20-22, 24).

Turning now to the evolution of ideas – in particular to the evolution of scientific theories – some have proposed to understand this in terms of Darwinian-like processes. For example, B. C. Von Fraasen:

In just the same way [as for example a mouse runs away from a cat because

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<sup>5</sup> Hughes, S. *Can I really know God?*, Eastbourne: Kingsway (1994, 2002), p. 44. A similar position is taken by Fyall, R.S. *Now My Eyes Have Seen You: Images of Creation and Evil in the Book of Job*, Leicester: Apollos (2002), e.g. p. 130. For a discussion of this and alternative positions, see Bimson, J.J. ‘Reconsidering a “cosmic fall”’, *Science & Christian Belief* (2006) 18 (1), 63-81.

animals that didn't run away got eaten and did not pass on their genes], I claim that the success of current scientific theories is no miracle. It is not even surprising to the scientific (Darwinist) mind. For any scientific theory is born into a life of fierce competition, a jungle red in tooth and claw. Only the successful theories survive – the ones which in fact latched on to the actual regularities in nature.<sup>6</sup>

Similarly, Imre Lakatos saw the success of science as dependent on the maximum proliferation of tenaciously-held and fiercely-competing theories;<sup>7</sup> and the title of a recent book on philosophy of science, *Theories on the Scrap Heap*, makes theory-selection seem a ruthless, winners-take-all scenario.<sup>8</sup>

It is one of the aims of this paper to seek valid analogies between the evolution of organisms, mathematical concepts and scientific theories. But in these parallel pictures of the life and death of organisms and of ideas as essentially a grimly competitive struggle for survival or pre-eminence, something fundamental in the web of relationships is lost. Moreover, such a picture is far from doing justice to the world of ideas and intellectual community of this author's experience: the mathematical. I want to suggest that the picture is, in a sense, upside down – that it can be viewed differently, in a way more consistent with the vision of the evolution of mathematical concepts to be outlined in the next section, and the ethical structures and often-gracious behaviour patterns of the mathematical community.

## **Life and death of mathematical concepts**

The import of this deliberately provocative subheading will be clarified by taking three different perspectives: (1) the mathematical historian's engagement with the past and involvement with the characters of study; (2) the attempt to capture by dialogue the historical formation and ancestry of mathematical ideas; and (3) the experience of the research mathematician in constructing or imagining new concepts.

### **1. Engagement with the past**

On visits to the archives of Trinity College, Cambridge, and University College, London, the author has had the privilege of reading original letters from the first half of the nineteenth century: boxes of personal communications, pen-dipped-in-ink, beautiful but almost illegible scrawl on unfamiliar paper, sometimes supplemented with afterthoughts scribbled in the margins or perpendic-

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6 Von Fraassen, B.C. *The Scientific Image*, Oxford: Oxford University Press (1980), p. 39.

7 Lakatos, I. *Mathematics, Science and Epistemology*, Cambridge: Cambridge University Press (1978).

8 Losee, J. *Theories on the Scrap Heap: Scientists and Philosophers on the Falsification, Rejection and Replacement of Theories*, Pittsburgh: University of Pittsburgh Press (2005).

ularly to the original lines, and bearing remnants of sealing wax and even on later letters the occasional penny black or penny red stamp. In a world remote from our modern world of computers and email, the personalities, daily lives and intellectual concerns of the characters of one’s historical research are powerfully evoked. It is easy to see why historians often come to speak of their characters with an affection normally reserved for living friends.

The central characters of my own interests are Charles Babbage, William Whewell, John Herschel, George Peacock, Augustus De Morgan and William Rowan Hamilton. These six men were outstanding members of an intellectual community that played an important role in transforming mathematics, science, philosophy and much else in their time, and bringing into being much that is part of our world nearly two hundred years later. Yet how different they were from us – the father of the computer (Babbage), the father of philosophy of science and coiner of the word ‘scientist’ (Whewell), the father of mathematical logic (De Morgan), the two who changed almost beyond recognition the meaning of the word ‘algebra’ (Peacock and Hamilton), and the man they all respected and whose scientific and theological writings helped to inspire Charles Darwin to do science (John Herschel). Much of their world, their worldview and what they cared intensely about, has passed away. Their motivations in doing the work for which we still celebrate them can look quaint and archaic to us, as do some of what they themselves regarded as their most important achievements.

It is from mathematics that the most dramatic examples come, in defiance of the allegedly cumulative nature of that subject. Peacock’s *Treatise on Algebra* (1830)<sup>9</sup> and Hamilton’s *Quaternions* (1843)<sup>10</sup> were each regarded as revolutionary in their time and spawned radical new departures, opening the way for fundamental advances in mathematics, including the eventual birth of vector calculus and abstract algebra. Yet each is largely forgotten today, except by historians, and even they generally underestimate, I think, the significance of these two intellectual events. For these works of Peacock and Hamilton are best appreciated as *transitional forms* in mathematics, productive but *provisional*, making possible other mental constructs and theories which would then supersede or transcend them. Most nineteenth century mathematicians regarded them both with awe and admiration. Quaternions, as a new type of number promising wide application, were perceived as the great Hamilton’s

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9 Peacock, G. *A Treatise on Algebra*, Cambridge: Deighton (1830).

