James Croll (1821–90) occupies a prominent position in the history of physical geology, and his pioneering work on the causes of long-term climate change has been widely discussed. During his life he benefited from the patronage of leading men of science; his participation in scientific debates was widely acknowledged, not least through his election as a Fellow of the Royal Society in 1876. For all that, the intellectual contribution that Croll himself considered to be of most significance—his articles and two books on metaphysics—has attracted very little attention. In addressing this neglect, it is argued here that Croll’s interest in metaphysics, grounded in his commitment to a Calvinist form of Christianity, was central to his life and thought. Examining together Croll’s geophysical and metaphysical writings offers a different and fruitful way of understanding his scientific career and points to the wider significance of metaphysics in late-Victorian scientific culture.

Keywords: James Croll; metaphysics; geology; religion; evolution
of Croll’s metaphysics provides a way of contextualizing his scientific investigations and filling out our understanding of his life and thought. It also directs attention to the importance attached to metaphysics among the elite men of science that Croll was anxious to court and debate.

In what follows, I provide an outline of Croll’s intellectual biography centred on his passion for metaphysics. A brief sketch of some formative influences and a synopsis of his first book, *Philosophy of Theism*, help to set the scene. The next section examines how the arguments presented in *Philosophy of Theism* informed Croll’s later scientific work. Particular attention is paid to the underlying metaphysical disagreements that sharpened and shaped the dispute between Croll and the physiologist and oceanographer William Benjamin Carpenter. The final section explores Croll’s participation in debates about the metaphysical consequences of the ‘doctrine of evolution’ in the closing years of his life. All of this is to demonstrate that metaphysical considerations informed the full range of Croll’s scientific interests and were a vital part of his engagement with a wider scientific and intellectual community.

FOUNDATIONS

James Croll was born in 1821 in Little Whitefield, a small village in the parish of Cargill a few miles north of Perth. He was the second of four sons; two died in infancy and his surviving brother suffered from debilitating kyphosis. Croll’s father, as well as cultivating a small plot of land, worked for much of the year as a stonemason, and his mother came to rely on Croll’s help with keeping the croft. These circumstances—along with Croll’s struggle with severe headaches from an early age—meant that he spent only six years in formal schooling supplemented by a little private instruction at home. His interest in science began at the age of 13 years through reading the *Penny Magazine* and was further encouraged by Thomas Dick’s *The Christian Philosopher* (1823) and Rev. Jeremiah Joyce’s *Scientific Dialogues* (1803–09). For all the importance Croll attached to this, it was his spiritual conversion that carried most significance. His parents were members of the Congregational Church in Perth, and Croll was raised in that tradition. Notably, however, it was only when aged 17 years that Croll began to take much more seriously the faith that he had been brought up to profess. In his autobiography Croll traces his conversion to reading *Human Nature in its Fourfold State* by the Scottish divine Thomas Boston (1676–1732). The influence of this popular religious book was still evident by the time that Croll wrote his autobiographical sketch not long before his death in December 1890. In writing of the twists and turns of his life and his struggles with chronic ill health, Croll evoked the ‘strange dispensations of providence’, a phrase—and a way of thinking—lifted directly from Boston’s book.

Croll’s intellectual and religious development continued during a particularly unsettled period in his life. On leaving home, he was employed as a millwright and subsequently spent time as a shopkeeper. During these years he continued his own education chiefly by reading philosophical and theological works. It was Croll’s immersion in Jonathan Edwards’s *Freedom of the Will* (1754) over several months in 1847 and 1848 that convinced him that Calvinism rather than Arminianism was the most intellectually rigorous and consistent form of Christian belief. From then onwards, Edwards’s writings provided the mainspring of Croll’s metaphysical reflections. Following Edwards, Croll
now believed that God exercised complete control over human decisions and directly
determined all the operations of nature. Edwards’s account of divine action also prompted
Croll to develop what would become his signature metaphysical argument, namely that
the ‘production of force’ in nature was ontologically distinct from the ‘determination of
force’ and that the latter was immediately and continuously caused by God.  

To supplement this close study of Edwards, Croll turned to the Scottish ‘common sense
philosophy’ of Thomas Reid, James Beattie and Dugald Stewart. Croll was particularly
impressed by Beattie’s accessible account of Reid’s realism, which he found to be an
effective antidote to scepticism about ‘the foundations of certainty’. Croll was persuaded,
in other words, that human perception of the external world is reliable, that nature is
intelligible, and that whatever begins to exist has a cause. This reading of Reid and
Beattie was subsequently tempered and refined by Croll’s study of Immanuel Kant’s
philosophical corpus. Although concluding that Kant’s transcendentalism led to an
untenable idealism, Croll came to regard the Prussian philosopher as second only to
Edwards in terms of formative influence. Yet for all the influence of Kant and Scottish
common sense philosophers—all of whom, despite their obvious differences, defended the
freedom of human volition—Croll’s thinking remained firmly tied to Edwards’s rigid
theological determinism.

Publishing a short pamphlet on ‘predestination’ in 1854 gave Croll a taste for putting his
arguments in print. In 1857 Croll, without work, found himself ‘at perfect leisure . . . to
draw up some thoughts on the metaphysics of theism’. The resulting book-length treatise was
Croll’s first major publication. Printed in Glasgow and published anonymously in London,
it began with a defence of the necessity of metaphysics for any successful argument for
God’s existence and ranged across a number of recondite areas of philosophy including
the nature of causality, determinism, human volition and Kantian notions of freedom. The
aim was to establish the most appropriate method for making a sound case for the
existence of God. The argument was that only indubitable metaphysical principles would
be adequate for that task. Too many writers, Croll suggested, had assumed that
multiplying examples of ‘contrivance’ in nature provided secure grounds for a belief in a
divine designer. The atheist need not deny the facts but could and did deny the inference
drawn from them. Croll’s objective, then, was to provide an account of the nature and
necessity of divine action not reliant on what he saw as a naive form of natural theology.

An important component of his argument was a defence of metaphysics in the face of
scepticism about its validity or necessity. To illustrate the folly of refusing the aid of
metaphysics, Croll supplied a sharp critique of his countryman Hugh Miller (1802–56).
According to Croll, although Miller had demolished a version of the ‘development
theory’ through an appeal to geological facts, his efforts would provide only a temporary
reprieve. As a matter of course, another ‘genius’ would overcome Miller’s objections and
provide a more satisfactory developmental account. More than that, the atheist geologist
or physiologist could with impunity assert that knowledge of final or efficient causes ‘lies
beyond the reach of the human mind’.  
The key to winning the debate, then, did not lie
in appeals to the working geologist or in long lists of ‘contrivances’ in nature.

