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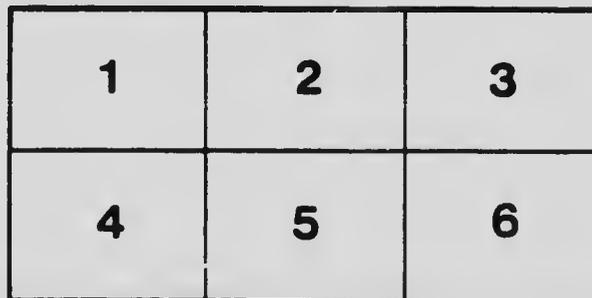
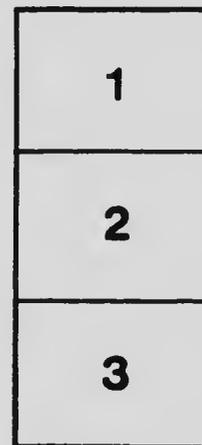
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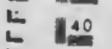
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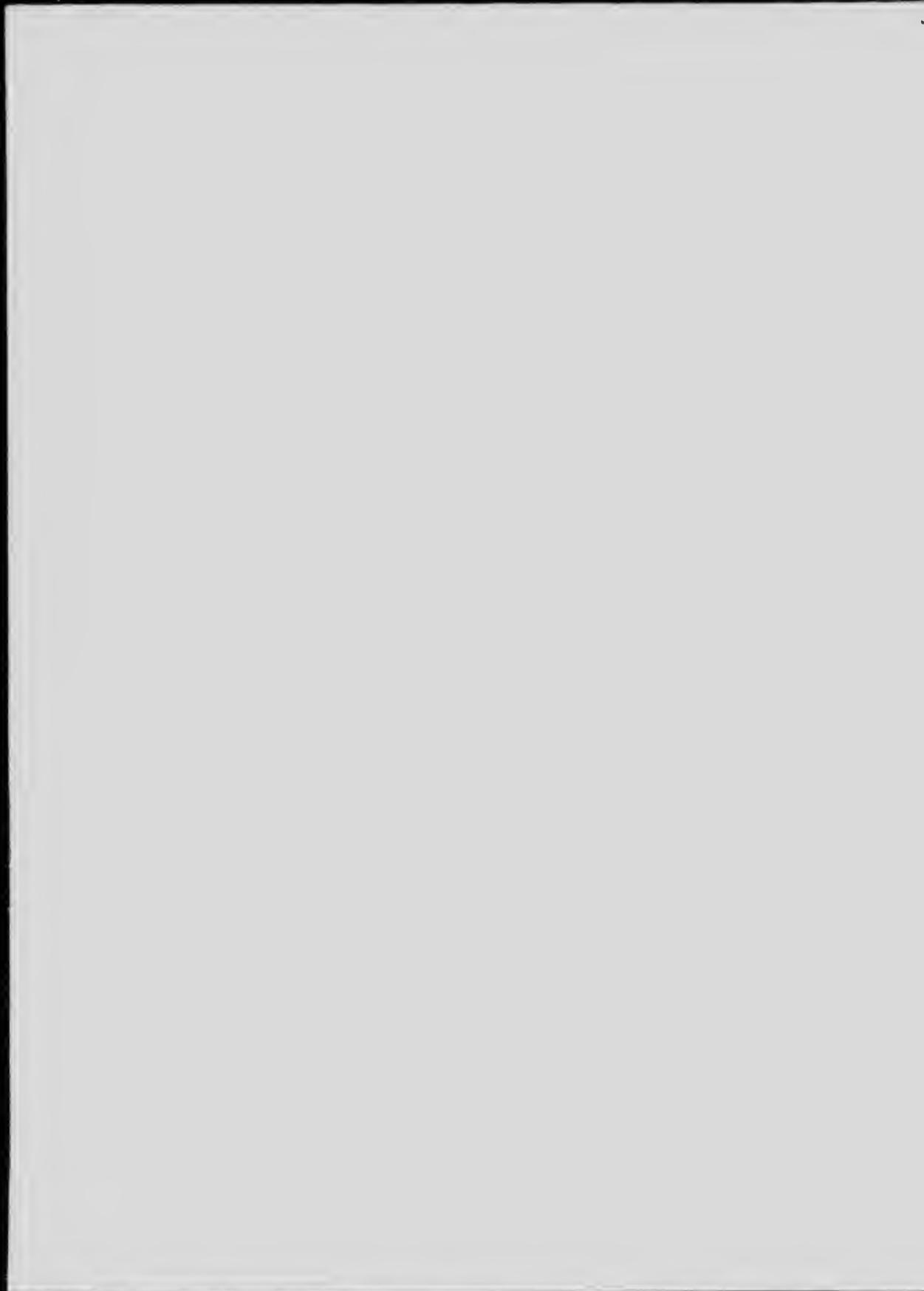
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Shakespeare and Biological Science

