Newton and Michelangelo*

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I wish to compare Newton and Michelangelo in the larger context of whether there is any similarity in the motivations of scientists and artists in their respective creative quests. There are many pitfalls in addressing this question: the motivations of individual scientists and artists are diverse; they are strongly dependent on personal tastes and temperaments; and a consideration of this subject in the abstract and in general terms will rapidly degenerate into dilettantism. On this account, I shall restrict my consideration to an example from the most rarefied level of creativity: Newton in writing the *Principia* and Michelangelo in painting the ceiling of the Sistine Chapel.

The *Principia* and the Frescoes, both in their realms are the supreme, unsurpassed expressions of human creativity. That their origins should be as similar as they are is an astonishing and a revealing fact.

Neither Newton nor Michelangelo began their masterpieces with alacrity or enthusiasm: Newton had to be persuaded by Halley and Michelangelo was forced by the imperious insistence of Pope Julius II. But once they started, their visions enlarged; and they both completed their great works in a time – about two years – that is hard even to imagine.

Let me first describe the story of the *Principia*: the origin of his ideas on the laws of gravitation, how they matured and how he came to write the *Principia*.

Newton's first thoughts on gravitation came to him in 1666 while he was sojourning in his manor in Woolsthorpe during the plague years. He deduced how the inverse square law of gravitational attraction between the Sun and the planets from Kepler's third law that the periods are proportional to the 3/2 power of the radii on the assumption of circular orbits. The argument was very simple:

Assume that the orbit is a circle of radius r described with a constant velocity v. Then

$$\frac{2\pi r}{v} = T,$$

where T is the period. By Kepler's third law

$$T \propto r^{3/2}.$$

Therefore

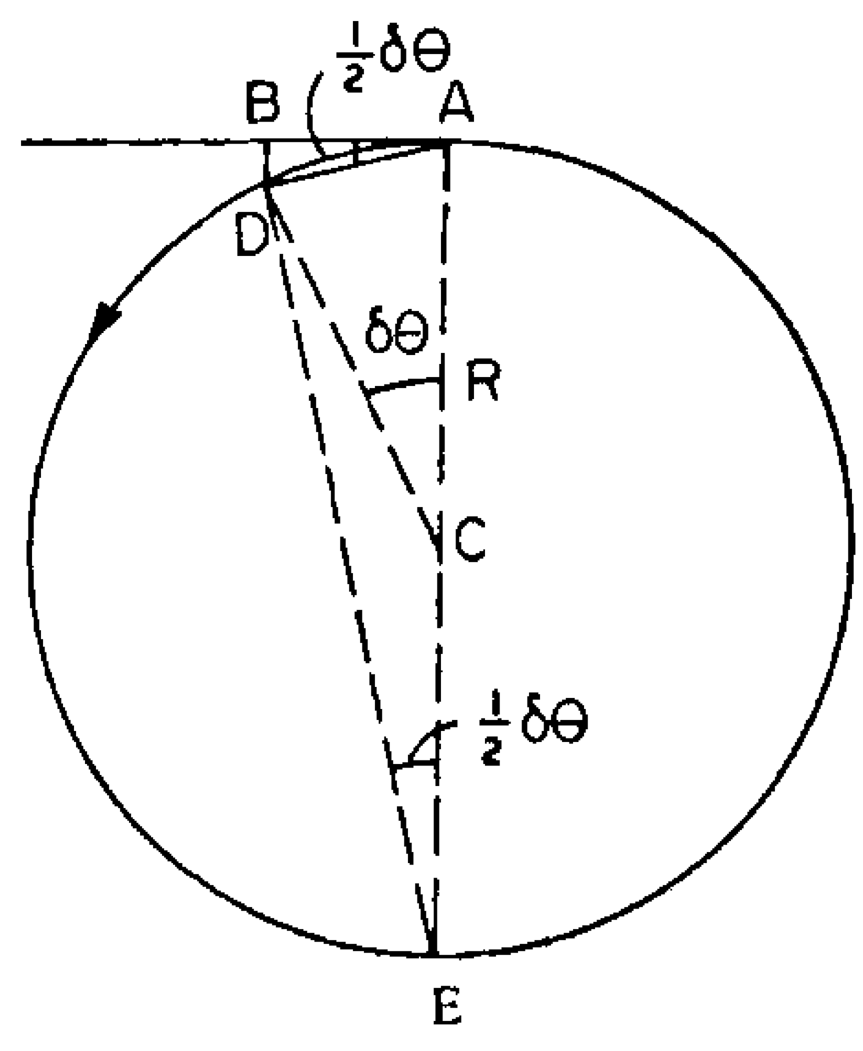
$$v^2 = \frac{4\pi^2 r^2}{T^2} \propto \frac{4\pi^2}{r},$$