10 Hamilton, W.R. ‘On quaternions; or on a new system of imaginaries in algebra’, *London & Edinburgh Philosophical Magazine* (1844) 25, 10-13, 241-246, 489- 495. Also in *Proceedings of the Royal Irish Academy* (Nov. 1843). The quaternion system is a development of complex or imaginary numbers  $x+iy$  (where  $x$  and  $y$  are real numbers and  $i^2 = -1$ ) to entities  $x+iy+jz+kw$ , where  $x,y,z,w$  are real numbers and  $i^2 = j^2 = k^2 = -1$ . Basic laws of complex numbers such as the law of the moduli extend beautifully to the more general system, which is able to represent physical concepts in three dimensions, including ‘vectors’, a term which Hamilton co-opted for the purpose, along with the term ‘scalar.’ Vector calculus grew naturally out of this system in the late nineteenth century, when quaternions passed into disuse.

most important discovery; and Peacock's *Algebra*, expounding a fully symbolical view of the subject and advocating a new freedom of form, was felt in its time to be a boldly novel and fiendishly difficult book. These two works are ancestors of concepts and fields central to current mathematics, but a mathematician today, who may be familiar with Hamiltonians, Hamilton's equations, the Cayley-Hamilton theorem and Hamiltonian cycles, may have little idea what a quaternion is, or who George Peacock was. Anyone trained within the intellectual heritage of these two achievements will, on reading the old letters or journals, find Hamilton's announcements of his quaternions oddly shrill, and Peacock's *Algebra* a puzzling compromise, their self-conscious novelties almost trivial now. For these are characteristic marks of provisionality.<sup>11</sup>

It is not being claimed that all mathematical theories are provisional in the same sense. Axiomatic theories like Euclid's geometry do not cease to be valid, by the internal tenets of mathematical validity, over time. Nor do mathematical theories applied to the modelling of the physical world simply change status from valid to non-valid. Rather the models may achieve greater precision over time, or come to be seen as 'better', 'worse', 'relevant' or 'irrelevant', for different scientific purposes or scales, as with non-Euclidean geometries. Similarly, different algorithmic recipes – like Leibniz's, Euler's, Riemann's, and Lebesgue's in the calculus, representing three centuries of development – may retain their validity for different purposes. However, Imre Lakatos and others have shown how mathematical 'works', seen as embedded in the style, partly-tacit definitions and control-beliefs of a given community of practitioners, and as exemplified here by Peacock's *Algebra* and Hamilton's *Quaternions*,<sup>12</sup> can and do cease to be part of the game. They may pass out of the arena of mathematical activity after helping to give rise to progeny that effectively supersede them.<sup>13</sup>

The lives of those six members of the nineteenth century 'Cambridge network' have contributed profoundly to the making of our world. But we have not simply built upon their structures (not even in mathematics), nor have we simply thrown away the old and replaced it with new (not even in the most subjective and transitory fashions of human life). Rather, the new has grown out of the old by a constant and subtle incorporation of the elements of the old in the new, with dissolution of the old – death is the natural metaphor – in producing the novelty and freshness of the new. The old passes, not away, but into the new. For this, the commonly used images of scrap heap, rubbish tip and

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11 For more detail on Hamilton and Peacock, and many references, see Hitchcock, A.G. 'Summoning the nerve: from algebra to algebras in 19th century Britain', in Cupillari, A. (ed.) *Proceedings of the Joint Conference of the British Society for the History of Mathematics & the Canadian Society for the History and Philosophy of Mathematics*, Cambridge, 9-11 July 2004.

12 Other e.g.s could be cited: the ancient theory of incommensurables, Cavalieri's theory of indivisibles, Cayley and Sylvester's theory of invariants.

13 Lakatos's 'logic of proofs and refutations' makes much of mathematical activity look very similar to empirical science – hence his word 'quasi-empirical'. Lakatos, I. *Proofs and Refutations: the Logic of Mathematical Discovery*, Cambridge: Cambridge University Press (1976).

archaeological strata are totally inadequate and misleading. Far more appropriate are the organic images of compost, forest-floor humus, and peat-bog.<sup>14</sup>

## **2. Capturing by dialogue the formation and ancestry of mathematical ideas**

The present author’s experience of writing dialogues in the history of mathematics<sup>15</sup> has confirmed the now widespread view that not only natural science but also mathematics is best understood as a communal enterprise, and that a *praxis-immanent* conception of science can be extended to mathematics. This means that communal practice and rhetoric is seen as an essential element in the process by which our knowledge is constituted, and new concepts emerge from the twists and turns of contextual dialogue, controversy and crisis. Plato, Galileo and many others have used dialogue for teaching or polemical purposes, for the dialogue form is ideal for representing the interaction and flow of ideas, and bringing to life the human intellectual adventure.<sup>16</sup>

Creating dialogues based closely upon primary sources has heightened my own awareness of the way mathematical concepts are seeded, formed and matured. I can only express it metaphorically. Concepts act upon each other in the ferment of debate to challenge and change each other, to join in producing hybrid or mutant off-spring, before passing from the scene. Concepts combine to create a fertile medium in which other concepts can take root and develop. In the most fruitful dialogues there is a conscious, gracious reciprocity and an unconscious mutual contagion, in Malcolm Bowie’s apt phrase, a joint submission and commitment to the apprehension of truth or the generation of novelty. There is sustained dialectical subversion, synthesis and transcendence, involving a kind of self-giving of the participants, and a kind of ‘dying’ of concepts, in the bringing to birth of new concepts.