BY

D. FRASER HARRIS

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SHAKESPEARE AND BIOLOGICAL SCIENCE

THREE hundred years ago this year the most remarkable Englishman that ever lived, died. In a sense it is no exaggeration to call William Shakespeare the most remarkable of Englishmen; for if one man wrote all the plays and poems attributed by critics to William Shakespeare, and if that same man possessed only some knowledge of practically every subject under heaven, which apparently he did possess, and at the same time did not own a book or leave a single manuscript behind him, then he was the most remarkable Englishman of all time. Whether the plays were the work of one man or of twenty men, there is no denying that they exhibit in their author or authors a surprising amount of learning in ancient history, English history, state-craft, the life of courts, folklore, law, botany, zoology, physiology, psychology and stage-craft.

Shakespeare has been called a complete intellect; and this would be justified if one contemplated only the profundity of his knowledge of human nature in all ages and at all social levels. Nothing that has ever passed through the human mind seems to have escaped him. It is easy to draw up a catalogue of the mistakes and anachronisms of Shakespeare; but were the list ten times the length it is they would be all atoned for by the penetration of his instinct and its unerringness wherever the workings of the human mind are concerned.

If in biological science Shakespeare *did* repeat the mistaken notions current in his day, it may be none the less interesting to examine some of these in detail, and by the light of our modern knowledge of life endeavour to understand what phenomena it was that engaged Shakespeare's attention.

I pass by altogether the numerous allusions both to bodily and to mental diseases: these have been exhaustively dealt with by writers eminently qualified to treat of them. At present I would rather draw attention to the physiology and psychology in Shakespeare's writings. Naturally the question arises, did Shakespeare know the physiology current in his day, and if so, did he give expression to what was generally believed, or as regards the matter of that science, as in so much else, did he transcend the views current in his time and flash forth beyond them in prophetic prevision?

It happens that Shakespeare lived at a time when most momentous discoveries were taking place in physiology. It so happens that Shakespeare and the world-renowned Dr. William Harvey, the discoverer of the circulation of the blood, were contemporaries for some 38 years of their lives, for Shakespeare was born in 1564 and died in 1616 while Harvey was born in 1578 and died in 1657. Harvey was 38 years old when Shakespeare died. By 1616 Harvey had not, however, announced his epoch-making discovery, which was not published until 1628 and even then not in England but at Frankfort-on-the-Main.

It is rather curious to remember that the earliest writings of Harvey known to contain any description of the circulation of the blood in which the heart is regarded as the central power for it, are dated 1616. These are none other than Harvey's manuscript notes for his Lumleian lectures, the first of which he delivered at the College of Physicians on April 16, 1616. These precious leaves, accidentally discovered, have been bound together and now repose in the British Museum.

Seeing that Shakespeare died on the 23rd of April, 1616, it is at once apparent that he could have known nothing of the Harveyian views on the circulation of the blood, the starting point of modern physiology, for the "*Exercitatio de motu cordis et sanguinis in animalibus*" was not printed for twelve years after that date. Thus Shakespeare could not have known of his great contemporary's discovery, because he died twelve

years too soon. Neither could Shakespeare's son-in-law, Dr. Hall of Stratford-on-Avon, have told him of it, as some have thoughtlessly suggested he might. For one thing, Hall did not marry Shakespeare's daughter until 1607. Some uncritical writers have assumed that Shakespeare must have known of the circulation of the blood because he was a contemporary of Harvey. The two great men may never have met. Harvey was a student of medicine at Padua from 1598 to 1602, the very time when Shakespeare was at the height of his activity. But even if they did meet, the young doctor was not in the least likely to discuss with the great actor his revolutionary view of a matter of pure physiology. If Harvey discussed so technical a subject before he gave it to the world, it would be exclusively with his medical brethren. We should expect from *a priori* considerations, without examining Shakespeare's works at all, that their author was not acquainted with the new views concerning the circulation of the blood. A close examination of these writings confirms this in the fullest manner.

