THE INTERNAL SENSES—FUNCTIONS OR POWERS?

Part II

We will now try to show that the internal senses have definite brain structures as sensoria and that a correlation of what our psychological analysis has shown about these senses with the knowledge derived from the results of neurological research can help us better to understand the functioning of the inner senses and also the functioning of the brain. The brain functions outlined here were arrived at by an extensive study of the available very recent research evidence. While we are presenting a *theory* of brain function, it is the only one available that integrates the reported facts in a consistent way. Indeed, it is the only theory available today. We will show that it fits in well with the traditional teaching of philosophy on the internal senses, which may be an additional reason for saying that it fits all known facts.

According to St. Thomas, the sensus communis is a sensory power that has as its formal object the activity and content of the external senses. Now let us see what the sequence is that starts from the external senses and ends with the act of seeing objects. First, the sensory receptors are acted on by specific energies possessed by sense objects. This action has psychological as well as physical and physiological effects. For instance, light produces an optical image of the viewed object on the retina. The retinal cells react with action currents that travel along the optic nerve to the optic tract and the lateral geniculate bodies, the thalamic relay station for visual impulses. From there, relays go to the afferent plexus, one of six cortical layers in the visual area. Normally, the physiological activity up to this point disposes the visual sense *to see*. This disposition, the psychological effect of visual stimulation, is the visual *species impressa*. The act to which it disposes the visual sense is the actual visual sensation. If the physiological

process stopped at this point, there would be an experience of light and color, but not of seeing things as we ordinarily know them. If we are to see objects, the afferent nerve impulses must connect with the cortical cells in the remaining five layers [1] of the sensory area. All these cells form an intricate network in which every cell is connected with several other cells. When these connections function the sensus communis apparently begins to operate; the effect of its act is the *experience of seeing a visual object.*

Accordingly, the sensorium of the sensus communis seems to be the feltwork of cortical connections between the afferent and the efferent layers, both in the sensory and the adjoining association cortex. Though the sensus communis is one power, it is specified by its acts; and its acts are the intentional representations of the activity and content of different sense modalities. For this reason, we should not be surprised to find that the visual cortex is necessary for perceiving visual objects, the auditory cortex for perceiving direction and pattern of sound, the cortex of the somatosensory area for perceiving an object by touch, etc. The unity of the sensus communis is preserved by the connection of every cortical sensory area with every other such area, both via short and long association fibers. The primary sensory cortex seems to mediate the perception of objects, but the adjoining association cortex seems to make possible the retention of sense impressions. There are relays from the sensory thalamic nuclei distributed both to the primary sensory areas and to the adjoining association areas. For this reason, we are inclined to postulate two *functions* of the sensus communis: one of *constructing* its intentional image (mediated by the primary areas), the other that of *retaining* it (mediated by the association areas).

St. Thomas ascribes the retention of the sensory construct produced by the sensus communis to the imagination, assum-

[1] The neocortex, which includes sensory, motor and association cortex, has six layers of cells. The cells receiving afferent fibers are usually in the fourth (internal granular) layer, while the afferent fibers arise from the fifth (pyramidal) layer.

ing that the power that receives something cannnot retain it. It seems, rather, that the power that retains the sensory changes may not be the same power that *revives* them. If the species of the sensus communis are preserved, they must be preserved as changes in the cortical cells (called " engrams " by neurologists), not in the primary sensory areas but in the corresponding association areas. The physical character of these changes we do not know, but they could very likely be analogous to the magnetic realignment of electrons on a recording tape rather than to engraved characters which the term engram seems to suggest.

Speaking more abstractly, from the background of philosophical psychology, what is preserved is a *species impressa* or a *species intentionalis*, reduced from being in act to being *virtualiter* in the faculty, at least as a disposition. This is a virtual intentional image. When the image of the object is revived, as happens in the act of imagination, it is not the act of the sensus communis that is repeated but an act of the imagination. For this repetition a formal intentional act must have been retained as a virtual image, and this virtual image raised to a state of actually determining the imagination to act. However, the species of the sensus communis that is preserved (see above) seems to be identical, at least as a representation, with the species of the imagination that is revived. The question is now: are they one species or numerically distinct?