and

$$\text{the centripetal force} = \frac{v^2}{r} \propto \frac{1}{r^2}.$$

Second, again on the assumption of circular orbits, the attraction between the earth and moon and the value of gravity $(= g)$ on the earth, i.e. the attraction of the earth on bodies on the surface of the earth, was compatible with the inverse square law of gravitation. And here again the arguments are simple:

In the following diagram the moon located at A at some given instant of time, will continue in the rectilinear path AB but for the attraction of the earth at C. It is the attraction of the earth that is responsible for the moon describing the circular orbit ADEA. Therefore BD represents the effect of the attraction. Thus,



$$\mathrm{BD} = \frac{1}{2}a_{cc}\left(\frac{\delta\theta}{2\pi}\right)^2 T^2$$

$$= \frac{1}{2}a_{cc}\left(\frac{R\delta\theta}{2\pi R}\right)^2 T^2$$

$$= \frac{1}{2}a_{cc}\frac{\mathrm{AD}^2}{(2\pi R)^2}T^2$$

$$= \frac{1}{2}a_{cc}\frac{\mathrm{BD\ BE}}{(2\pi R)^2}T^2$$

$$= a_{cc}\frac{\mathrm{BD}}{4\pi^2 R}T^2.$$

Therefore,

$$a_{cc} = \frac{4\pi^2 R}{T^2}$$

$$= \frac{39.48 \times 3.815 \times 10^{10}}{(29.74 \times 24 \times 3600)^2} \simeq 0.272$$

But a body (apple!) on the earth, attracted by gravity g $(= 978)$, accelerates it by the amount

$$a_{cc}\ (\text{of apple}) = 978$$

$$= 3614 \times a_{cc}\ (\text{Moon})$$

$$\simeq (60)^2 \times a_{cc}\ (\text{Moon})$$

In other words, the attraction of the earth falls off as the inverse square of the distance, since the ratio of radius of the moon's orbit and that of the earth is ~ 60.

Even though the results were promising, Newton did not pursue the subject further for another 13 years.

In 1679, stimulated by some correspondence with Hooke, Newton showed that Kepler's law of areas was not specific to the inverse-square law of attraction but that it was valid for any law of centripetal attraction; and further that for a body revolving in an ellipse, the law of attraction directed to its focus is inversely as the square of the distance.

Nevertheless, he was reluctant to publish his results because of his uneasiness with the assumption,

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$$\frac{a_{\text{ᴄ}}(☾)}{g}=\left(\frac{\text{Radius of the earth}}{\text{Radius of the moon's orbit}}\right)^2,$$

implies that the earth attracts objects on its surface as if its entire mass is concentrated at the centre – an assumption most emphatically against 'common sense' (unless one had known of its truth already). Newton was to prove the theorem in question in 1685 which he had not suspected before the demonstration.