If Shakespeare then did not know the Harveian doctrine, what view did he know? The reply is that he evidently held the views which had been taught in the medical schools of Europe for 1400 years, the views of Claudius Galen, that great dictator in all matters medical.

The Galenical notions of the movement of the blood can be understood only after still earlier views are comprehended.

The distinction between arteries and veins was made before even the time of Aristotle. Shortly after the death of Aristotle, Erasistratus (300 B.C.) of Alexandria taught that blood for the nourishing of the body travelled up and down the veins only; whereas in the arteries "vital spirits" alone were found. Erasistratus thought that arteries during life did not contain blood because after death arteries are found to be empty. Galen made the discovery by vivisectional methods that the arteries contain blood during life. Accord-

ing to Galen the veins contained "erude" blood, the arteries pure or spirituous blood, that is, blood mixed with vital spirits. The Galenical doctrine of spirits, on which learned Europe subsisted for a millennium, was fairly complicated, as it recognized no less than three different kinds related somewhat in the following manner. The food in the intestine was supposed to be absorbed into the liver, where it was elaborated so as to be possessed of "natural" spirits. This erude blood then passed to the right side of the heart, into which all the veins of the body opened. This blood still erude was supposed to nourish the body by passing up and down the veins as with the ebb and flow of a tide. Its natural spirits in modern terminology would be equivalent to "powers of nourishing." Most of this erude blood was supposed to percolate through invisible pores in the septum, dividing the right from the left ventricle of the heart, only a little of it going by the pulmonary artery to nourish the lungs. In the left ventricle the blood was supposed to be mixed with air drawn in in the act of breathing. Aristotle taught that the inspired air was needed to cool the "innate heat" of the heart; Galen adopted this view and added another result of the mixing of blood and air, namely, the elaboration of "vital" spirits. The great arterial vessel of the body, the aorta, arises from the left ventricle, so that blood, plus vital spirits, passed by the arteries to the tissues and organs to confer on them the powers of performing their specific functions. The vital spirits, therefore, promoted functional activity. Finally, said Galen, blood plus vital spirits is carried to the brain—an organ which Aristotle declared was cold and bloodless—and there becomes the seat of the production of a third order of spirit—the "animal." This production of animal spirits went on in the ventricles or cavities of the brain. These animal spirits, which as a term survive only in colloquial English, were to Galen what nerve-impulses are to us; but they were a great deal more, for they were the very instrument of the soul itself. The word "animal" does not in this connection mean "belonging to a beast;" it means

pertaining to the soul or anima, the Latin equivalent for the Greek psyche (*ψυχή*) life or soul. The full Latin expression is *spiritus animalis*.

The animal spirits of Galen are equivalent to consciousness in modern language, and to motor and sensory innervations as well. Such is a simplified account of the doctrine of spirits which was the orthodox medical teaching as late as during the lifetime of Shakespeare. It persisted in common parlance until long after, for in the reign of Queen Anne (1702) the "Daily Courant" advertised a perfume as efficacious because "it increases all the spirits, natural, vital and animal" which is quite in the Galenical order.

Shakespeare was perfectly familiar with at least the names of Hippocrates and Galen. In the "Merry Wives" (Act III, Sc. 1) we have Sir Hugh Evans, in speaking of Dr. Caius, saying:—

He has no more knowledge in Hibbocrates and Galen,
—and he is a knave besides.

Both Aesculapius and Galen are mentioned by the host in Act II, Sc. III, of the same play. In Coriolanus (Act II, Sc. 1) we have the phrase: "The most sovereign prescription in Galen." Shakespeare was evidently also aware of the reputation of Paracelsus as the leader of a school of medical thought, as it happens, a virulently anti-Galenical one. Galen and Paracelsus are mentioned in the same line in Act II, Sc. 3, of "A King's Well"—

Both of Galen and Paracelsus.
Of all the learned and authentic fellows.

Seven Doctors of Physic are to be found in Shakespeare's plays: Dr. Caius, a French physician, in the "Merry Wives;" Dr. Butts, physician to Henry VIII; two doctors in "Macbeth;" Cornelius, a physician in "Cymbeline;" Cerimon in "Pericles" and a doctor in "King Lear."