Imagination, taken here as the image-making power, can draw on the species prepared by the sensus communis and so can either represent an image of a past situation (in recall) or recombine such past impressions in new and original ways (fantasy). When the imagination functions in *recall*, neural impulses from the association areas seem to be relayed to the nearest limbic area and from there via the hippocampus and fornix to the hypothalamus and midbrain, and back to the sensory thalamic nuclei. These nuclei, the relay stations for afferent impulses from the receptors to the sensory and asso-

ciation cortex, have three separate cell layers, one apparently connected with the primary sensory, the other two connected with the sensory association cortex. (See Fig. 1) In recall, neural impulses from the hippocampus seem to switch into the

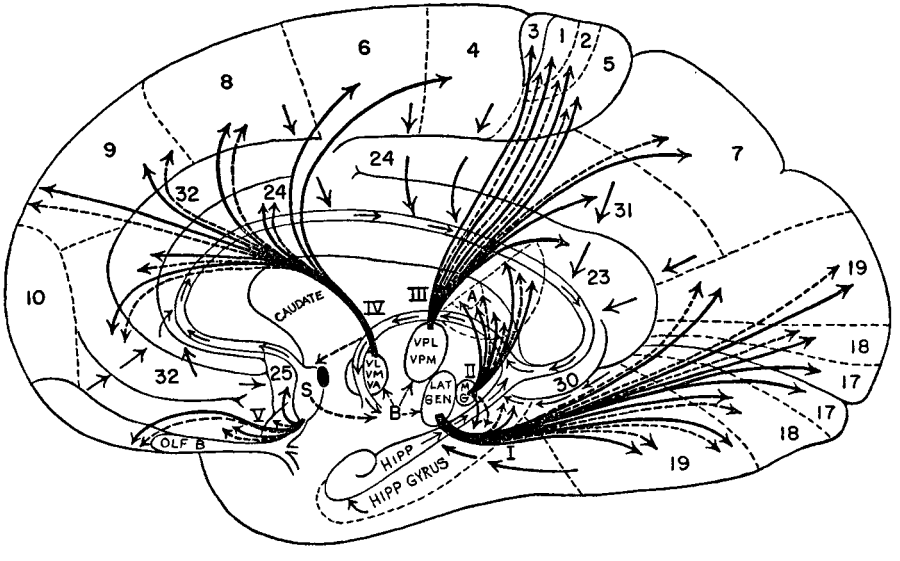

Fig. 1. Circuits Mediating Sense Experience and Recall

Sensory impulses travel via thalamic sensory nuclei to cortical sensory and association areas, mediating sensory experience. Associated impulses are relayed to limbic areas (25, 32, 24, 31, 23, 30, and hippocampal gyrus), mediating appraisal. This appraisal of something seen, heard, felt, etc. initiates the spontaneous recall of similar things which is mediated via hippocampus, thalamic sensory nuclei and the various cortical association and limbic areas. Motor impulses travel via ventral thalamic nuclei to frontal motor and association areas (see Fig. 3) and are similarly registered and recalled.

——— Reception and registration. ------ Recall. Arrows indicate the direction of conduction. Short arrows indicate the connections for appraisal and recall.

I visual system. II auditory system. III somesthetic system (including taste). IV motor system. V olfactory system. Arabic numerals represent Brodmann areas.

A cortical auditory area. B brain stem. HIPP hippocampus. LAT GEN lateral geniculate nucleus. MG medial geniculate nucleus. OLF B olfactory bulb. S septal area. VA anterior ventral nucleus. VM ventromedial nucleus. VL ventrolateral nucleus. VL ventrolateral nucleus. VPL ventroposterolateral nucleus. VPM ventroposteromedial nucleus.

projection to the sensory association cortex and so reactivate the pattern of changes preserved in that area in exactly the same way as it was laid down. When this happens, the imagination reproduces the original images in the original temporal sequence.

When the imagination functions in *fantasy* (and dreams), the active brain circuits include relays from association areas to limbic areas as before, but from there connect with the amygdaloid nuclei, a structure in the temporal lobe close to the hippocampus but not directly connected with it. The amygdala then sends relays via the stria terminalis to the thalamic association nuclei and the cortical association areas (see Fig. 2). Both the " recall " and the " fantasy " circuit function con-