The real story of Newton's development of his theory of gravitation with the concomitant writing of the *Principia* begins with Halley's visit to Newton in Cambridge in August, 1684 to inquire of Newton the character of an orbit that a particle would describe in a central inverse-square law of attraction. Newton's immediate response was that the orbit will be an ellipse and that he had established that result some years earlier. Halley, astonished at this prompt response, asked for a demonstration. Newton could not find his demonstration among his papers; and he promised to rework his proof and send it to Halley in due course. In trying to re-derive the result, Newton became sufficiently involved in the subject to give a course of lectures during the Michelmas term of 1684. He forwarded the substance of these lectures to Halley in November of the same year. Halley was so excited with what he received that he visited Newton again in November, and tried to persuade him that he should write out his lectures for publication.

After his visit to Newton in November, Halley reported to the Royal Society on December 10, 1684, that he had

> . . lately seen Mr Newton at Cambridge, who had shown him a curious treatise *De Motu*, which was promised to be sent to the Society to be entered upon their Register

Halley had, thus, at long last persuaded Newton to write out the results of his investigations for publication; and the writing of what was to become the *Principia* began in earnest.

Indeed, Halley was described by Conduit as 'the Ulysses who produced this Achiles'.

In the spring of 1685, Newton's attitude to writing the *Principia* changed when he proved, apparently after some initial difficulty, that the gravitational attraction of a spherical body on an external particle is the same as if its entire mass is concentrated at its center. Newton had not expected this result; and it is not difficult to imagine that it must have goaded Newton to further effort. As Newton wrote to Halley on June 26, 1686,

> I never extended the duplicate proportion lower than to the superfices of the earth, and before a certain demonstration I found last year, have suspected it did not reach accurately enough down so low, and therefore in the doctrines of projectiles never used it nor considered the motions of heavens

In an address given on the bicentenary of the publication of the *Principia*, J. W. Glaisher said,

> Newton proved this superb theorem – and we know from his own words that he had no expectation of so beautiful a result till it emerged from his mathematical investigation – that all the mechanism of the universe at once lay spread before him

Newton's initial expectation of quickly completing the task of writing was thus frustrated. But under Halley's discreet but constant persuasion and quiet encouragement, *De Motu Corporum* evolved and broadened, swelling first in the early summer of 1685 to a pair of related books and then to a third book on the 'System of the World' until in its final version was ready for the printer in April 1687.

As Newton has recorded,

> I wrote in 17 or 18 months beginning in the end of December 1684 and sending it to the Royal Society in May, 1686, excepting that about 10 or 12 of the propositions were composed before.

As Rouse Ball has written,

> . . . the first two books were really written in about six months, and the period of eighteen months which the whole composition is said to have occupied includes the time in which copies of them for the press were prepared, and much of the material for the third book collected.

The manuscript for the first book was sent to press before June 7, 1686. In it the three laws of motion (which every student of science can recite) are formulated with clear distinction between the notions of the inertial and gravitational mass and their equality; a logical and a coherent account of the dynamics of the motion of particles in general and under the influence of centripetal forces, in particular; the laws of gravitation; and the gravitational attraction of spherical and slightly oblate bodies and of spherical shells.

In the third Book, the propositions of Book I are applied to the principal phenomena of the solar system, the determination of the masses and distances of the planets and their satellites and an extended discussion of various perturbations affecting the orbit of the moon. The theory of tides is worked out in detail. The oblateness of the earth is shown to be caused by the earth's rotation; and it is quantitatively related to the difference in the polar and the equatorial values of gravity. Newton also investigates the motion of comets and shows that they belong to the solar system and explains how from three observations the orbit of a comet can be deduced.

This extraordinary range and variety of problems, almost all treated here for the first time, and written in magisterial style in less than two years, raises *Principia* to a level of intellectual achievement unparalleled in the history of science.

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I turn now to Michelangelo.

In March 1508, Pope Julius II called on Michelangelo to paint the ceiling of the Sistine Chapel. Michelangelo first stoutly declined on the grounds that he was a sculptor and not a painter and that he had no experience whatever in painting frescoes. But the Pope would have none of it. And before the imperious insistence of the Pope, Michelangelo had no choice. Even after his acceptance of the Pope's command, he continued to be reserved and bitter; but his attitude changed when the Pope allowed him to change the theme. Originally the Pope had wanted him to paint the 12 Apostles. Michelangelo was able to convince him that it was in his words a 'poor theme'. The Pope commissioned him anew to choose his own theme. The result is what we see today: Not the Apostles, but the entire story of the Genesis: The Creation of the Universe, of Man, and of Evil.