Efforts have been made to identify Shakespeare's Doctor Caius with the distinguished Englishman, Dr. John Key

(Johannes Caius). Besides that Dr. Caius died 28 years before the "Merry Wives" was written, the Caius of the play is a Frenchman who cannot pronounce English correctly, a sort of character not at all resembling the learned and serious founder of the college at Cambridge and the President of the College of Physicians at London. The notion that Shakespeare's amusing doctor is the great Frenchman, Sir Theodore de Mayerne, is not much more likely.

Let us now examine the passages in which mention is made in some sort or other of blood, blood-vessels or heart.

In "Love's Labour's Lost" (Act. IV, Sc. 3) we have the expression: "The nimble spirits in the arteries," a direct echo of the Aristotelian-Galenical teaching.

The veins are mentioned much more frequently. In King John (Act III, Sc. 3) we find the expression "blood . . . runs tickling up and down the veins." The interest in this is, of course, the phrase "up and down," which is precisely what was taught as regards blood in veins before the uni-directional flow of blood was demonstrated by Harvey. The pre-Harveian notion of a tide, that is, an up and a down, a to and fro movement in the veins is exactly reproduced in this passage. In the same play we find the line—

Whiles warm life plays in that infant's veins,

and must at once be reminded of the exceedingly old belief that the life was pre-eminently in the blood. Not only do we have in Scripture the phrase, "for the blood is the life," but also in the Hippocratic writings the same idea. The Hippocratic writer based his belief on the familiar observation that when the blood has run out of the body of a slaughtered animal the animal dies.

Once more in the same play we have this idea quite distinctly put (King John, Act V, Sc. 7): "The life of all his blood is touched corruptibly."

Possibly the best known passage in which the movement of the blood is alluded to is in "Coriolanus" (Act. I, Sc. 1),

where Menenius Agrippa, a friend of Coriolanus, speaking of the belly, says:—

True it is . . . that I receive the general food at first
Which you do live upon, and fit it is,
Because I am the storehouse and the shop
Of the whole body: But if you do remember,
I send it through the rivers of your blood
Even to the court, the heart—to the seat o' the brain,
And through the cranks and offices of man,
The strongest nerves and small inferior veins
From me receive that natural competency
Whereby they live.

Now, while it is quite absurd to see in this not only modern physiology but a prophetic vision of Harvey's discovery, the passage is not wanting in biological interest. The general idea of the abdominal viscera receiving food and working it up into blood destined for the nourishment of the whole body, including the nerves, is in this passage and is so far physiologically correct. But undoubtedly it is the phrase "rivers of your blood" that should arrest us, for, if literally accepted, it does indicate the notion of a flow in one direction only. The flow of a river is the very opposite of a tidal flow.

To insist, however, that because Shakespeare used the expression "rivers of blood," he actually foresaw the discovery of the circulation is to read a great deal too much into this passage; possibly Shakespeare meant no more by "rivers" than if he had said "streams." If we had none other than this passage to go upon, we might admit that Shakespeare had before him the Harveian notion of a flow only in one direction; but in the light of what he writes in Act. V, Sc. 1,

The veins unfilled, our blood is cold, and then
We pout upon the morning, are unapt
To give or to forgive; but when we have stuffed
These pipes and these conveyances of our blood
With wine and feeding, we have suppler souls
Than in our priest-like fasts.

we cannot but believe that Shakespeare held no view other than the Galenical one of his own day, namely, that the veins, not the arteries, convey the nourishment to all parts of the body. The revivifying effect of alcohol, taken with food, is fully appreciated.

Shakespeare certainly held what Harvey so greatly emphasized that the heart is the chief organ in the vascular system. This is clearly intended in Falstaff's harangue about Sherris wine in Henry IV, Part II: Act IV, Sc. 3: "The second property of your excellent sherris is—the warming of the blood which, before cold and settled, left the liver white and pale which is the badge of pusillanimity and cowardice; but the sherris warms it and makes it course from the inwards to the parts extreme. It illumineth the face which, as a beacon, gives warning to all the rest of this little kingdom, man, to arm; and then the vital commoners and inland petty spirits, muster we all to their captain, the heart." There is much in this of correct physiology; the allusion to the pre-eminence of the heart has quite the modern ring.