Eschewing an a posteriori argument for God’s existence, Croll argued that theism could
be successfully defended only by first demonstrating the truth of the axiom that ‘every event
must have a cause’. This was an argument made by Edwards in his Freedom of the Will but
it was placed in relation to later developments in metaphysics and alongside contemporary
scientific claims. Croll was aware that Kant considered this principle a transcendental law
regulating human cognition and not a law of nature-in-itself. Against this Kantian move, Croll called on Thomas Reid to argue that no good reason could be given to deny the conviction that this ‘fundamental law of our intelligence’ mirrored reality. Croll did, however, qualify this common sense conclusion by abstaining from other dogmatic assertions about what constituted the foundational rules of thought and the reality they were supposed to reflect. This reserve was generated as much by Croll’s commitment to Edwards’s arguments against common sense libertarianism as it was by Kant’s transcendentalism. This caution aside, Croll nevertheless insisted that the principle ‘every event has a cause’ was indeed an indubitable metaphysical foundation on which to build a solid case for the existence of God. This claim would become the linchpin of Croll’s subsequent attempts to offer a metaphysical basis for theism in a scientific age.

Croll’s argument, with its critique of inductive natural theology and its reliance on a fundamental axiom about the nature of causality, was not particularly original. Although there is no evidence of direct influence, Philosophy of Theism bears a striking resemblance to William Josiah Irons’s The Whole Modern Doctrine of Final Causes (1836). Like Croll, Irons insisted that moving from observed contrivances to a divine designer was deeply problematic. He also argued that the principle ‘whatever begins to be has a cause’ was a fundamental ‘truth of reason’ that pointed to intelligence as the only true cause. Where Irons and Croll diverged dramatically, however, was on the subject of human ‘free agency’. Irons was convinced that humans were free intelligences and were thus true causes. Croll, staying faithful to Edwards, disagreed. God alone was the true cause of everything including human volition. Irons was also more resolute in his scepticism about the very possibility of a ‘proof’ of God’s existence. He allowed that the principle ‘whatever begins to be has a cause’ pointed to ‘some cause of all things, which is intelligence’ but denied that this secured anything like a belief in one eternal God. Croll, in contrast, believed that his doctrine of causality cleared the way for a definitive proof of the existence of a single and supreme intelligence.

The most original aspect of Croll’s argument was the essential distinction he drew between the production and the determination of a particular event, act or force. This allowed him to argue that the mere production of a certain ordered occurrence in nature did not account for its ‘disposition’ or direction. There was no such thing as a self-determining cause. Living organisms provided the most obvious example for elaborating what Croll was driving at: the ‘dispositions’ and ‘arrangements’ of organic forms could only be explained if the idea of those forms existed before their appearance. It followed that a supreme intelligence was the direct cause of ‘the determination of [all] motion’. Although this divine agency was first and foremost intellective, it necessarily followed that it operated according to will and desire or ‘sensitivity’. This argument veered towards Edwards’s occasionalism and allowed Croll to maintain a clear separation between an eternal God and a contingent universe.

With just 500 copies published, Croll’s Philosophy of Theism did not circulate widely. It did, however, receive review attention in several religious periodicals. The reception was mixed, but most reviewers noted the cogency of at least some of the argumentation. The more positive reviews welcomed Croll’s attempt to provide a metaphysical counterpart to more ‘empirical’ defences of theism. Others were more critical, particularly of the short shrift that Croll gave to Paley-style natural theology. James Morison, the anti-Calvinist editor of The Evangelical Repository, penned the most sustained critique. Not surprisingly, Morison took exception to Croll’s ‘roundabout echo’ of Edwards’s
arguments on free will and found Croll’s ‘autocratic tone’ jarring. In Morison’s assessment, Croll’s argument boiled down to ‘mere verbal legerdemain’ and ‘shed little light’ on an important subject.\(^{18}\) There is no reason to think, however, that this indictment did anything to put Croll off metaphysics. Morison’s sharp rebuke was not designed to terminate the conversation or discredit Croll’s abilities as a thinker. Before his conversion to Calvinism, Croll had for a time attended Morison’s church in Glasgow and, despite their sharp differences, they remained on friendly terms.

Shortly after Croll’s book appeared he secured a position as a writer for a Glasgow temperance newspaper. Then, in 1859—having impressed Walter Crum, President of Anderson’s University in Glasgow—Croll found a more permanent position as a museum caretaker. The new post brought Croll into contact with local geologists and with other leading scientific figures including William Thomson, Crum’s son-in-law. It also allowed him access to the library of the Glasgow Philosophical Society. On his own account, Croll found himself torn between continuing his metaphysical inquiries and making the most of this new opportunity. His mind, he noted, was ‘evenly balanced between the love of physics and the love of philosophy’ so that it took ‘a strong effort of will’ to concentrate on one or the other.\(^{19}\) The wealth of scientific texts in the library and Croll’s proximity to influential men of science tipped the balance. This did not mean that metaphysics was eclipsed. Croll, after all, was convinced that ‘it matters not in what science, or in what part of any science we begin, all our explanations at last end [in metaphysics].’\(^{20}\) Not surprisingly, then, the draw of metaphysics continued to influence Croll even as he deliberately turned his attention to science.