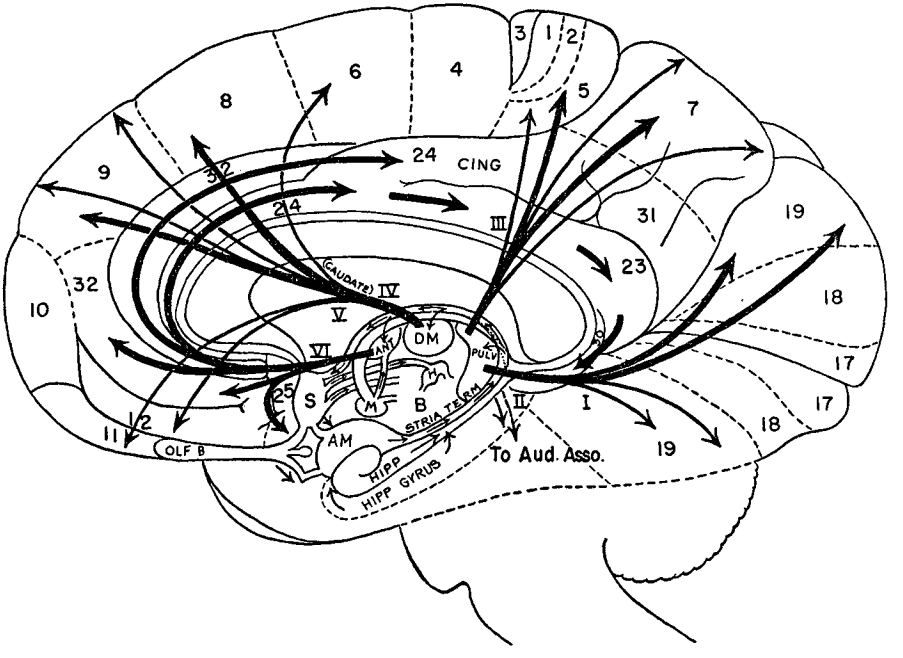

Fig. 2. Circuits Mediating Fantasy and Memorative Power

Identification of an object by recalling similar things (relays from association cortex to limbic areas and from there via the hippocampus-fornix circuit to the brain stem and thalamic sensory nuclei back to the sensory association cortex) and remembering their effects on us (relays from association cortex to limbic areas and from there via the hippocampus-fornix circuit to the anterior thalamic nuclei, the cingulate byrus and other limbic areas) results in imagining possible effects of this thing on us and possible ways of coping with it (relays from limbic areas via amygdala to thalamic association nuclei and cortical association areas).

I-IV circuits serving fantasy: I visual, II auditory, III somesthetic, IV motor, V olfactory imagination. VI circuit serving the memorative power.

AM amygdala. AT anterior thalamic nucleus. B brain stem. CING cingulate gyrus. DM dorsomedial thalamic nucleus. H habenula. HIPP hippocampus. M mammillary body. OLF olfactory bulb. PULV pulvinar. S septal area. STRIA TERM stria terminalis.

tinuously during waking, and are inactive in deep sleep. During light sleep, the " fantasy " circuit seems to function while the " recall " circuit seems to be blocked, probably because the hippocampus is one of the first structures affected in both sleep and anesthesia. Without automatic recall, the imagination functions only in fantasy, which accounts for dreaming. Recent research has shown that light sleep is accompanied by dreaming even when the sleeper does not remember his dreams.

We hold with St. Thomas that there are two powers, the sensus communis and the imagination, which help us to know the object. But it seems that the sensus communis has two functions, one to construct the object from sense qualities, the other to preserve it and so determine the imagination to act. The imagination, in turn, seems to have two functions, the one recall, the other fantasy. Both sensus communis and imagination are diversified by their acts which concern each and every sense modality. In spite of this diversity of acts, the unity of the sensus communis is preserved by the feltwork of interconnections in its sensorium, the sensory and association cortex. The unity of imagination corresponds to the unity of the structure which receives neural impulses from every association area and relays and distributes them back to these areas in a more or less circuitous way: the amygdala in fantasy, the hippocampus in recall.

The other two internal senses specified by St. Thomas can be described in a similar way. The estimative sense has as its formal object goodness or badness, suitability or unsuitability, utlity or the lack of it: the *rationes insensatae*. Now we know that among the things that are appraised as good or bad, suitable or unsuitable, can be (1) a sense impression, (2) a muscle movement, (3) an object, or (4) an action. Sense impressions are experienced via the external senses through their organs, the different sensory receptors with their neural connections to the sensory thalamic nuceli and the sensory cortical areas. In cases where we appraise single sense impressions or movements (a bright light, an intense sound, a hard pressure,

a painful movement) as bad, unsuitable, the species impressa of the estimative sense can be produced by the raw sense data as received from the external senses. On the other hand, when an object or an action is appraised as good or bad, suitable or unsuitable, the species impressa is produced by the act of the sensus communis: the sense impressions that have been combined into an object, the single movements that have been combined into actions. This functioning of the estimative sense on sense impressions as well as on objects would suggest that the sensorium of the estimative sense must include connections that reach the thalamus from the periphery as well as connections from the thalamus to the cortex.

But serious difficulty is apparent immediately: There is nothing in the sense qualities as apprehended by the external senses or even as apprehended by the sensus communis that would allow the perception of suitability. It is for this very reason that the formal object of the estimative sense is said to be *rationes insensatae*. But if they are not sensed, where do these rationes come from? This question has always been a problem. Brennan, for instance, says:

> " How are we to explain the origin of these insensate forms which act as prudential criteria, so to speak, by which the animal knows whether an object, here and now impinging on the exterior senses, is something useful or harmful? Obviously, not from experience, since Aquinas explicitly says that such forms do not originate by perception. The only alternative is innatism." [2]

Supposing all the species of the rationes insensatae to be innate, philosophers found it easy to identify the estimative sense with " instinct."