The association of a pale or white liver with cowardice is of long standing. The ideas are not so absurd as one might at first think: for a perfectly bloodless liver is pale, of a grey brown colour. Now the exhibition of violent and aggressive emotions is always associated with a determination of blood to some part of the body, so that a bloodless and therefore pale liver might somehow be related to the opposite of aggressiveness.

This is not, however, the interesting thing in Falstaff's speech; it is the place he gives the heart, for the pre-Harveian physiology by no means gave the heart its important place in the bodily economy. One of Harvey's predecessors in vascular discovery, M. R. Columbus, denied the heart even to be muscular. That distinguished man of science, Steno, was violently criticised for his irreverence in asserting that the heart—the seat of the soul—was in its essence none other than a common muscle.

One of the main contentions of the Harveian physiology was that the heart was dynamogenic for the whole circulation. Every artery is filled, said Harvey, by blood forced into it through the compulsion of the cardiac beat. To Harvey, the heart was a force-pump, and the problem of the circulation was one in haemodynamics, to use a modern term. Harvey combated the old view that the arteries actively suck in blood as a bellows does air. Undoubtedly the arteries are living tubes, but they expand not in virtue of their vitality but by the blood-pressure within them acting against their force of elastic recoil.

Shakespeare seems to have had an inkling of the pre-eminence of the beating organ in the chest; he knew not only fairly accurately where the heart beat was, but how emotions directly affected it, as when Macbeth exclaims,

Whose horrid image doth unfix my hair,
And make my seated heart knock at my ribs.

One of Shakespeare's allusions to blood reaching the heart has been made a good deal of by certain writers on the history of physiological discovery. The passage is in *Julius Caesar* (Act II, Sc. 1), where Brutus exclaims:—

You are my true and honourable wife,
As dear to me as are the ruddy drops
That visit my sad heart.

All that this asserts could be known from observing slaughtered animals, namely, that blood is in the heart; and yet some writers have gone so far as to maintain that Shakespeare anticipated Harvey in the matter of the discovery of the circulation. This must be put down to excess of hero-worship.

There is, however, quite a striking passage in "*Measure for Measure*" (Act IV, Sc. 3) where the heart is mentioned in a new connection:

LUCIO: O pretty Isabella; I am pale at mine heart to see thine eyes
so red.

The thought in Shakespeare's mind was probably that the emotion of sorrow or sympathy blanches the heart in the same way that some emotions blanch the skin of the face. While the literal physiology of this is incorrect, there is the recognition of the important effect of psychical states on the condition of the heart.

Before passing on to Shakespeare's allusions to the nervous system and to psychological considerations, we might notice some phrases which refer to subjects of distinct physiological interest. For instance, when it is said in Richard II (Act I, Sc. 3),

Things sweet to taste prove in digestion sour,

we have a remark in agreement with the latest results of physiological chemistry. The sugars, it is now believed, in being digested, pass through a stage of lactic acid; in other words, a sour stage.

The expression, "life-preserving rest" (Comedy of Errors, Act V, Sc. 1), is an excellent physiological description of what rest really means. Rest is essentially recuperative; all work, nothing but activity, would wear out the organism; it must rest in order to live, therefore rest is "life-preserving."

The exact physiological condition in starvation could not be put better than in the line in Coriolanus (Act IV, Sc. 2),

I sup upon myself, and so shall starve with feeding.

In inanition the body lives on itself, as it is said; what is actually happening is that the heart and central nervous system are living on the fat and muscles of the body. The former two—the noble tissues—are living at the expense of the rest of the body; it is, therefore, physiologically correct to say that in starvation there is feeding.

No less interesting than Shakespeare's allusions to the vascular system are those to the nervous. In his day, unlike ours, all emotional conditions were not at once referred to the cerebrum and so disposed of; there was a complicated distribution of them amongst the various viscera. Even much

later than Shakespeare's time, the seat of the soul was held to be in the heart; for instance, by Vico (1678-1774). Descartes assigned it to the pineal gland; Van Helmont placed it in the pylorus or "pit" of the stomach. Although Aristotle said the soul was in the heart, other Greek thinkers placed it in the diaphragm (phren); hence "phrensy" (frensy) or madness of the soul; hence also "phrenology," a discourse on the supposed localization of things mental. From time immemorial, emotions have been associated with viscera, as in the Old Testament where bowels yearned, and in the New, where there were bowels of compassion. Everybody knows that the spleen was the seat of anger, for we yet speak of a choleric, meaning an angry man, and a "fit of the spleen," meaning of rage.