## **3. Constructing new concepts**

General topology<sup>17</sup> is a branch of pure mathematics notorious for its abstrac-

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14 The peat-bog image illustrates the way the past sometimes impinges more suddenly and dramatically on the present through the bringing to light of ideas, records or artefacts interred and long-preserved in libraries or archives.

15 Motivated by a growing awareness of the need to bring the human story and the history of ideas into the heart of teaching mathematics, I have attempted to reconstruct in dialogue both the ‘internal’ rational development of ideas and the ‘external’ human cultural stimuli, motivations and emotions; e.g. Hitchcock, A.G. ‘Entertaining strangers: a dialogue between Galileo and Descartes’, in Schaffer, E.S. (ed.) *Comparative Criticism* (1998) 20: *Philosophical Dialogues*, Cambridge: Cambridge University Press, pp. 63-85.

16 A notable exponent of dialogue form, well known to science-religion scholars, is Austin Farrer, whose philosophical writings and sermons are frequently graced by witty dialogues, e.g. between a king and a cat, or between himself and an imaginary questioner or opponent.

17 Roughly speaking, topology is the mathematical study of shape, form, ‘nearness’ and continuity. It abstracts properties of real numbers that complement the algebraic structure.

tion. Researching in this field, the present author has experienced, in common with all pure mathematicians, the extraordinary way in which a concept, initially defined by the mathematician, can – like the wooden puppet Pinocchio or a character in a novel – take on a life of its own.<sup>18</sup> What appears an act of creation or invention, looks in retrospect more like discovery or midwifery. A concept may live vigorously for a time, having its own, often surprising, way and bringing its own peculiar light to bear upon its conceptual environment, while its clarity grows through engagement with other concepts. Then there emerges a successor, or an adjusted conceptual framework, in which, although the mathematician often continues to use the same name, the original concept is no more. Its elements have been transmuted, its original bodily definition interred. It has done its work; its light is dimmed and finally extinguished. The notions of right and wrong, correct and incorrect, applied to the life of such a concept seem inadequate, even in this most exact of sciences. Was that life wasted? Of course, the working mathematician may make a logical mistake, but, that aside, it is often impossible to say how much later concepts and insights depend upon and draw from the life and death of the former. What are the criteria for success of a concept? In mathematics, success is hard to define. It commonly includes *incorporation* in a theory of elegance and beauty; *generality* in capturing the common essence in many different instances; *fruitfulness* in leading to solving of important problems, *applications* to other fields and *interconnections* between previously disparate results. But what of the concept or theory that lived briefly, fell into the ground of intellectual debate and died, thereafter to bring forth much fruit? Perhaps it lived to provoke debate, and helped to get us off the ground, to show the way for others, if only by exploring a dead-end; to demonstrate limitations, or to enlarge the vision and challenge to new departures, before it passed away. Like Hamilton's quaternions or Peacock's symbolical algebra<sup>19</sup> such concepts have surely not lived in vain. They may be due more honour in some conceptual 'heaven' than many a later, more sophisticated, longer-lived and better-known concept!

The phenomenon of simultaneous and independent discovery, occurring frequently in mathematical history, bears witness to something all researchers know: the way that concepts have of hovering 'in the air' – they are adumbrated, hinted at, some time before they burst upon the scene, as if the mathematical community were pregnant with the baby well before, by the physical event of precise definition and publication, its face appears in the ripeness of time. The mathematical community today affirms mathematics as indeed a communal enterprise, and recognises by many institutional rituals the cooperation and mutual courtesy that is part of mathematical development. It takes far greater pains over citation than it takes over priority disputes. It goes to great lengths to honour its heroes and heroines – both the young, for a single

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18 e.g. 'hyperassociation map', in Hitchcock, A.G. 'Topologies on uniform hyperspaces', *Quaestiones Mathematicae* (2006) 29(3).

19 Ptolemy's 'epicycles' or Becher and Priestley's 'phlogiston' are examples from other fields.

outstanding achievement, and the old, for a lifetime of achievement. Great mathematicians usually give credit to the many lesser-known people whose work was instrumental in their achievements. The community encourages and rewards great teachers and planners who help to nurture young talent. Increasingly, it takes its history seriously. In these gracious customs and ethical structures, I believe the wider scientific community is not dissimilar. Can these apparent images of grace derive from some deeper principle?