**Caught Between Worlds**

Croll’s first scientific papers, published in 1861 and 1862, dealt not with geology or astronomy but with the nature of electrical currents. These appeared in *Philosophical Magazine*, a periodical that published the work of prominent natural philosophers, including William Thomson, Croll’s unofficial patron. Croll also became fascinated with the science of heat and published a series of short papers on the subject in *Philosophical Magazine* and the *Chemical News*. It was, however, his 1864 article on the ‘physical cause’ of secular changes in the Earth’s climate that made his reputation as an original scientific thinker and helped secure his appointment in 1867 to the Scottish branch of the Geological Survey.\(^{21}\) The basic premise was that variation in the eccentricity of the Earth’s orbit lay behind major changes in global climate. Pronounced eccentricity led to an ice age or ‘glacial epoch’ marked by periods of extreme cold that, as a result of the precession of the equinoxes, switched several times between the Northern Hemisphere and the Southern Hemisphere. The novelty of the argument lay in the claim that orbital variation *indirectly* caused climate change by altering the operation of certain geological ‘agents’, the most important being ocean currents.\(^{22}\) An interest in fluid mechanics and thermodynamics helped Croll develop this line of inquiry that was later fleshed out in *Climate and Time*, published in 1875. Here Croll also expanded on related arguments about geological time.\(^{23}\)

Although ostensibly free from metaphysical concerns, *Climate and Time* rested in a number of ways on Croll’s philosophical commitments. Most obviously, his metaphysical argument for the existence of God meant that Croll harboured no compelling theological
reason to resist estimates of geological time prevalent among geologists and evolutionists. Croll’s favoured metaphysical arguments also shaped his science in more subtle ways. There was, for example, a methodological symmetry between his metaphysical investigations and his scientific ones. Both began with fixed ‘principles’ rather than observed facts. This common starting point was not about expediency or personal preference but was ultimately grounded in Croll’s metaphysics. Before dealing with these more subtle crossovers, the ways in which Croll’s metaphysics more explicitly punctuated and framed his participation in debates about geological time deserve further comment.

Geological time and molecular teleology

In addition to providing geologists with an explanation for ice ages, Croll argued that his theory provided, for the first time, an absolute measure of the date and duration of more recent geological periods. In 1866, using a formula developed by the French astronomer U. J. J. Leverrier (1811–77), Croll calculated the variation in the eccentricity of the Earth’s orbit first over 1 million years and then, in 1868, extended it back to 3 million years before 1800 and 1 million years into the future. From this it was possible to pick out periods of severe cold and to correlate these with geological evidence of previous ice ages. Croll’s interest in dating successive geological periods in an absolute sense and in the related question of the age of the Earth continued to occupy him over a period of 20 years or more.

In all of Croll’s engagement with measuring geological time there is a distinct lack of concern with whether or not an old Earth was compatible with a biblical account of creation. As a devout Congregationalist, Croll might have been expected to address an issue that many of his co-religionists regarded as an urgent challenge. This apparent indifference to the religious implications of an old Earth is evident in Croll’s engagement with William Thomson’s better-known contributions to the age of the Earth controversies in the mid-Victorian period. Although Croll broadly adhered to Thomson’s argument that the Earth was likely to be less than 100 million years old, he did not use this figure to cast doubt on uniformitarianism or on Darwin’s theory of evolution. Rather, he suggested that the anxiety among geologists that these estimates did not provide sufficient time for the uniform and gradual action of geological agents to create observed landforms was misplaced. To ease that anxiety, Croll proposed a simple thought experiment that would convey an immediate sense of geological time scales. Imagine, he suggested, a strip of paper 1000 inches in length representing 1 million years running around a spacious room. One-tenth of an inch was equivalent to 100 years—the maximum duration of a person’s life. This mental jolt, Croll supposed, would help geologists to reconsider their impression that the Earth had to be much older than physicists were suggesting. It is notable that Darwin used Croll’s illustration in the fifth edition of the *On the Origin of Species* (1869) to suggest that, although tens of millions of years seemed to be ‘a very short period for so many and such great mutations in the forms of life, as have certainly occurred’ it need not be thought insufficient.

Croll was quite happy to offer Darwin some comfort. At the same time, he was also anxious to provide succour to those who may have felt that ‘millions of years’ squeezed God out of the picture. Somewhat unconventionally, Croll provided this in the middle of a series of three scientific papers on the age of the Earth published in *Philosophical Magazine* in 1868. At the heart of a discussion about how best to conceptualize
geological time Croll offered to his readers a succinct summary of his metaphysical understanding of divine action. Every part of nature, he suggested, from worlds to atoms, is ‘evidently working out a final purpose, according to a plan prearranged and predetermined by the Divine Mind’. This was not deism—in Croll’s scheme the ‘Divine Mind’ predetermines final purposes not at the beginning of time but ‘from all eternity’. Instead, it underlined Croll’s conviction that God was continually active in the world not simply as the ultimate author of ‘ordinary providence’ but in the more arresting sense of causing immediately and constantly the direction of all motion. This metaphysical aside contravened the practice of avoiding such matters in scientific papers published in *Philosophical Magazine*. This suggests that Croll did not include it without due thought. It allowed him to assert his belief in God while at the same time engaging with a subject frequently regarded as a threat to traditional religious belief.

This was not the only occasion during this period on which Croll made this kind of intervention. Four years later, Croll gave a much fuller account of his metaphysical argument for God’s existence in the pages of *Philosophical Magazine*. Entitled ‘What determines molecular motion?’ the target of his article was Thomas Henry Huxley. Importantly, it was not Huxley’s attack on Thomson’s estimate of geological time that Croll found theologically troubling. Croll resisted Huxley’s attack on Thomson on scientific grounds and tended, in any case, to argue for a less conservative estimate of the Earth’s age than his one-time mentor. Instead, Croll’s target was Huxley’s claim that ‘the whole world, living and not living, is the result of the mutual interaction, according to definite laws, of the forces possessed by the molecules of which the primitive nebulousness of the universe was composed.’ Against this naturalistic account of ‘molecular teleology’ Croll argued that force as such cannot provide an explanation for its ‘mode of operation’. Using again the distinction between the production of motion and the determination of motion, he argued that even planetary orbits—one of Croll’s trademark scientific interests—could not be explained by only appealing to the combined action of centrifugal and centripetal forces. The combination of these forces, like the exploding gunpowder in a rifle, provided an account of the production of movement but could not explain the specific path taken by the projectile. In addition, something ‘other than force’ was required. Repeating another argument made in *Philosophy of Theism*, Croll insisted that this was even more apparent when considering the precise disposition of molecules in living organisms. Physical and chemical ‘energy’ was a necessary but certainly not a sufficient cause of life. Heat, for example, ‘produces dissolution not evolution’. Like Huxley, Croll believed that Darwin’s theory of natural selection could not dispense with some form of ‘molecular teleology’. Unlike Huxley, however, Croll concluded that this form of teleology must mean ‘there is something else to be known other than mere force before we can penetrate the mystery of nature.’ Among other things, this metaphysical argument—rather than a scheme harmonizing the ‘facts’ of divine revelation and the empirical findings of science—meant that Croll was unshackled by theological worries about an almost inconceivably old Earth.