Curiously enough, love was placed not in the heart but in the liver. Shakespeare adopts this localization when he makes Pistol say (Merry Wives, Act II, Sc. 1) that Falstaff loves Ford's wife "with liver burning hot."

We have seen that whereas Aristotle placed the soul in the heart, Galen placed it in the brain; and Shakespeare, if he consciously followed any school of thought, was Galenical rather than Aristotelian, for he makes Prince Harry, in King John, say of the King:—

It is too late, the life of all his blood
Is touched corruptibly, and his pure brain
(Which some suppose the soul's frail dwelling place),

and so on, as though it were not yet decided to be but some supposed it in the brain.

Possibly one of the most remarkable of all the passages of biological significance in Shakespeare is in "Love's Labour's Lost" when Holofernes, speaking of ideas, says:—

"These are begot in the Ventricle of memory, nourished in the womb of pia mater, and delivered upon the mellowing of occasion."

Holofernes is a schoolmaster and therefore presumably represents a learned man, and certainly here his allusions are

sufficiently erudite to puzzle a good many fairly well educated people.

The "Ventricle of memory" is a phrase borrowed from the Arabian doctors of medicine who held that the brain possessed three cavities or ventricles in which the three subdivisions of the chief soul resided. The anterior was related to sensations, the middle to imagination, the posterior to memory. (Modern anatomists describe five cerebral ventricles.) These views were adopted by the theological Doctors of the Church in the Middle Ages. They were one of the beliefs against which Andreas Vesalius, the father of anatomy, particularly inveighed in his celebrated treatise the "De Corporis Humana Fabrica," published in 1543. In dealing with the brain he wrote—"I wonder at what I read in the scholastic theologians and the lay philosophers concerning the three ventricles with which they say the brain is supplied." "He then," says Sir Michael Foster, "goes on to ridicule the views held by these philosophers, namely, that a front ventricle is the receptacle of sensations which, passed on to a second ventricle in the middle of the head, are there used for imagination, reasoning and thought, and that a third ventricle near the back of the head is devoted to memory." Shakespeare adopts the unscientific terminology of the pre-Renaissance writers in the matter of mental states related to cerebral ventricles.

The expression "nourished in the womb of pia mater" is certainly obscure. "Pia mater" is the name given by anatomists to the highly vascular and soft membrane which, closely investing the brain and central nervous system, conveys to it the nourishing blood-vessels. It does in a sense nourish the brain, and, therefore, metaphorically might be said to bring to development anything functionally related to the activity of the brain. Whether or not Shakespeare knew of the anatomy of this membrane it is impossible to determine; but assuming that ideas are "begot" in a cerebral ventricle, it would be permissible to continue the simile and regard them as nourished by the membrane that nourishes the organ of

thought. The completion of the analogy between giving birth to a child and bringing forth a thought is, of course, thus possible. The passage is very striking and shows Shakespeare familiar with at least the anatomical terminology of his day.

The allusions in Shakespeare's writings to the activities, both normal and morbid, of the central nervous system are quite as interesting as those relating to the heart and blood-vessels. The symptom of giddiness is mentioned several times in the plays.

In King John (Act IV, Sc. 2), for instance, we have the line:—

Thou hast made me giddy with these ill tidings.

Sudden violent emotion is very liable to produce giddiness; but few persons except those trained in physiology could explain exactly how this is so.

The emotion, usually of an unpleasant kind, arises on its physical side as an excitement of certain cells of the cortex cerebri; these cells discharge impulses to the nerves of the heart, which have the effect of making the heart-beats ineffective (inhibiting them) for driving enough blood to the brain and central nervous system. The result of this is a general lowering of blood-pressure, so that the cells of the central nervous system, whose duty it is to innervate the muscles engaged in balancing the body, do not now get enough blood. The body, therefore, sways and tends to fall, and the subjective sensation accompanying this disturbance of equilibrium is a feeling of giddiness. Cerebral anaemia, in short, produces giddiness. It also produces loss of function in the sensory cerebral centres, and chiefly in the centre for vision, so that the person affected suffers from imperfect sight.