### ‘Self-giving’ and ‘sacrifice’ at the heart of things

Austin Farrer, in *Love Almighty and Ills Unlimited*, treats the problem of pain and waste with characteristic insight and humour, taking the worst that the Darwinian picture contains and reformulating it in philosophically neutral terms as part of the necessary mutual interference of systems in a universe that is to produce humans. Accepting the full force of a possible challenge to his proposed picture as ‘preposterous tragicomedy’, with ‘splendours displayed, dazzlingly bright but astonishingly brittle and precarious’, and recognising the ‘vast damage’, and ‘huge destruction and waste’ intrinsic to such a universe of interacting systems, he asks (and argues for a negative answer to) two questions: Could it be otherwise? Would we wish it otherwise? He adds:

...cruelty is a term misapplied. Nature is no malicious empress, presiding in an amphitheatre where creatures are hounded to their destruction.... And what characterises the natures of things (if we must moralise them) is not malicious cruelty, but innocent self-love.... Most tadpoles are food for fishes, but they have a lively time, until it suddenly ends.... Yet do they [beasts that have violent ends] not run with hope until they are taken, and fight to win until they are killed?... How can we suppose it possible that the alarm bell of pain should cease to ring, or the animal cease to resist its own dissolution, before the resistance is proved futile by being broken? Then, vitality fading, pain decreases; and the animal which has struggled fiercely dies quietly.<sup>20</sup>

Farrer poses explicitly the question of a wider meaning for efficacious self-sacrifice: ‘It is a commonplace that suffering teaches moral wisdom; and some religious confessions make it a dogma that personal pain can be offered as a sacrifice, to the advantage of our neighbour. Whereas the suffering of beasts must be deemed perfectly useless, irredeemable by any spiritual act or moral attitude.’<sup>21</sup>

He has earlier pointed towards a continuum of ‘sacrificial’ giving, from inorganic to organic to human, considering first a star, which explodes and dies. We

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<sup>20</sup> Farrer, A. *Love Almighty and Ills Unlimited*, London & Glasgow: Collins (1962, Fontana edn. 1966), pp. 81-90 of Fontana edn.

<sup>21</sup> Farrer *op. cit.*, (20), p. 85.

might call this a dis-creative event and be tempted to see evil in it. Evil for what or whom? asks Farrer. Coming right down to earth, Farrer considers a young snail crushed: 'The damage to the sum of things is small. If it lived it would have spoiled several handsome plants; by its death it fed a songbird.'<sup>22</sup>

Farrer is quoted here partly because he makes so well the neutral philosophical case that a universe that includes humans might have to involve something like the Darwinian scenario, and might still have love at the bottom of it and at the end of it.<sup>23</sup> But it is also helpful to take further his positive hints at an economy of something analogous to 'self-giving' yet consistent with 'self-love', running through the universe. I propose that the Darwinian picture – like one of those puzzling two-dimensional pictures from which a hidden three-dimensional scene will emerge if you look at it in a particular way – has, hidden within its texture, a richer and morally more satisfying scenario describable only in theological terms. The Christian faith has always taught – not least through the Eucharist – the importance of self-denial and self-sacrifice as the way to finding one's true self and as the gift of love to God and neighbour, resting upon the self-giving of Christ in incarnation, ministry and crucifixion, and all deriving ultimately from the eternal self-giving of God (e.g. Matt. 10:39, Jn. 13:1-17, 1 Jn. 4: 7-11). At the very heart of the originating Trinitarian creative act, at the centre of the redemptive act of the Father's giving the Son for love of the world, and enthroned at the final consummation, is the eternal figure of the 'Lamb that was slain from the creation of the world' (Rev. 13:8).<sup>24</sup> Thus the act of self-sacrifice is embedded within the act of creation, and imaged in every derivative act of procreation, sub-creation and co-creation, whether personal or communal. Many creative artists,<sup>25</sup> scientists, mathematicians and mothers will testify to such an experience of voluntary self-sacrifice. In this

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22 For more on non-human suffering, from biological, theological and philosophical points of view, see Southgate, C. *op. cit.*, (3); Deane-Drummond, C. & Clough, D. (eds) *Creaturely Theology: On God, Humans and Other Animals*, London: SCM Press (2009); and Linzey, A. *Why Animal Suffering Matters*, Oxford: Oxford University Press (2009).

23 What John Polkinghorne calls 'the free process defence of natural evil' has been given also in Polkinghorne, J.C. *Science and Providence: God's Interaction with the World*, London: SPCK (1989), 2nd edn. Templeton Press (2005), chap. 5; and Polkinghorne, J.C. *Scientists as Theologians*, London: SPCK (1996), e.g. pp. 45- 46. Christopher Southgate espouses a similar idea he calls the 'only way' argument, in Southgate *op. cit.*, (3).

24 The idea of the Creator suffering in and with the creation has been brought to the fore by the process theology of A.N. Whitehead and C. Hartshorne. It is found (in more orthodox context) in Brunner, E. 'The Christian doctrine of creation and redemption', in *Dogmatics*, vol. 2, London: Lutterworth (1952), p. 20; and also in the work of Jürgen Moltmann, e.g. Moltmann, J. *The Crucified God*, Wilson, R.A. & Bowden, J. (trans.), London: SCM Press (1974). More recent studies of what has become known as 'kenotic theology' are: Polkinghorne, J. (ed.) *The Work of Love: Creation as Kenosis*, Cambridge: SPCK (2001); Murphy, G.L. *The Cosmos in the Light of the Cross*, Harrisburg PA: Trinity Press International (2003). See Bimson, J.J. *op. cit.*, (5) for an excellent discussion.

25 The artist's experience of self-sacrifice in creativity is central to the writings of theologian J.H. Vanstone, and has been brilliantly and movingly described by historian Margaret Spufford in Spufford, M. *Celebration: A Story of Suffering and Joy*, London: Continuum Intl. Pub. Group Ltd. (1996).

light, there is little surprise in finding the scientific and mathematical communities displaying features corresponding to creative self-giving. Less expected, perhaps, is the presence of analogous features (a) in the world of ideas, and (b) at subhuman levels of biology and even in the inorganic and in the history of the cosmos, where conscious moral choice is irrelevant.