Now there is no doubt that some experiences of good and bad are innate. Something sweet is appraised by the newborn babe as good to swallow, whether it is milk or saccharine solution. A moving object of a certain size is appraised by the duckling as good to follow, whether it is a duck, a man, or

[2] R. E. Brennan, The Thomistic Concept of Imagination. *New Scholasticism, XV (1941), p. 158.*

merely a moving block of wood. If we consider swallowing or following an instinct, we cannot explain how this instinct could be set in motion by an artificial object (saccharine solution, a moving block of wood). What seems to be innate is not the impulse to action (to swallow, to follow, etc.); it is the appraisal of sweet liquid as good to swallow, of moving objects as good to follow. This appraisal results in a tendency to act act (appetite) which brings about action. Similarly, ducks have an innate aversion to flying shapes with short necks, rather than having an instinct to escape from predatory birds; the ewe has an innate aversion to a certain shape with a particular smell and behavior, rather than having an instinct to flee from a wolf.

From these innate appraisals of good or bad can be formed appraisals of objects that are not amenable to such innate judgment. So the rat learns that the pressing of a bar brings food, and appraises the bar eventually as good to press. Animals may even learn to correct innate sense estimates. So the kitten brought up with a pet rat learns that this rat is good to be with, and even when the rat darts in front of the kitten, it will appraise the rat, but not as good to catch and kill, as before, as good to play with. Normally, anything of a similar size that moves quickly is the occasion for an appraisal that this is good to catch and, eventually, to kill.

In some, at least, of these innate appraisals we can trace the way in which they are achieved. We know that we can appraise sensations and muscular movements as well as objects and actions. In fact, we have indicated above that even the innate appraisal of some *thing* as good or bad is based on the appraisal of a sense quality or a complex of such qualities (shape plus motion, shape plus smell, etc.) One basis on which we can appraise something as good or bad is the intensity of stimulation. The more intense a sense impression, as compared with the optimum, the more unpleasant it will be until it becomes actually painful. A light touch may be pleasant but increased pressure is no longer pleasant and gradually becomes actively

unpleasant and finally painful. Now the intensity of sensations is not sensed per se: the visual sense does not apprehend the intensity of light or color, nor does the sense of touch apprehend the intensity of pressure. What is sensed (sensibile per se) is the pressure, and the pressure has an effect on the body that depends on its intensity. This effect is not *sensible per se* but *sensibile per aliud.* If there are organs that are affected by stimulation intensity, these organs could mediate the experience of good or bad, suitable or unsuitable, etc. We have shown in a recent book [3] that there is a neural system (which we have called the estimative system) that has fine nerve endings as peripheral receptors which are affected according to the intensity of sensory stimulation. This system includes relays to the medial thalamus and the cortical limbic areas and is intimately connected with all the sensory systems at peripheral, midbrain, thalamic and cortical levels.

We suggest that the sheer apprehension of a sense impression or a simple muscle movement as good or bad requires the functioning of this system of fibers, including the nerves from the receptors to the medial thalamus and the relays from there to the afferent cells of the limbic cortex [4] (anterior and posterior cingulate gyrus, retrosplenial and hippocampal gyri, septal area and island of Reil in the temporal lobe). This would be analogous to the apprehension of sense qualities which requires the functioning of the different sensory systems including sensory nerves from the receptors to sensory thalamic nuclei and relays from there to the sensory cortex.

Even the immediate appraisal of an object as good or bad, i. e., of an object that can be so appraised without the help of memory (hot food, a warm bath, a rose) may depend on apprehending the intensity of one of its sensory qualities (the quality of contact with hot food, of warmth in the bath, of

[3] M. B. Arnold, *Emotion and Personality.* 2 vols. Columbia University Press, 1960.

[4] The limbic cortex consists of three layers of cells in which the receiving (granular) layer is completely separate from and superimposed on the efferent (pyramidal) layer.

scent in the rose). What the sense impression does to the organism seems to be the cause of the species impressa in the vis aestimativa. There seems to be good reason for saying that in some instances the *rationes per se insensatae* do become *rationes per aliud sensatae,* and this *aliud, sensibile per se.* Thus the vis estimativa seems to have functions that resemble the functions of an external sense. Its perceptions (e. g., pain) are not a function of any external sense; even touch. Organic pain is really a feeling that is the result of the functioning of the vis aestimativa. This is what we call the external estimative sense. How the *rationes insensatae* can be found in the perception of the sense complexes we mentioned above (shape plus motion, etc.) has not been worked out as yet.