This is interestingly noted in Henry IV (Part II: Act IV, Sc. 4) where King Henry says:—

And now my sight fails and my *brain* is giddy,—

Shakespeare correctly attributing the giddiness to the organ involved. Shakespeare has not failed to note the subjective

sensations which a giddy person experiences in that stable, external objects seem to be moving round him and particularly in the direction opposite to that towards which he last moved. Thus we have in "The Taming of the Shrew," (Act V, Sc. 2):

He that is giddy thinks the world turns round.

The complete physiological explanation involves the knowledge of so much anatomy that it will not be attempted here.

Hamlet (Act III, Sc. 4) makes a remark in reference to the functional activities of the nervous system of so profound a character that we hesitate to believe that Shakespeare really knew all it involves:—

Sense, sure, you have,
Else you could not have motion.

The principle that sensory impressions must precede motor in the education of the nervous system, is now regarded as of immense practical importance. It is a fact which, of course, could not have been known to Shakespeare that those tracts in the central nervous system which subserve sensation are developed functionally a considerable time before those which subserve movement.

Shakespeare's marvellous observation had, however, shown him the truth of this important generalization without the possibility of his having any acquaintance with the physiological bases for it.

As one would be prepared to find, the more exclusively the topic has to do with the human mind, the more penetrating is Shakespeare's treatment of it.

The oftenest quoted example of this is the psychic blindness of Lady Macbeth:—

DOCTOR: You see her eyes are open.
GENTLEWOMAN: Ay, but their sense is shut.

That the eyes are open is not enough to ensure vision unless the centre for vision in the brain is also in activity, is the physiology underlying this passage.

It is a state of mind-blindness the result of extreme abstraction of the attention, a condition analogous to the state of the brain in hypnotism where a person can, by suggestion, be made blind although his eyes are open. Lady Macbeth is described as "fast asleep" but with open eyes. This is not natural sleep, for in it the eyelids are always closed. Shakespeare correctly describes a condition popularly called "trance" where, although the eyes may be open, there is no vision in the unconscious brain behind them.

Shakespeare clearly believed the brain to be the organ of the formation of images, or ideas. One more example of this may be given from the "Merry Wives" (Act IV, Sc. 2):—

FORD: Well, he's not here I seek for.

PAGE: No, nor nowhere else, but in your *brain*.

Coloured after-images or, as some call them, the results of retinal fatigue, are also alluded to in one of the plays. In "The Taming of the Shrew" (Act IV, Sc. 5) Katherine says:—

Pardon, old father, my mistaking eyes
That have been so bedazzled with the sun
That everything I look on seemeth green.

This is a literal experience known to many: if the eyes are over-stimulated by exceedingly bright sunlight and one goes indoors suddenly, everything takes on a rather ghastly greenish hue.

The last passage involving biological interest we may take from Hamlet (Act I, Sc. 5) where the ghost remarks,—

The glow-worm shows the matin to be near,
And 'gins to pale his uneffectual fire.

A minor point of interest is in connection with the paling of the light because of the dawn. The light of the glow-worm in common with all lights would begin to appear paler as the morning daylight increased. More technically, the light of the glow-worm is relatively feeble owing to the stimulation of the retina by a much intenser light. It is the same phenom-

enon as the extreme paleness of the moon's light when seen during the day. But there is a much more interesting word in this passage, the word, "uneffectual" as applied to the "fire" or light of the worm. Surely Shakespeare means to convey the notion that the "fire" of the glow-worm is uneffectual because it is unaccompanied by heat. Now, the fact has been established only quite recently that when organisms emit light, it is by an oxidative process known as chemiluminescence, in which the chemical energy is used directly for conversion to light-energy without passing through the stage of heat. In this sense, then, the light of the glow-worm is an uneffectual fire, because being accompanied by no heat it could set fire to nothing. Fire which will not set fire to anything is indeed uneffectual.

It need hardly be pointed out that it is only Nature that has succeeded in producing light without heat. Mankind has never yet achieved what man so greatly desires, a source of light without an accompanying very high temperature, for the heat generated along with the light is wasted energy as far as illuminating purposes are concerned. The spectrum of animal light shows it to be devoid of vibrations both towards the red and the violet end of the spectrum; it is therefore chemically inert, which is another aspect of its ineffectiveness.

D. FRASER HARRIS

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