First, we clarify our use of the words *analogy* and *image*. Two scenarios may be called *analogous with regard to a specified set of selected features* in one scenario, when these can be mapped in a one-to-one correspondence with recognisably similar features in similar configuration in the second scenario. Consider the following seven statements, some of which will be explained and justified in what follows:

- (i) It was through the life and death of countless stars that certain elements came to be available for making up organic creatures like me.
- (ii) It was through the life and death of innumerable species that the genetic constituents essential to my being came to be available.
- (iii) It was through the life and death of millions of *spermatozoa* that the event of conception essential to my existence took place.
- (iv) It was through the life and death of billions of organisms that the nutrients essential to my physical life came to be available for me.
- (v) It was through the life and death of a long succession of mathematical ideas that the concepts essential to my latest topology paper came to be available for me.
- (vi) It was through the life and death of many scientific theories that current cosmology and biology have been made available for me to frame statements (i)-(iv).
- (vii) It was through the life and death of many experimental procedures that the results became available for provoking or testing these scientific theories.

These seven scenarios, vastly different in almost every other way, are yet analogous with regard to the features highlighted by the structural parallelism in the statements. Not all involve selection in a competitive environment. Only three use the words ‘life’ and ‘death’ in a literal sense, but all give to the word ‘death’ a positive ring: it is ‘good death’, at least from ‘my’ point of view. In none can we justifiably claim that there is something directly recognisable as willed ‘self-sacrifice’ going on but, with suitable metaphorical extension of language, we may claim to observe something akin to ‘self-giving’. Let us agree to describe the common set of features we have described as a principle of ‘self-giving’, with the understanding that there may be no conscious ‘self’ involved, and no intentional agency.

Now, if our theology places ‘self-sacrifice’ at the heart of all creation, we may well ask whether there is an *image* of it here, in any of these scenarios of ‘self-giving’. That would imply only that we can find therein some elements of the

idea, those that may be transposed to the new context from the much richer, fully personal context in which the term 'self-sacrifice' arises. The image may be weaker or stronger, less or more evocative of its original. The image is not itself an analogy, but a symbol in the new context, resonating (perhaps softly) with the sound, shining (perhaps dimly) with the light, of the original. Thus, in finding an *image* of 'self-sacrifice' in any realm of human life, we do not necessarily claim that there will be close *analogies* with other images of self-sacrifice. As a three-dimensional sculpture that looks like an E from the North and like a U from the East can be produced, so two projections, transpositions or images of the same root idea into two different realms may appear to have little affinity with each other. Their association becomes evident only through their joint connection to a more fundamental idea. In some such way may we recognise the footprints of divine grace in such disparate realms as biological evolution, mathematical and scientific development, sport, music, or internet collaborations. Commonalities may be most clearly seen, not by immediate analogy, but by referring to common origins or transcendent realities, just as footprints and fingerprints are connected by their belonging to the same person.

Returning to the question of whether there is discernible a principle of self-giving at work in the genesis and interaction of concepts and theories, we have in the previous section already made a case for this in the discipline of mathematics, in both epistemological development and corresponding community ethos. In the next section we shall consider the development of natural science. For now, it suffices to point out that there is significant linguistic evidence for a pervasive analogous principle in human thought. For we habitually talk of ideas in such metaphorical terms as these: *servicing a purpose, giving way to, employing the notion of, drawing sustenance from, one idea incorporating or revitalised by another, serviceable to, subservient function, subsumed within the more general, considered in conjunction with, fruitful interchange.*

Considering next the question of whether there is a principle of self-giving at work in biological evolution. Some profound thinkers have gone even further in finding therein a strong image of the idea of self-sacrifice. Charles Raven made the point forcefully on a number of occasions: 'the greatest of all French naturalists, Jean-Henri Fabre, when asked about the ghoulish death-roll of Nature, declared that the more he studied it the more he was convinced that 'all life, however unconsciously, was obedient to a sublime law of sacrifice'.<sup>26</sup> Arthur Peacocke gave assent to this idea in his Bampton Lectures, observing that 'to talk of God as suffering in the expression of the creative love that elicits man' is 'consistent with the processes of creation through evolution them-

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<sup>26</sup> Originally in Raven, C.E. *Orthodoxy and Science*, date unknown. Raven quoted Fabre again to this effect in his Gifford Lectures: Raven, C.E. *Natural Religion and Christian Theology*, 1951 Gifford Lectures, Series 1: *Science and Religion*, Cambridge: Cambridge University Press (1953), p. 15.

selves being characterised by eliciting new life through suffering, pain, and death (“the sublime law of sacrifice”).<sup>27</sup> He quotes<sup>28</sup> with approval Charles Raven: ‘from atom and molecule to mammal and man each by its appropriate order and function expresses the design inherent in it and contributes, so far as it can by failure or success, to the fulfilment of the common purpose’.<sup>29</sup> Holmes Rolston, in his Gifford lectures *Genes, Genesis and God*, coined the phrase ‘cruciform naturalism’ for his idea of a universal principle of creative suffering in the natural order, with the cross of Christ as its chief exemplification.<sup>30</sup>

Even the devotional author, Selwyn Hughes, quoted earlier, displays something of a shift in his thinking, while admitting that this might be controversial for many Christians:

Many years ago I heard a great Welsh Bible teacher by the name of W.L. Rolands make the point that the sacrificial spirit which was in the heart of God as he created the universe is reflected in the very creation he made. ‘In one sense’, he said, ‘the cross and the spirit of self-sacrifice is built into all creation. The seed dies that the plant may live. It is even in our blood. The white corpuscles watch for infection, and when they find it they throw themselves upon it and die in order that the organism might live.’ An intriguing, though controversial, thought. It is certainly true that the spirit of self-sacrifice is evident in life...