The internal senses that complete this external function of the vis aestimativa are the *internal estimative sense* and the *vis memorativa* of St. Thomas.[5] Just as the sensus communis uses the species impressa produced by the external senses to give us the likeness of the object, so the internal estimative sense uses the species impressa delivered by the external estimative sense to appraise the effect of this object on us. Whatever the intensity of stimulation provided by an object, this intensity is part and parcel of this object in its relation to us. We know the object as it affects us; and this knowledge is mediated by the simultaneous functioning of the internal vis aestimativa and the sensus communis.

To identify the object as something we have encountered before and to remember its effects on us in the past, the imagination and the memorative power in addition are required. We have suggested before that the sensory and association cortex is the neural system of the sensus communis. The changes in the cortical cells produced by the sensus communis seem to be preserved in the association cortex and result in a

[5] Brennan, *op. cit.*, argues that no external sense experience is complete until both sensus communis and the imagination have functioned on the same object. Accepting this position, we can say that the experience of sensory evaluation is complete when the internal vis aestimativa and the vis memorativa act upon what is reported by the external estimative function.

disposition to see visual, hear auditory, feel tactual images whenever the imagination activates these dispositions, either in recall or fantasy. When we are visualizing something, we are aware of making pictures of past or possible events and are also aware of the content of our activity, these pictures themselves: it is the sensus communis that makes it possible for us to know that we are either recalling an actual happening or making a fantasy picture. But the sensus communis cannot help us to realize the event or action pictured as either *past* or possible, nor to be aware of something actually sensed, as *present.* For these appraisals the internal estimative sense is needed.

The neural system of the internal estimative sense seems to be the feltwork of connection in the *limbic cortex,* from afferent to efferent layer, analogous to the sensus communis which has as sensorium the feltwork of cortical connections between afferent and efferent layers in the sensory and association cortex. The connections of the limbic areas are received from the medial thalamus (with afferent relays from the receptors of the external estimative sense) and also from the association and sensory cortex. This means that the internal estimative sense derives the species impressa not only from the senus communis and the imagination, but also from the external estimative sense. The unity of the estimative sense is accounted for by the interconnections of every modality-specific limbic area with every other such area via long and short association fibers.

The fact that both circuits serving the imagination go from the sensory and association cortex to the limbic areas and only from there are relayed to the amygdala (in fantasy) or the hippocampus (in recall), to be redistributed to every association area, seems to mean that every object has to be appraised first as " good to know " before it will be attended to further and thought about. When something is seen, for instance, the act of the sensus communis disposes the imagination to act in such a way that it is not only seen in actuality but also as

a picture in the imagination. This happens as soon as the sensus communis knows the act and content from the external senses and consequently, to put it neurologically, as soon as cortical relays from the afferent cell layer have connected with the other layers in the cortex. But when the object is not present, or not present in precisely the way we want to think about it, the appraisal by the vis aestimativa has to initiate an action-tendency which is an impulse to recall or imagine this object. This is done when neural impulses from the sensory cortex reach the limbic areas. It depends upon this appraisal which of the circuits mentioned above will be activated.

St. Thomas, replying to an objection, says:

"Ad tertium dicendum quod sicut una potentia oritur ab anima, alia mediante, ut supra dictum est, ita etiam anima subiicitur alii potentiae, mediante alia. Et secundum hunc modum, phantasticum et memorativum dicuntur passiones primi sensitivi." [6]

(To the third we say: Just as one power arises from the soul through the medium of another, so the soul is subject to a potency through the medium of another. It is in this way that the imagination and memorative power are called passions of the first sensitive.)

This would imply that the imagination could depend upon the sensus communis and be so to speak, a further development of it, just as the vis memorativa is a further development of the vis aestimativa. Now it is interesting to see how exactly this view is borne out by the way in which the brain structures serving these powers are arranged. The imagination, for instance, is mediated by the "recall" circuit which starts from the sensorium of the sensus communis, the association cortex, and runs via the hippocampus and sensory thalamic nuclei back to it, while the "fantasy" circuit has the same starting point but runs via the amygdala and the thalamic association nuclei to different patterns in the same sensorium. Analogously, the neural substrate mediating the action of the vis memorativa is a circuit starting out from the limbic cor-

[6] *Summa Theol.* I, 78, a. 4, ad 3; ed. Leon. V, p. 255.

tex, the sensorium of the vis aestimativa and also coming back to it. When something seen, for instance, is appraised, neural impulses run from the posterior hippocampal gyrus (the visual limbic area), via the hippocampus and fornix to the mammillary body in the hypothalamus and from there are returned via the anterior thalamic nucleus back to the hippocampal gyrus (and are also distributed to the other limbic areas).