**Metaphysical undercurrents**

Croll’s ongoing interest in metaphysics had other more indirect effects that subtly but decisively influenced the shape, direction and content of his scientific work. As already suggested, there was a procedural symmetry between his metaphysical and scientific
thinking. In both cases Croll resisted making observed facts the definitive starting point for theorizing. As Croll put it in *Climate and Time*, 'no amount of description, arrangement, and classification, however perfect or accurate, of the facts which come under the eye of the geologist can ever constitute a science of geology.... geology, like every other science, must possess principles applicable to the facts.' This clearly echoed his insistence that only watertight metaphysical principles were sufficient to construct a properly rational argument for the existence of God and that it was impossible, without a clear grasp and justification of these principles, to infer certain conclusions from matters of fact.

More significant, however, was the underlying metaphysical rationale for Croll’s insistence on the importance in science of starting with clear physical principles. An appeal to the ‘laws of geological agents’ was, Croll suggested,

> no mere arbitrary mode of procedure which may be adopted in one science and rejected in another. It is in reality a necessity of thought arising out of the very constitution of our intellect; for the objective law of the agent is the conception by means of which the effects [of the agents] are subjectively united in a rational unity.

In other words, with Kant, Croll was convinced that the intellect operated according to certain *a priori* concepts, but against Kant, Croll believed that these concepts or ‘laws’ mirrored the rational structure of nature, which itself directly depended on the continuous action of an all-wise God. It was a short step from this position into the kind of metaphysical territory that Croll was, for now, consciously excluding from his immediate field of interest. For all that, the unspoken implications were clear: geological principles not only regulated the human intellect but could also be traced to the continual and immediate action of God. Of course, in terms of an intellectual division of labour, a clear separation remained between Croll’s conception of science and of metaphysics. Even so, for Croll science ultimately rested on a belief in a world ordered according to the workings of a supreme intellect. Physical principles and their analogues, natural laws, far from being independent agents in nature, were simply descriptions of the ongoing operations of the divine mind.

Croll’s underlying metaphysical commitments come into clearer view when set alongside those of his chief intellectual adversary, William Benjamin Carpenter (1813–85). Famously, Croll and Carpenter participated in a rancorous and prolonged debate over the physical causes of ocean currents in the late 1860s and early 1870s. For all the importance attached to scientific argumentation, the debate was about more than science. A metaphysical dispute simmered beneath the surface.

By the time that Carpenter crossed swords with Croll over the cause of ocean currents he was a senior scientific statesman. His election as President of the British Association in 1872 was in recognition of his major contributions to physiology, comparative psychology, botany and oceanography. However, like Croll, Carpenter—a life-long Unitarian—was also deeply committed to defending theism against the irreligious ‘tendency of the age’. His defence was made on the assumption that scientific advances had ruled out traditional arguments for the necessity of divine action to explain nature’s existence and organization. His argument, made since the 1840s, that physical and vital ‘energies’ in nature were not ontologically distinct but were closely correlated ‘modes’ of the same force, had made him amenable to the evolutionism found in *Vestiges of the Natural History of Creation* (which he helped to revise) and, later, in *On the Origin of Species*. His interest in human psychology led him to argue that there was also a close correlation between conscious human volition
and the ‘automatic’ or reflex actions of the nervous system. Perhaps not surprisingly, Carpenter’s model of divine action drew a direct analogy between the free actions of the human will over the automatic reflexes of the body and the relationship between the divine will and nature. This analogy assumed that divine and human volition were self-determining and ‘free’. And a consequence of this stress on an unrestrained ‘will’ rather than on ‘intellect’ was a certain amount of scepticism about discerning God’s thoughts in nature. It also encouraged an emphasis on field observations as the final arbiter between competing geological theories. Carpenter’s clearest exposition of this view was given in his Presidential Address to the British Association in 1872. The ‘laws of nature’, as formulated by generations of human observers, must be taken to be provisional at best. Only a few of these so-called laws could be regarded as universally valid and even then it was necessary to maintain a ‘reserve of the possibility of something different’. The practical consequences were obvious. It was essential to subject any explanatory account of a particular natural phenomenon to the ‘trial of experience’. This was especially true of geology, which was not yet in a position to appeal to secure physical principles.

The contrast with Croll was stark. Croll, as we have seen, did not believe that human or even divine volition was self-determining—every act, including the ‘act’ of willing something, had a predetermining cause. Moreover, instead of pointing to the operation of the divine will, he emphasized divine thought or intellect. In this, as so often, the influence of Jonathan Edwards was evident. Croll clearly subscribed to Edwards’s view that ‘God’s will is steadily and surely determined in everything by supreme wisdom.’ It followed that nature, as determined by a supreme intellect, had a clear rational structure. This structure also governed human cognition. It was thus mistaken to think that the human mind simply fumbled its way towards laws by generalizing from a series of sense observations. Physical principles, to be sure, did not spring directly from human minds fully formed. Even so, they had a more certain basis than provisional hypotheses generated from fact gathering.

The specific theories of ocean currents championed by Croll and Carpenter thus rested on their divergent understanding of divine action and scientific method. True to form, Croll insisted that his argument that ocean currents were produced by systems of prevailing winds was based on clear physical principles. His repeated complaint against Carpenter’s account was that it relied on a hypothetical cause contrary to known physical principles, particularly those derived from the science of heat. This was especially true, Croll maintained, of Carpenter’s central claim that the difference in the density and column height of cold polar water and warm tropical water was the ‘primum mobile’ of ocean circulation. This proposal, Croll believed, was ‘wholly irreconcilable with the ordinary principles of mechanics’.