Is this spirit of self-sacrifice a reflection of the fact that we are made in God’s image? If it is then the law of self-sacrifice which is to be found in the heart of God and in the texts of the Bible is to be found also in the very texture of human life. As I said, this is a very controversial thought and I do not wish to pursue it any further.<sup>31</sup>

Following Raven and Peacocke in turning the Darwinian picture thus on its head – or right side up – it can look quite different. The cosmos itself becomes a gigantic metaphor for a fundamental spiritual law. Every living creature may now be seen as given for other creatures, and indeed for countless creatures that come after it, in roles that go far beyond the obvious ones of parenting, nurturing and protecting the young, or playing a part in the social structure of a colony. By preserving and passing on its genes, by the final yielding of its body at the end of the proper fight as food for others, or by the complex

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27 Peacocke, A.R. *Creation and the World of Science (The 1978 Bampton Lectures)*, Oxford: Oxford University Press (1979, reprinted 1998, in paperback 2004) p. 199.

28 *ibid.* p. 198.

29 Raven, C. E. *Natural Religion and Christian Theology, 1952 Gifford Lectures, Series 2: Experience and Interpretation*, Cambridge: Cambridge University Press (1953), Vol. ii, p. 157.

30 Rolston, H. *Genes, Genesis and God: Values and their Origins in Nature and Human History*, Cambridge: Cambridge University Press (1999). See also Preston, C.J. & Ouderkirk, W. (eds.) *Nature, Value, Duty: Life on Earth with Holmes Rolston III*, Dordrecht: Springer (2007).

31 Hughes, S. *Every Day with Jesus*, Farnham: CWR (23 March 2005).

processes of decay and decomposition after death through which the elements of its body become the source of nurture for other life, the sacrifice is made.

In what sense each dying in the non-human world may be seen as an image of what we call self-sacrifice in human life must be carefully considered, for there may be no 'self' to be given and the giving is rarely voluntary in any human sense of the word. Self-willed or not, whether understood in terms of creature-agency, creator-agency or 'double-agency', in so far as the giving limits or diminishes the individual creature in the greater cause of life on earth, it participates in an act of vicarious sacrifice. From a theological perspective the victim is elevated to the role of offering, the parallel being found in Christ who is simultaneously victim and love-offering.<sup>32</sup> Who makes the offering? The Father gave the Son in love, but also the Son speaks of laying down his own life. 'Yet not my will, but yours be done.' The question of who wills the dying is profoundly complex, in that divine act of self-sacrifice. We customarily use the idea of self-sacrifice to describe the bravery-unto-death exhibited by a soldier in battle, where the 'laying down of his life' is seldom willed by the soldier in any proximate, immediate sense; in fact he does – and is expected to do – all in his power to survive, within the bounds of his higher calling to win the battle. The soldier's personal acceptance of posting to exposed position and risky service of his country or community is a 'willingness to die' of a different order. There are varied degrees and levels of consciousness, and nuances of willingness, in what we call 'self-sacrifice'. There is usually a sufficiently strong image of it in the dead soldier's story to justify our ceremonial language, and similarly in the 'self-sacrifice' of the martyrs of the faith. By extension, we may find another, albeit much fainter, image in animal death.

There are many more subtle ways in which animals may instinctively, unwittingly 'give' themselves. As playmate, sparring partner or pacer, as decoy and victim-substitute, the weaker animal serves the stronger of its kind; paradoxically, even by its celibacy, it serves all posterity of its kind, in allowing the stronger to breed. Similarly, the predator serves the posterity of its prey-kind by ensuring the well-breeding of the next generation. There are the complex relations of symbiosis, the oxpecker-bird serving the buffalo as the buffalo serves the tick and the tick serves the oxpecker, and there is the small but still significant role of merely helping to swell numbers to ensure that the odds are on life continuing.

If it appears incredible that 'self-giving' is an appropriate way of seeing such involuntary, instinctive or unconscious action, it may help to consider this 'giving' in conjunction with concepts like obedience, gratitude, honour and worship. What is given is to be received with gratitude. Both the giver and the offering are to be honoured. Is it out of place for me to feel gratitude towards (as well as for) an animal? Do theologians not sometimes speak of animals and

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<sup>32</sup> Robert J. Daly roots the idea of sacrifice and atonement within Trinitarian theology, in Daly, R.J. *Sacrifice Unveiled: The True Meaning of Christian Sacrifice*, London: T. & T. Clark (2009).

even inanimate creatures as worshipping in their own way? The spectacle evoked in the Revelation of St John (5:13), where all created things are joined with the hosts of heaven in the song of creation, hints at a kind of universal self-giving, a giving and receiving of due honour for each creature’s part in the great doxology, and a universal creaturely participation in resurrection.