The act of the memorative power is the reviving of an earlier appraisal. A very few objects or situations can be appraised immediately, either on the basis of intensity (e.g., a hot iron) or on the basis of innate rationes insensatae (e.g., flying shapes with short necks, appraised as bad by the duckling). Most appraisals have to be made by remembering what this thing has done to us in the past. This effect of things on the body can be reduced to an appraisal of somatic pleasure or pain, i. e., to an appraisal of stimulation intensity. The animal and, still more, the child, can be trained to avoid something dangerous without ever having experienced its effects; but only master or parent can train them. Both animal and child have experienced punishments as well as rewards from them before training by a mere command is effective. To appraise something that is merely seen in the distance and can as yet give us neither pleasure nor pain, we must remember its past effects and imagine its possible effects. To do so, we need a visual image but also, and primarily, a revival of a past appraisal. This is a memory in the form of a mere judgment of good or bad, suitable or unsuitable, because that is the modality of the estimative sense. This revival of past appraisals is the work of the memorative sense. Since this power has the same relation to the vis aestimativa as the imagination has to the sensus communis, its species impressa is produced by the estimative sense, just as the species impressa of the imagination is produced by the sensus communis. There is only one circuit serving the memorative power because we can only revive past appraisals, we cannot make possible appraisals; two circuits

are necessary for the imagination because we can imagine both past and possible events.

Very often, an appraisal is revived without the corresponding visual, auditory or tactual image. In such cases, there may be a vague, ill-defined apprehension, tension or irritability in situations we cannot remember having experienced before. Or there may be a sense of well-being we cannot account for. In such cases we experience emotions that have their origin in a revived appraisal of good or bad though we are not aware that it is a revival. In the same way, we have no direct awareness of the functioning of the vis aestimativa but simply experience the feelings or emotions that result from it. Through the vis aestimativa we know only the functioning of sensory powers that can be appraised as good or bad, past or present, that is, of powers with neural systems that come in contact with the sensorium of the vis aestimativa. So we are aware that recalling something may be difficult, unpleasant, that thinking is hard work, that seeing, hearing, touching, is pleasant or unpleasant. All these activities are served by systems that are connected with the estimative system. But we are not aware of the act of the sensus communis as pleasant or unpleasant because the sensorium of that sense (the interconnections between afferent and efferent layers in the sensory and association cortex) is not connected with the corresponding layers in the limbic cortex. We are not aware of the sensus communis, the vis aestimativa and the vis memorativa in their acts: the sensus communis cannot know its own acts—no sense power can reflect on itself; and it cannot know the acts of the estimative and memorative powers because the neural interconnections between the afferent and efferent layers (the sensorium of the sensus communis) have no relays to the sensorium of the estimative sense.

The memorative power provides for a revival of past appraisals; and this revival can be as little judged by the vis aestimativa as could the original appraisals. We are not aware of such a revived appraisal as referring to the past because

the judgment that something is past also belongs to the estimative sense which cannot judge its own acts. When the sensory image is recalled as well, it can be judged as past, and the object it represents as good or bad. Many psychologists have noted the phenomenon of seemingly irrational emotions, of feelings that seem to be " objectless." Freud explained them as the result of repressed impulses. But this explanation does not account for such emotions when the situation that aroused them can be recalled without difficulty, though the connection between what was experienced then and is experienced now has never been realized. We can explain the emotion reexperienced today as the result of a revived appraisal of an old traumatic incident, whether or not that incident was actually recalled; this explains the emotion and explains also cases where the original incidents have never been repressed.

In conclusion, to round out our correlation of brain function with the functioning of the interior senses, we want to emphasize that these senses are active not only in sensation but also in preparing and guiding movements. The vis aestimativa, for instance, is necessary for all voluntary action and even for some reflexes. There are reflexes that are touched off by sensations which have to be appraised by remembering their earlier effects; and these reflexes employ voluntary movements (e.g., the blink reflex). There are others that are touched off by sensations though the reflex movement is involuntary (the pupillary reflex, knee jerk, etc.); and finally, there are reflexes that do not require any awareness of what it is that is touching them off (the pyloric reflex, the sphincter reflex, etc.). In all these cases, the neural estimative system is active but this activity is not always conscious.

We have mentioned before that the neural estimative system mediates the effect of stimulation intensity. Now we can add that it also mediates the effect of heat and cold, via its fine peripheral fibers that are connected with cutaneous receptors.[7] These fibers provide relays to the motor nerves of the

[7] Arnold, *op. cit.*, vol. 2, p. 190.

involuntary muscles in the blood vessels. These vessels contract (during cold) or relax (during heat) and so constitute the effector link of a segmental reflex. The flushed bodily state is sensed as warmth; the contrary state is sensed as cold. These states are later appraised as pleasant or unpleasant, according to the stimulation intensity. It would seem reasonable to suggest that other segmental reflexes also may be mediated by the peripheral fibers of the estimative system which register the effect of stimulation and initiate muscle movement via the appropriate motor nerves.