Although Carpenter was sensitive to this sort of criticism and enrolled other men of science better versed in physics to deflect it, his own explanatory scheme leaned heavily on observations made on board survey vessels. For Carpenter, Croll’s account was too prepossessing, relying as it did on a dogmatic espousal of fixed principles. As he put it in a paper read to the Royal Society in 1871, ‘no disproof of the validity of [my] explanation can neutralize the inferential evidence in its favour...and I cannot protest too strongly against the statement that no body of observations can establish a doctrine.’ It is also telling that in his defence of his understanding of natural laws made as President of the British Association he used as his leading example the expansion of water as it approaches freezing point, a natural fact that contradicted the ‘law’ that cooling bodies
necessarily contract. This exception to a natural rule meant that cold water could provide ‘the immense motor power’ necessary to drive ocean circulation.41 Ultimately, Carpenter’s anti-necessitarian view not only reflected his account of natural laws as provisional human perceptions of nature’s uniformity but was also consistent with his voluntarist account of divine action.42

The result of these diverging views was a permanent standoff. By 1876 Croll gave up his attempts to fully overturn Carpenter’s theory of ocean currents. Although defending prevailing winds as the main cause of ocean currents was essential for maintaining his theory of secular changes in the Earth’s climate, it did not allow Croll to pursue in a more explicit way his metaphysical studies. This was a source of increasing regret. From 1876, despite the increased recognition of his scientific work, Croll expressed his desire to turn to more philosophical concerns. Once again, however, Croll had to resist this desire. He was in receipt of several small grants awarded to support ongoing scientific research, and this brought certain obligations. He also faced several high-profile criticisms of his theory of climate change and felt that a defence was necessary. For all that, Croll (figure 1) felt the constant tug of his long-held ambition to produce a major work on
metaphysics. As he later saw it, the remaining 15 years of his life involved a battle against circumstances to find the time and energy to turn again to his favourite study and first love.

**EVOLUTION AND DETERMINISM**

In 1879 Croll did manage to pause from other duties and intellectual work to consider again the subject of evolution and teleology. After a course of reading to acquaint himself with the latest literature, Croll put together an article entitled ‘Evolution by force impossible: a new argument against materialism’. It is clear from his search for an appropriate outlet for his argument that Croll wanted to attract the attention of influential thinkers. He first tried *Contemporary Review*, a journal known to Croll for its publication of articles concerned with the challenges of ‘modern thought’.43 After a long wait, his paper was rejected. Frustrated by this result, Croll wrote to Thomas Henry Huxley for help. Suggesting that the article would ‘please you though you certainly will not agree with it’, Croll asked Huxley to recommend it for publication in either *Nineteenth Century* or *Fortnightly Review*.44 Huxley’s reply does not survive, but from Croll’s reaction it is clear that Huxley was unwilling to recommend publication. Croll was stung. He wrote again and suggested that Huxley had ‘misapprehended the real drift of [the] argument’, which remained ‘fatal to any purely mechanical or physical theory of evolution’.45 In the end, Croll had to make do with the more congenial but less influential *British Quarterly Review*, a periodical aligned with evangelical Nonconformism.

Once again, Croll’s objective in his article was to counter the common belief that matter, motion and force provided a satisfactory account of molecular teleology. He began by arguing that the various branches of science were ‘converging towards molecular physics [or] into questions regarding the dynamical action of the ultimate particles of matter’.46 His argument then offered a further elaboration of the distinction between the production and determination of molecular motion. This distinction applied as much to ‘theories of life’ as it did to theories of (say) heat. Precisely because no force or energy was required to determine the directedness of molecular motion, the only possible explanation for molecular motion in whatever ‘mode’ it occurred was ‘intelligence or thought’. This provided grounds for reasserting his long-held conviction that ‘the fundamental relations of nature are identical with the conceptions of thought.’47

Moving beyond what he had formerly argued, Croll then turned his attention more explicitly to evolutionary accounts of organic nature. His argument, Croll suggested, was quite compatible with Darwin’s ‘great principle of natural selection’. More than this, natural selection provided a leading example of a directed force that was inexplicable without an appeal to a divine mind. In Croll’s view, selection as Darwin conceived it depended on ‘the way in which forces are adjusted’. In other words, Darwin assumed that force was in a fundamental sense ‘directed’—‘blind’ or indeterminate force could not do the job.48 For all that, Croll argued that the explanatory reach of natural selection—because it left entirely unexplained the molecular teleology that Croll held was fundamental—was limited. Natural selection could pick out the ‘best [organic] forms’ for preservation but could not cause the determination of molecular motion or the ‘inner cause’ of organisms. Natural selection therefore held a ‘subordinate position’ within a larger economy of causes in nature.
Although Croll had failed to persuade Huxley that his argument was worth publishing, when it did eventually appear in print it stimulated exchanges with several other prominent biologists and philosophers. Alfred Russel Wallace, although suggesting that ‘extreme materialists’ would shrug off Croll’s argument on the basis that ‘conceptions of eternal matter and forces are no more difficult than the conception of a determining power, which is neither matter nor force’, nevertheless found the article ‘very forcible and well reasoned’. George Romanes also wondered whether conceiving of matter and force as ‘permanent’ rendered Croll’s explanation unnecessary. Despite that sceptical query, Romanes conceded that their exchange would ‘have to end in another edition of my anonymous book, undoing the principal argument’. The philosopher Shadworth Hodgson (then President of the Aristotelian Society) found Croll’s appeal to ‘objective ideas’ in nature problematic, not least because he could not see how ‘intelligence or thought could be an agency’. He nevertheless allowed that Croll had established his main point that undetermined force or motion could not account for evolution.

The fact that Croll was engaged with these individuals and not with another set of, on the face of it, more congenial interlocutors is significant. Whatever the nature of Croll’s relationship with William Thomson—and it was clearly important at the start of his scientific career—he did not participate in Thomson’s circle of ‘North British’ physicists who, in rather different ways from Croll, made concerted efforts to undermine a materialist account of life and mind. The reasons for this lack of involvement are not easily recovered. Obvious differences in social position, education, occupation and denominational affiliation do not provide a satisfactory explanation. None of these prevented Croll from participating to some degree in Thomson’s circle or, at the very least, from engaging with their published arguments. More enlightening are the differences between Croll’s metaphysics and those proffered by Thomson and his confraternity. Most obviously, Thomson’s antipathy towards speculative metaphysics and his unabated enthusiasm for Paley’s argument from design set him fundamentally at odds with Croll. But more substantive differences also mattered. Unlike Thomson, Croll did not regard the ‘fortuitous concourse of atoms’ as the only grounds for explaining inanimate agency. Nor did he think animate agency had a mysterious capacity to direct molecular motion. The directionality, if not the brute fact, of all natural motion for Croll, whether organic or inorganic, was determined immediately by God and not by a fixed law, whether physical or biological. The use that Thomson and James Clerk Maxwell made of the notion of ‘free will’, both in relation to hypothetical entities such as Maxwell’s ‘demon’ and in relation to human beings and God, jarred with Croll’s adherence to Edwards’s theological determinism and his emphasis on divine intellect rather than divine will. This is not to suggest that metaphysical disagreement fully explains the strain in Thomson and Croll’s relationship. Thomson sided with Carpenter in the dispute over ocean currents; his obituary of Croll, read before the Royal Society, reminded his audience of this divergence of views. Even so, the significance of metaphysics for Croll, Thomson and other North British physicists meant that fundamental disagreements in that area were not easily overlooked. Arguably, the fact that Thomson’s metaphysics had significant scientific and political correlates placed further obstacles to enrolling Croll as an ally.