### ‘Good death’ in science: the compost heap and the scrap heap

William Rowan Hamilton’s inspiration for his epochal works in optics, ‘Conical Refraction’ and ‘On Systems of Rays’, came from the concept of the *ether*.<sup>33</sup> He expressed this in characteristically poetic language: ‘the science of Physical Optics...enables us almost to feel the minute vibrations of that mighty ocean of aether, which bathes the farthest stars, yet winds its way through every labyrinth and pore of every body on this earth of ours’.<sup>34</sup> Similarly James Clerk Maxwell’s revolutionary insights into the wave-motion of light and electromagnetism, culminating in *Maxwell’s equations*, were developed within a conceptual framework involving the ether: ‘light consists of the transverse undulations of the same medium which is the cause of electric and magnetic phenomena’. Hamilton’s and Maxwell’s thought and imagination were grounded in the provisional notion of the all-pervading ‘aether’ – supplemented in Maxwell’s case by such mental props as rods, pulleys and rubber bands – whose ‘dying’ in the fullness of time was heralded by the famous Michelson-Morley experiment. To ignore this formative, provisional role of the concept of ether as, for instance, Michel Janssen does: ‘the medium mentioned so prominently in this passage was eventually relegated to the scrap-heap of history’, is typical of the dismissive attitude of many scientists and even some historians to outmoded and rejected theories whose critical role in nurturing and bringing forth our current theories is down-played.<sup>35</sup> Perhaps we should rather speak of ‘late theories’, and have them laid gratefully to rest with all due honour, in the same way that extinct biological species may be perceived not so much as tragic victims as honoured offerings. The ‘aether’ lived fruitfully in our human intellectual quest to understand the way the world is and may be said to have died a ‘good death’!<sup>36</sup>

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33 I have used the now almost universal American spelling. Hamilton and Maxwell used the older (English) spelling ‘aether’ or ‘æther’.

34 Speech at the meeting of the British Association for the Advancement of Science, in Edinburgh, seconding a vote of thanks to the President and Vice-Presidents, as reported in Jameson’s *Philosophical Journal* and reprinted in Graves, R.P. *Life of Sir William Rowan Hamilton*, vol. 2, pp. 108-109.

35 Recall the title of John Losee’s book, *op. cit.*, (8).

36 There are naturally many examples where concepts that were at one time dominant appear to have been in some respects a hindrance, e.g. the earth-centred Ptolemaic system, or the Bohr-Rutherford planetary-orbit model for the atom, or phlogiston theory, or corpuscular theory (which some believe seriously hindered the work of the talented Christopher Huygens). But the same concepts acted (if only by their problematic nature) as launching grounds for the later, more successful theories, and it is often the case that provisional commitment to the simpler and more intuitive was indispensable for the framing of the very questions that provoked the ideas of the more complex.

This phrase ‘good death’, while hardly amenable to precise definition, carries many helpful connotations and resonances. One thinks of the wonderful life-in-death smell of well-rotted compost – the smell of once-living things passing, under the action of other living things, to give life to new things. The compost heap forms a good image for the fruitful self-giving, provisional life and unwasted death of God’s creatures – but also of man-made concepts; an image for God’s ways of sustained creating-in-time of his creatures – but also for man’s always provisional ‘naming’ of the creatures. A progressive ontology invites, and is imitated by, a progressive epistemology, in which we may see ‘good death’ at work in the *epistemic degradability of transitional concepts and theories*.

The term ‘evolutionary epistemology’ seems to have been coined by D. T. Campbell,<sup>37</sup> referring to Karl Popper’s claim<sup>38</sup> that the logic of Darwinian natural selection is identical to the logic of the growth of knowledge in a problem-solving continuum from amoeba to Einstein. If the amoeba fails to solve its problem, it will be eliminated, while if Einstein fails to solve his, his theory will die. Popper was not arguing for, or depending on, some principle of cognitive natural selection. ‘The method of the trial and elimination of errors belongs to *the logic of the situation*.’ What he showed was that, just as organisms can be considered as proposals shaped by the environment and exposed to natural selection, so linguistically formulated theories are proposed by human minds and exposed to falsification by empirical testing, or more generally by criticism by human minds. As Peter Munz puts it: ‘Organisms are embodied theories and theories are disembodied organisms.’<sup>39</sup>

Sharing thus an identical logic, an analogy may be drawn between the evolution of organisms and scientific theories, by which theories may be said to share much of the pattern of co-creative ‘self-giving’ proposed by Raven and Peacocke for the evolving world of organisms. It is true that mutations are generated randomly whereas ideas are generated by human reason, with purpose and creative insight injected into the background randomness; and the selecting environments are of course quite different. But, nevertheless, organisms live by the life and death of other organisms in much the same way that theories live by the life and death of other theories. Shared features are: the emergence in an environment constituted by others, the creative competition, the selective elimination in favour of others, the ‘given-ness’ of each for others and for the whole.