Reflexes that are touched off by sensations (pupillary reflex, knee jerk) also require that the effect of such sensations be gauged in some way, this time by thalamic relays from estimative system receptors rather than by peripheral estimative fibers. When it comes to the blink reflex, it has been found that this is established some considerable time after birth; in fact, when animals are put in a dark room right after birth and kept there until they are several months old, it takes weeks after they have been allowed to live again in a normal environment before they show the blink reflex. This means that they have to experience the pain of having the eyeball come in contact with something and to gauge the direction of movement of this thing as it approaches their eyes before they will close them spontaneously. Obviously, this requires not only the estimative sense but the memorative power, and consequently the functioning of the cortical portion of the estimative neural system; and with it, the normal activity of the sensus communis and the imagination, mediated by the sensory and association cortex, The activity of these powers is also required for all voluntary movement.

There is one point about voluntary movement that deserves special mention. Such movements always imply a patterning of muscle action which depends on a knowledge of the object and the direction in which it can be reached. I must know that a ball can be caught with one or both hands; that in walking, movements in one direction will take me toward my

goal, in another, away from it. Neurologists have talked about a " body scheme " within which individual movements can be projected. This means essentially that we can imagine possible movements and can preserve the disposition to repeat movements made in the past. We actually find that the same circuit we have identified as the neural system for fantasy also connects the sensory and association cortex via the amygdala with the premotor and prefrontal cortex (the motor association area). (See Fig. 2) To imagine a movement, the imagination must receive the species impressa from the kinesthetic sense. When the movement is imagined, neural relays go from the somatosensory cortex via the limbic cortex of the posterior cingulate gyrus to the amygdala and from there are relayed via the dorsomedial thalamic nucleus to the frontal association area. When the movement is imagined or actually carried out, the cortical cells are changed in such a way that a disposition to move in the same way is preserved. When the same movement is repeated, this disposition is strengthened and will constitute a habit or skill.

When something is appraised as good, a tendency to action (appetite) is aroused which, in man, may be a will impulse as well as an emotional tendency. The neural substrate for the emotional tendency is a complicated circuit which connects the limbic cortex (sensorium of the vis aestimativa) via the hippocampus and fornix with the midbrain and cerebellum where the neural impulse is amplified and patterned according to the limbs and muscles needed for this particular action. (Fig. 3) From there, relays go via the ventral thalamus to prefrontal, premotor and motor areas. The relays to the motor association cortex seem to mediate the experience of wanting to move in a particular way (premotor cortex) and also register the movement about to be made (prefrontal cortex). The " traces " so made in the cortical cells are preserved and can be activated by the imagination via a circuit from the limbic cortex to the hippocampus, ventral thalamic nuclei and motor association cortex (in recall). They will also be activated by actual movements that are repeated.