In the end, it was not the lack of support from others that prevented Croll from pressing on with his metaphysical critique of materialism. By 1883 Croll was in financial dire straits. Ill health had forced him to resign from the Geological Survey two years
previously, and his appeal for a civil pension failed despite support from a large number of notable scientists and politicians. Croll knew that work on metaphysics rather than science would not attract financial support and that a book on philosophy was unlikely to sell well. Shelving once again plans to concentrate on metaphysical inquiries, Croll continued publishing scientific papers. Between 1883 and 1890 Croll authored a handful of articles on largely geological or climatological topics. Collections of earlier articles were also gathered together in two books. The first, *Climate and Cosmology*, published in 1885, was put together from a series of short pieces responding to criticisms of his theory of climate change. Three chapters at the end of the volume dealt with the age of the Sun. The second book, *Stellar Evolution*, published in 1889, was also largely composed of previously published material, this time on the origin and age of the Sun and, even more ambitiously, on ‘pre-nebular evolution’. In both books, then, Croll moved to topics of a more speculative nature and ones that lay adjacent to explicitly metaphysical debates about the origin of the Universe, the Solar System and life. In the prefaces Croll also registered his desire to turn from physics to philosophy. In the preface to *Climate and Cosmology* Croll noted that ‘advancing years and declining health constrain me to husband my remaining energies for work in a wholly different field of inquiry—work which has never lost for me its fascination but which has been laid aside for upwards of a quarter of a century.’ In *Stellar Evolution* Croll promised a ‘future volume’ dealing with some of the metaphysical concerns that the book raised but did not tackle in detail.

It was only in the last few months of his life, with the help of an amanuensis, that Croll completed his last and, in his view, most important book, *The Philosophical Basis of Evolution*. It appeared just weeks before his death. Although curtailed by poor health, Croll’s ambitious aim was to examine the ‘fundamental principles’ on which the ‘doctrine’ of evolution rested. As before, Croll began with the axiom that every event has a cause. This principle presupposed that causes were directed to certain effects and, Croll insisted, such directionality or ‘determination’ could not be explained according to the nature or operation of the forces involved. It followed that evolution, which relied on a deterministic account of causality, could not be explained by referring solely to matter, force or energy.

To these basic claims Croll added additional arguments about evolution in conversation with contemporary biologists and philosophers. Among the most prominent was Croll’s take on natural selection. As in his earlier article, an emphasis on molecular teleology led Croll to question claims that natural selection provided an explanation for the origin of new organic forms. Croll insisted again that natural selection was a purely negative force that weeded out unfit varieties but did not in any sense ‘produce’ the varieties that survived. Natural selection was a necessary condition for evolution, but not a sufficient or even a primary cause. Croll, like other critics, noted that ‘divested of its figurative dress’ natural selection could have no ‘positive efficiency’ and provided no explanation for ‘favourable variations’. Because natural selection was in no sense ‘an agent...which acts’, it remained essential to posit ‘objective ideas’ to account for the specific arrangement of molecules making up any living organism.

Croll also offered a survey of evolutionists who, unlike Wallace and, for the most part, Darwin, did not consider variation as ‘indefinite’ but rather as channelled along particular paths. Although apparently sympathetic to this way of thinking, Croll expressed misgivings. He found, for example, Friedrich Albert Lange’s suggestion that there was a
chemical law of development that was independent of natural selection unsatisfactory. For Croll, a chemical ‘law of development’ could not account for the particular mode of molecular motion underlying organic forms. This mode, though interchangeable with other forms of energy such as heat, electricity or magnetism, could not be determined by those alternative forms. In the end, Croll did not attempt to adjudicate between the ‘neo-Darwinian’ selectionists such as Wallace and August Weismann and those who appealed to structural controls as a condition for, rather than a product of, natural selection. What remained unexplained by both camps was the specific and *sui generis* determination of molecular motion in living forms. This explanatory gap opened for Croll the opportunity to defend the real existence of formal and final causes, or plan and purpose, in nature.\(^{61}\) This did not automatically prove that ‘the plan was designed or the end purposed’, but in the final analysis and on metaphysical grounds such a conclusion was irresistible.

*The Philosophical Basis of Evolution* was not widely reviewed but it did leave a mark. One of most favourable accounts appeared in *Dublin Review*, despite being judged as written somewhat in the ‘vein of Scotch Calvinism’.\(^ {62}\) The review’s author, F. R. Wegg-Prosser, an independently wealthy Catholic, welcomed Croll’s demonstration that belief in God was not only compatible with the ‘evolutionary hypothesis even in its full Darwinian shape’ but also that theism ‘necessarily underlies the whole [evolutionary] system’.\(^ {63}\) James Iverach, Professor of Apologetics at the Free Church College in Aberdeen, echoed Wegg-Prosser’s positive assessment. Croll brought to one the most difficult questions in philosophy and theology ‘qualities of the highest order’ and the book was ‘worthy of his high reputation’.\(^ {64}\)

Such appreciation was by no means universal. In *Nature* the comparative psychologist Lloyd Morgan found merit in some of Croll’s claims but concluded that his defence of theism was unoriginal and overly reliant on ‘well-worn arguments’. Worse, talk of ‘objective ideas’ in nature came ‘perilously near a metaphysical as opposed to a scientific conception’.\(^ {65}\) It might have been more damning from Croll’s point of view to say that positing the existence of ‘objective ideas’ came perilously close to an empirical rather than a metaphysical claim. But he was no longer alive when Morgan’s review appeared. Instead, Oliver Lodge stepped forward as an unlikely ally and defended Croll’s assertion, apparently put in question by Morgan, that changing the direction of matter in motion involved no expenditure of energy. This claim was ‘perfectly correct’.\(^ {66}\) Morgan was quick to reply, conceding the point but denying the inference that the ‘direction of motion can be changed... by vital force, mind or will power’. To allow this—as Lodge and Croll did in their different ways—would be to ‘upset our notions of physical causation’ and collapse a still more important distinction between ‘physical and metaphysical control’.\(^ {67}\)