Today technology moves on at a much faster pace than theory or paradigm change. This highlights another striking scenario, in experimental science, of

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37 According to Derek Stanesby, in Spurway, N. (ed.) *Theology, Evolution and the Mind*, Newcastle: Cambridge Scholars Publishing, (2009), p. 96. See Campbell, D.T. ‘Evolutionary Epistemology’, in Schilpp, P.A. (ed.) *The Philosophy of Karl Popper*, La Salle, IL: Open Court (1974). I owe the insights of this paragraph to Stanesby.

38 Popper, K.R. *Objective Knowledge: An Evolutionary Approach*, Oxford: Clarendon Press (1972).

39 Munz, P. *Philosophical Darwinism: On the Origin of Knowledge by Means of Natural Selection*, London: Routledge (1993).

the principle of self-giving – the new and celebrated results drawing heavily on the passing life of the old and ‘obsolete’. Most experimental results are destined to be quickly superseded, but this often thankless work is essential in order that future work can build on it and be shaped by it. The rough data points shape the instruments that generate the finer data points. The off-stage drudgery and short-lived results of routine ‘normal’ science are indispensable for the development of science. The notion, common in our celebrity-struck culture, that isolated genius is all and the mediocre are ultimately superfluous, is fundamentally wrong-headed. Many false starts, bad misses and dead-ends go into enabling the ultimate triumph, the final goal. Countless unsung explorers, measurers and map-makers of the unknown have given their lives in the enterprise of opening up the heights and depths to others.

‘Good death’ is the presence of the past, giving its substance and potentiality – all its life – to be incorporated via the present moment into the life of the future. It is the creative cycle of physical life and death portrayed in Psalm 104. It is the world of mental constructs, equally with the world of physical entities, constantly re-thought, the new out of the old, in a flux of becoming that involves constant dying and bringing forth of new conceptual life. It is the theme of self-sacrifice and each-given-for-others that runs through the music of Christian doctrine. It finds its parallel in the ‘cloud of witnesses’ in the New Testament letter to the Hebrews, each in their dying communicating faith and hope to those living after them. It is the rootedness of each spatio-temporal being in a medium constituted by all that has been, and perhaps even all that will be, or ‘is’ in the eternal creative act. For us to be what we are, involves a Space-Time Universe.

### **The significance of the individual**

In some sense the individual is sacrificed for the whole. But what is the individual in itself? How do we assess individual value in the light of the givenness of all things? How does the doctrine of the resurrection of Christ impinge on the saga of ‘good death’? If we take the life of some seemingly insignificant creature – a life apparently wasted, ‘solitary, poor, nasty, brutish and short’, can we find eternal significance there? Certainly, ecology concurs with Christian theology in asserting that this creature counts, as does each blade of grass made to sprout ‘where no man lives’ in ‘a desolate wasteland’, as the Lord said to Job (Job 38:25-27). Each creature pours out its momentary vitality and beauty, celebrating the astonishing resilience and fecundity of a processing world of things that have been; honouring its creator by existing now and by contributing far more than we could have guessed, before the advent of chaos theory, to the ongoing making of the world of things yet to be. Nothing is wasted: this is the crucial difference between the two images, compost heap and scrap heap. But the Christian doctrines of redemption and restoration of all things, and of ‘the resurrection of the body’, take us much further, especially in the light of our increasingly acknowledged connectedness with and depend-

ence on all bodily things. In Jeremy Law's well-depicted vision of the redemption of evolution, 'Neanderthals are decisively not a mere working sketch to be consigned to the dustbin of history as inherently surpassable. They rather are lost strands of conversation waiting to be taken up again by God.'<sup>40</sup> This fragment of the conversation is neither isolated nor incoherent – Neanderthals played their part as sparring partners or pace-setters for *Homo sapiens*. They are due honour for this and much more.

The soil from which the plant is fed, and the 'dust' from which the human body has been formed, are constituted by countless numbers of once-living things, each given for others. Stars 'died', and insects died, that I might be, as physical creature. The Lamb of God died that I might be, as fully personal child of God. It is consistent with this vision that each momentarily existent creature in the Space-Time Universe is eternally present to its Creator; each matters in communal co-creation, shares in the glory of the redemption, participates in the resurrection (of bodies?) and the life of the new Heaven and Earth, and is celebrated in the consummation. The whole, the mechanism, the system, exists for the ultimate redemption and perfection of each participant creature.

## Conclusion

According to Jeremy Law, 'the process of evolution provides a theological advantage in this task of theodicy over the essentially static view of the past, for it affords the inevitable death of individuals a new significance. Death has been the engine of development of protean forms of life.'<sup>41</sup> The aim of this paper has been to draw out some of this positive significance and what it entails for our view of nature and our view of the mathematical and scientific enterprises. In particular, it suggests a fundamental difference in attitude – mirrored in Christian ethics regarding the poor, the weak and the old – to predecessors, to 'losers', the 'outmoded', the provisional and the extinct. This view has potential for shedding new light on the nature of the work of scientific and mathematical communities and providing a sound theological rationale for the observable passions of their members and the deep-rooted ethics and gracious exchanges of their institutional structures. It sounds a call to a truly eucharistic science:

*Blessed are you, Lord, God of all creation. By your goodness we have this mathematics and science to offer, which the Universe has given and human minds have made. We offer to you ourselves, our theories and our communal engagement with reality, to do your work in your world.*

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40 Spurway *op. cit.*, (37), p. 152.

41 Spurway *op. cit.*, (37), p. 132.