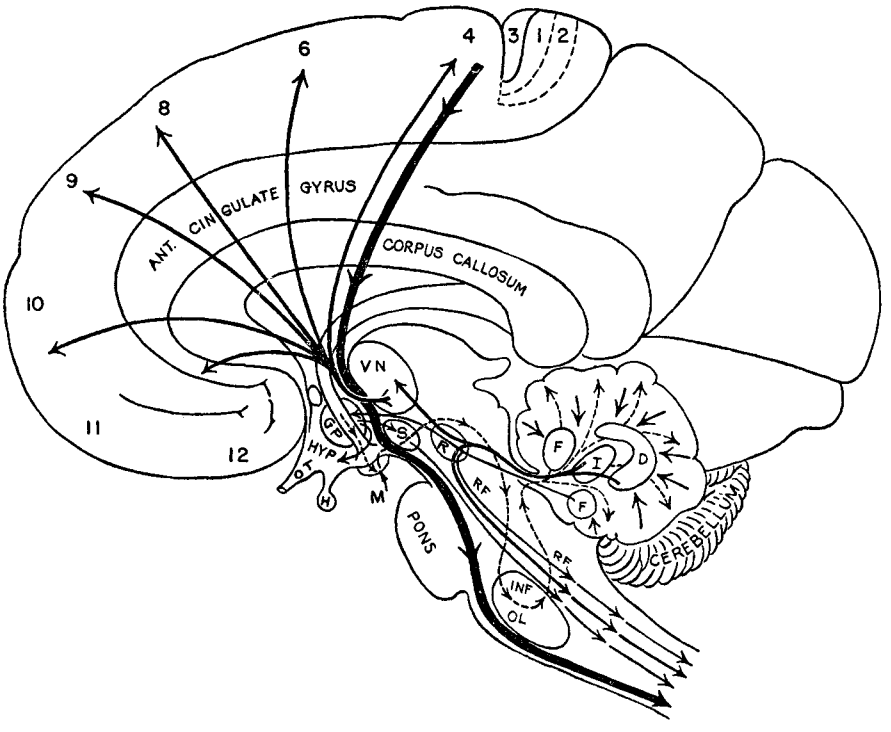

Fig. 3. The Circuit Mediating Emotion and Action

When something is appraised as good (via relays to the limbic cortex), a tendency to action is aroused which is mediated by relays from limbic cortex via the hippocampus-fornix to brain stem and cerebellum. From the cerebellar roof nuclei (dentate, fastigial, interposited) the organized action pattern is relayed: (a) via ventral thalamic nuclei to the frontal lobe, connecting with corticobulbar and corticospinal tracts and mediating the felt tendency to action as well as the intended movement; (b) via globus pallidus to extrapyramidal pathways, exciting the autonomic nervous system and organizing background motions; (c) via globus pallidus to hypothalamic neurosecretory nuclei, initiating the secretion of appropriate hormones.

- - - - - - - Relay from hippocampus to cerebellum. ——— Relay from cerebellum to frontal lobe. ——— Relay from cerebellum to extrapyramidal and hypothalamic effectors. ═══ Corticospinal tract.

D dentate nucelus. F fastigial nucleus. GP globus pallidus. H hypophysis. HYP hypothalamus. In interposited nucleus. INF OL inferior olive. M mammillary body. OT optic tract. R red nucleus. RF brain stem reticular formation. S subtantia nigra. VN ventral thalamic nuclei.

When the intention to move is formed, whether by a deliberate will impulse or an emotional tendency, that intention must be translated into nerve impulses that will activate the required muscles in exactly the right sequence and pattern. We imagine the direction and way in which we want to move, but the movement has to be carried out by a host of individual muscles. In computer terminology, we could say that the imagination provides the task and another power has to do the actual programming of the muscles required for it.

It is possible to speculate which power could do that. We are not aware of the programming but we are conscious of moving, of wanting to move and even of moving more easily the second time. This awareness requires a knowledge function which can only be the sensus communis. The programming of muscles also requires a power that " knows " the muscles and their functional interrelation. Apparently, this knowledge is mediated by connections from the somesthetic cortex to the motor cortex. On the assumption that the sensorium of the sensus communis is the feltwork of cells and connections between afferent and efferent layers in the neocortex, we could infer that these intermediate layers of the motor and motor association cortex also belong to the sensorium of the sensus communis. Motor imagination would provide the species impressa, and the connection from the " imagination " circuits to the afferent layer of the motor association cortex would mediate it. The act of the sensus communis would be knowing the act and content of the motor imagination and also, constructing a motor pattern for individual muscles (analogous to constructing an object from sensory elements). This pattern could then activate the pyramidal cells in the efferent layer of the motor cortex and would be communicated to the motor nerves which will activate the muscles in the prescribed sequence.

Philosophical analysis shows us that we are aware of felt tendencies to move and enables us to attribute this awareness to the sensus communis. But it will not allow us immediately

to conclude that there must be a direct involvement of the sensus communis in the motor cortex. It is not usual in philosophical analysis to specify in detail the way in which we are aware of appetitive activity (which is a tendency toward an object) and the way in which we know the tendency to move the members of the body in a coordinated manner. However, if we follow through in reflecting on this distinction we can see that the sensus communis does not only know the sense appetite when it is acting but also the motor power (vis motrix).

What we have tried to do in this paper is to examine the concrete empirical and scientifically observable phenomena ontologically connected with a psychological process that is analysed by the Scholastics philosophically. Peghaire does not seem to expect much from such an enterprise. He says:

" As a faculty, the cogitative does not fall within the scope of positive science. As for its operation, it is so easily confused on the one hand with that of the imagination and memory, by which it is always helped, and on the other with that of the intellect, behind which it hides, as it were, that minds with a bias for observed facts would naturally fail to single it out." [8]

It seems to us that a " bias for observed facts " could very well have seen the cogitative sense as a faculty falling within the scope of positive science, and the sensus communis as a power necessary to integrate sense impressions and translate intentions into actual muscular movements. Positive science without understanding is not much good, certainly. But to broaden the figure, is *intellectus* without *scientia* any better? Both are all of a piece.

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[8] J. Peghaire, A Forgotten Sense, the Cogitative, according to St. Thomas Aquinas. *Modern Schoolman, XX (1943), 123-140, 210-229*, p. 229.