The preparation for the frescoes of the Sistine Chapel began in May, 1508. The erection of the scaffolding was finished by July. The actual work of painting, carried out by Michelangelo himself, was started not later than January 1509. He began near the entrance, progressing towards the altar. The three episodes, the drunkenness of Noah, the Deluge, and the sacrifice of Noah were painted first; and they were completed by September 1509. A year later two more and again a year later all 9 histories, together with the Sibyls and the Prophets were completed.

On August 14, 1511, on the eve of the feast of the Assumption of Virgin Mary, the frescoes of the ceiling were unveiled; and on October 31, 1512, the first mass was celebrated.

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There is another aspect of great works such as the *Principia* and the Frescoes of the Sistine Chapel that is characteristic of them; and that is the evolution of creative power which they manifest.

Let me consider first the frescoes of the Sistine Chapel. A trained art critic who is also an artist, will be able to illustrate the evolution of Michelangelo's creative power as his painting proceeds from the Drunkenness of Noah to the Separation of Light from Darkness. Being neither an artist nor an art critic, I shall select for comment one feature of the central panels: the face of the Creator in the last five panels in the order in which Michelangelo painted them.

(1) In the Creation of Eve:
The Creator's face is benign and compassionate – very human;
(2) In the Creation of Adam:
The stupendous head is God-like but still human;
(3) In Separation of Land and Water:
The face presents a powerful image – the fore-shortening of the figure throws into relief the wonderful, creative blessing hands;
(4) In the Creation of Sun, Moon and Planets:
The Creator breaks forward with a face expressing the stupendous force needed for the creation of the abode of all living things;
and finally
(5) In the Separation of Light from Darkness:

Never has the ineffable been expressed in art with such intensity. Here, the supreme act of creation attains an almost dehumanized abstraction – in magnificent contrast with the benign features in the Creation of Eve.

Let me now turn to the *Principia*. Unfortunately, the occasion does not allow me to describe the growing intellectual power and physical insight of Newton as we proceed from Book I to Book III of the *Principia* in the manner I have described the evolution of Michelangelo's artistic power. I must be content with quoting some marvelous statements that Newton makes through the course of the *Principia*; and these may suffice to illustrate the same things.

(1) After formulating the Laws of Motion, the concept of force and the differing notions of the inertial and gravitational mass and the underpinning notions of space and time, Newton realizing the inherent difficulties of resolving the web of intertwining concepts, cuts the Gordian knot with the simple statement:

> How we are to obtain the true motions from their causes, effects, and apparent differences, and the converse, shall be explained more at large in the following For to this end it was I composed it.

(2) After completing the dynamics of point particles. Newton is ready to prove his superb theorems on the attraction by spherical and non-spherical bodies. And here is his opening statement:

> In mathematics we are to investigate the quantities of forces with their proportions consequent upon any condition supposed, then, when we enter upon physics, we compare those proportions with the phenomena of Nature, that we may know what conditions of those forces answer to the several kinds of attractive bodies. And this preparation being made, we argue more safely concerning the physical species, causes, and proportions of the forces

(3) In Book III, before stating and proving the marvelously coherent set of 14 Propositions establishing his universal law of gravitation, he prefaces by formulating 4 rules of Reasoning in Philosophy. Here is his Rule I, unsurpassed in clarity and style of expression.

> *We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances*
> To this purpose the philosophers say that Nature does nothing in vain and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes

(4) And finally the poignant note of the concluding sentence:

> And to us it is enough that gravity does really exist, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea.

Let me conclude with this note:

What I have tried to say during the past half an hour is simply this:

When a supremely great creative mind is kindled, it leaves a blazing trail that remains a beacon for centuries

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