For all his criticisms, Morgan held back partly out of respect for the recently deceased Croll. Two months later, however, a review in the highbrow *Academy* showed no such restraint.\(^ {68}\) The reviewer found Croll’s metaphysical defence of theism antiquated, speculative and facile. To swiftly make the move from perceived order to a ‘sudden and large demand to straightway requisition a deity’ begged far too many questions. What was more, Croll had misunderstood Newton’s second law of motion. In the end Croll’s book teetered on the edge of absurdity. The only redeeming feature—Croll’s argument that ‘direction of energy can be accomplished without upsetting its conservation’—told against ‘materialistic monists’.\(^ {69}\) Oliver Lodge, the author of this rather savage review, had unfurled his true colours.
It may have been a case of the settling of scores. Croll had dismissed out of court Lodge’s ether theory in *Stellar Evolution*. Whatever the reason, the reviews by both Lodge and Morgan damaged Croll’s reputation in the very circles that he had long hoped to influence. Both reviewers had, of course, their own metaphysical commitments to defend and, given those commitments, it is no surprise that they found Croll’s book unpalatable. Lodge was allergic to traditional varieties of theism, which he found incompatible with scientific progress. Morgan was committed to a monist philosophy that, although not anti-theist, was certainly opposed to Croll’s dualism. Quite clearly, for Croll the divine mind and inert matter were ontologically distinct. The Creator did not simply breathe life ‘into a few forms or into one’, as Darwin famously (and perhaps disingenuously) allowed.\(^70\)
The entire cosmos, viewed at a molecular level, depended moment by moment on God’s creative action.

**CONCLUSION**

Ending on this metaphysical and religious note is not in harmony with how Croll is usually remembered. If he is mentioned at all today, it is as a humble ‘janitor’ who, through native genius and strenuous intellectual effort, made a significant, even astonishing, contribution to our understanding of the causes of ice ages. This echoes some of the widely circulated ways in which Croll was represented by his contemporaries. It is undoubtedly true that Croll’s scientific work achieved a hearing at the highest levels and was recognized as a major achievement. Charles Darwin, we might note, signed Croll’s certificate of nomination to the Royal Society with ‘real pleasure’.\(^71\) It is also true that as an autodidact, Croll fitted the Smilesian mould and was useful to those wishing to promote science as a route to social and intellectual improvement.

We can, however, contrast these ways of commemorating Croll with his own assessment of his life and work. In this telling, metaphysics is much more conspicuous. It was not just that metaphysics was Croll’s favourite study—he considered it the highest and most important form of intellectual inquiry. For Croll, science could not provide answers to the most fundamental problems of nature. Denying this narrowed the field of human investigation and undermined the foundations of scientific inquiry. Science itself not only inevitably terminated in metaphysics but depended, moment by moment, on metaphysically derived principles. No wonder, then, that he considered his article on ‘evolution by force impossible’ to be ‘by far the best thing I have ever written’\(^72\). Whatever might be made of these personal judgements, they underline the importance that Croll attached to his metaphysical studies and lend credibility to the argument that Croll’s two major works on metaphysics were much more than bookends to an entirely separate scientific career.

Yet it cannot be denied that as a metaphysician Croll was, to many, something of a failure. It hardly needs to be said that the reasons for this varied depending on who was making the judgement. Some can nevertheless be discounted. The downplaying of Croll’s metaphysics was not, for example, due to the fact that his philosophical arguments were hotly disputed. So, too, were many if not most of his scientific proposals. Nor was it due to the exclusion of metaphysics from the range of subjects thought worthy of discussion by the elite interlocutors that Croll especially wished to engage. Metaphysics had acquired a renewed fascination in the wake of debates about evolution. The success and influence of the
Metaphysical Society and, after its demise in 1880, the continued success of its unofficial organ, *Nineteenth Century*, is clear testimony to this. Both the Society and the journal also demonstrated that there was ample room for serious disagreement on metaphysical matters among the elite figures with whom Croll corresponded.

Perhaps the most convincing reasons for the marginalization of Croll’s metaphysics lie buried beneath polite refusals and in private correspondence. There are hints that queries about the appropriateness of Croll’s tone and argumentative style played a role. More obviously, however, Croll’s lifelong commitment to Jonathan Edwards made it difficult for him to win favour from those who associated the New England theologian with a harsh and outmoded Calvinism. This was the influential judgement of Leslie Stephen, for example. In an assessment of Jonathan Edwards that appeared in 1873, Stephen noted how exceedingly hard it was to ‘clear away the ... thick, hard and often revolting ... crust of ancient superstition’ that obscured the ‘genuine metal’ found in Edwards’s writings. Croll operated with what Stephen described as Edwards’s ‘elevated theory of the universe’ but he did so precisely because he was in whole-hearted agreement with Edwards’s much derided theological system.73

We might wonder as well whether Croll engaged the wrong conversation partners. As we have seen, despite relying on their patronage in other areas and borrowing heavily from their science, Croll did not make much attempt to participate in the metaphysical discussions of the ‘North British network’ of physicists. He clearly differed from them on a number of, for him, vital metaphysical issues and, true to form, maintained a critical distance isolating himself from a powerful informal lobby united in their opposition to materialism. Neither did Croll engage in any serious way with his fellow Calvinists, many of whom were deeply immersed in debates about the metaphysics and theological implications of evolution.74 With reference to this group, we might note that while Croll was in deep sympathy with the Calvinist character of much Presbyterian theology, in keeping with the emphasis of his own denomination on the autonomy of individual congregations, he maintained a fierce independence from its leading representatives. More specific reasons can also be suggested. It is likely, for example, that at least some leading Scottish Calvinists found Croll’s full embrace of Jonathan Edward’s determinism troublesome. In his account of Edwards published after Croll’s death, James Iverach worried that Edwards’s philosophical argument for determinism ‘is now held mainly by agnostics’.75 Edwards’s form of Calvinism did not seem to attract significant support among those most likely to be sympathetic to it.

There is, of course, a wider point to all of this. Exploring Croll’s struggles to promote his metaphysical arguments sheds light on more than his own biography. It also points to the wider significance attached to metaphysics in late-Victorian scientific culture. The resistance that Croll faced was not due to a lack of interest in metaphysical matters or because such concerns had been effectively excluded from the proper business of science. Something like the opposite may be closer to the truth. It was precisely because metaphysical disputes so often simmered under the surface of scientific debates that Croll’s trenchant articulation of Edwardsean metaphysics met with either stringent criticism or silence. Whatever might be made of Croll’s philosophical writings, bringing them back into clear view reminds us of the energy that his scientific contemporaries invested in defending their own far-from-marginal metaphysical concerns.
James Croll, metaphysical geologist

Notes


5 This autobiographical account appears in Campbell Irons, op. cit. (note 3), pp. 9–41.

6 Ibid., p. 25. See also T. Boston, Human Nature in its Fourfold State (William Collins, Glasgow, 1830), p. 289. Boston’s point is that although God’s ways are often inscrutable, the Christian cannot experience anything, however trying, that can undermine the assurance that they are in a permanent state of grace.


9 Ibid., p. 29.


11 Ibid., p. 101.

12 W. J. Irons, On the Whole Doctrine of Final Causes (London, J., G. and F. Rivington, 1836), pp. 73 and 76.

13 Ibid., p. 77.

14 Ibid., p. 129.


16 Examples include Br. For. Ev. Rev. 7, 466–468 (1858); Br. Q. Rev. 27, 562 (1858); MacPhail’s Edinb. Eccl. J. 24, 381–385 (1858); Tait’s Edinb. Mag. 28, 189 (1858); United Presbyt. Mag. 2, 413 (1858). Shorter notices appeared in a number of other religious periodicals.

17 See Tait’s Edinb. Mag. 28, 189 (1858).


19 Of course, in Croll’s thinking, this ‘effort of will’ was not self-caused but was ultimately determined by God.

20 Croll, op. cit. (note 10), p. 73.


22 Croll did not like his argument being described as ‘the eccentricity theory’.

23 A good general account of Croll’s work on geological time can be found in J. D. Burchfield, Lord Kelvin and the Age of the Earth (Macmillan, London, 1975), pp. 62–70 and 125–127.
Croll had published a short pamphlet on the bearing of geology and that of astronomy on the doctrine of creation in the mid 1850s but, as far as I am aware, this has not survived. A passing mention of the creation of Man 6000 years ago ‘according to the Mosaic chronology’ occurs in J. Croll, ‘On geological time and the probable date of the glacial and upper Miocene period’, Phil. Mag. 35, 363–384 (1868), at p. 382. Croll’s views on the ‘antiquity’ or the evolutionary history of humanity are not known.

Here I differ from Burchfield, who states that Croll, like Thomson, was opposed to uniformitarianism (Burchfield, op. cit. (note 23), p. 67). This difference is the product of Burchfield’s definition of uniformitarianism. As Smith and Wise (op. cit. (note 4), p. 593) point out, Croll did not oppose uniformitarianism as such (quite the contrary) but rather what he took to be exaggerated estimates of the Earth’s age. Nevertheless, Burchfield rightly notes the entirely different tenor of Croll’s arguments on geological time compared with Thomson’s and demonstrates the extent to which Croll’s position—particularly in his later work—was constructed against as much as for Thomson’s views.

Croll, op. cit. (note 24), p. 375.


No other author in the volume in which Croll’s metaphysical claim appears makes an equivalent intervention or raises theological concerns.


Croll, op. cit. (note 30), at p. 11.


Ibid., p. 4.

For a detailed account of the ‘Croll–Carpenter controversy’ over the cause of ocean currents, see E. Mills, The fluid envelope of our planet: how the study of ocean currents became a science (University of Toronto Press, 2009), pp. 44–81.


Ibid., p. 208.

Ibid., pp. 196 and 207.


This label is notoriously slippery but it does help to highlight a significant difference between Carpenter and Croll. Carpenter consistently emphasized volition rather than intellect in his accounts of divine action, and regarded God’s will as self-determinative (a conception that Croll found incoherent). He also accepted the possibility that God could depart from his orderly way of working if he so willed. See Carpenter, op. cit. (note 36), p. 241. In certain respects at least, Croll’s metaphysics was more intellectualist than voluntarist.

James Croll, metaphysical geologist

44 J. Croll to T. H. Huxley, 15 March 1882, Huxley Collection (hereafter HC), Records and Archives, Imperial College London, MS 121.51.
45 J. Croll to T. H. Huxley, 31 March 1882, HC, MS 12.349.
47 Ibid., at p. 62.
48 Ibid., at p. 63.
50 Ibid., p. 398.
51 Ibid., p. 403. Romanes was referring to his A candid examination of theism (Trübner & Co., London, 1878). There he used Spencer’s argument about the ‘persistence of force’ to undermine appeals to theism as the only viable explanation for order in nature. In a posthumously published article Romanes rejected Spencer’s argument and, without explicit acknowledgement, used Croll’s language of the ‘determination’ of force to argue that Spencer failed to provide an explanation for the ‘particular channel in which [a specific manifestation of force] flows’. In the end, theism provided ‘the only nameable explanation’. This was not quite the concession that Croll might have hoped for, because Romanes went on to argue that a number of intractable problems remained for the ‘natural theologian’ committed to this line of argument. G. J. Romanes, Thoughts on religion (Longmans, Green & Co., London, 1904), p. 33.
54 As Smith and Wise (op. cit. (note 4), p. xii) point out, Thomson’s ‘anti-metaphysical’ stance did not mean he was innocent of metaphysical assumptions.
55 Thomson’s obituary is reproduced in Campbell Irons, op. cit. (note 3), pp. 499–501. As we have seen, of course, this scientific disagreement had a metaphysical backdrop. The similarities between Carpenter’s and Thomson’s metaphysical views are worth noting.
56 A detailed account of Thomson’s views on God, natural law and free will and the relationship of those views to his science and his politics is found in Smith and Wise, op. cit. (note 4), pp. 84–99 and 612–645.
57 Campbell Irons (op. cit. (note 3), p. 374) hints that William Carpenter ‘prejudiced’ Gladstone against Croll’s application for a civil pension by suggesting Croll was an atheist.
61 Ibid., p. 159.
63 Ibid., at p. 371.
68 The critical tone of this review might be explained in part by Croll’s curt dismissal of Lodge’s arguments for the ether made during the latter’s London Institution lecture in 1882. Croll, op. cit. (note 59), at pp. 87–89.
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70 Darwin, *op. cit.* (note 27), p. 579. Citing from the 5th edition underlines the fact that Darwin retained this form of words in all editions of *The Origin of Species.*


75 Iverach, ‘Jonathan Edwards’, *op. cit.* (note 64), at p. 128.