Domains of Investigation — main contents of the website

A. Movements and feelings of animal bodies (actual life)
B. Contests (sports and games)
C. Engineered organisms
D. Music practice and performance
E. Practices of bodily consciousness

A. Movements and feelings of animal bodies (actual life)

> God who gave Animals self motion beyond our understanding is without doubt able to implant other principles of motion in bodies which we may understand as little. Some would readily grant this may be a Spiritual one; yet a mechanical one might be showne, did not I think it better to passe it by.
>
> Isaac Newton in correspondence, concerning his theory of light.

1. Actual life is the original domain of freedom.
2. First investigations: wiping reflexes of decapitated frogs.
3. Progressive investigations of bodily freedom start with wiping reflexes, lead to itching and scratching and extend to habits in the home.
4. In initial psychological models, bodily habits are described by forms of movement that are based on properties of materials.
5. Extended psychological models include mental images that influence exercises of freedom during routines of food preparation, changes in locomotion gaits and a choice of dinner from a restaurant menu.
6. Modeled by operations of an idealized holistic brain, multiple kinds of imagery (feelings, awareness, consciousness) participate in exercises of freedom of a competing athlete, performing musician and yoga practitioner.

[Prior versions of materials in this domain were developed in the ***free-will puzzles project*** "How to solve free-will puzzles and overcome limitations of platonic science" (2016) (as to §§ 1-4 here) and in the first part of the ***paradigms project***, "Actual Time, Detached Time and Controlled Time: Physical Paradigms and Energy Constructions" (2018) (as to § 6 here).]

1. Actual life is the original domain of freedom.

My approach employs a process of construction. Initial elements are muscular movements and related feelings of animal bodies, especially my own movements and my own bodily feelings. Mental operations and social interactions come later. I use the phrase ***actual life*** to name a foundational domain of movements and feelings. Investigations of freedom in other domains, psychologies of freedom and anticipated engineered organisms are based on concepts drawn from actual life.

I presume that all four-limbed vertebrate animals (*tetrapods*) have an actual life that resembles my own as to touching and self-touching, locomotion, selective eating, digestion and sleep. More resemblances are found in social tetrapods that engage in sexual selection and have homes, families and communities. In neighborhood parks, birds, squirrels and children manifest common impulsive movements, e.g., squabbling over food and sudden collective running or flight.

In this approach, the common actual life of tetrapods is prior to concepts of objects in an environment or a mental image of reality — as a human infant is prior to an adult. The daily lives of adult human beings generally incorporate an external reality that is organized around permanent objects and locations, anticipated events and personal relationships. Here, in contrast, investigations focus on repetitive movements and bodily feelings that occur while a person is brushing their teeth, climbing a hill, practicing the violin or relaxing in stretched yoga positions.

The following paragraphs introduce the domain of muscular movements and bodily feelings in a broad, sweeping way. Investigations focus on specific situations, simple models and imaginative constructions rather than universal concepts. I presume that actual life has capacities for development and invention — creating new movements and feelings — that reach beyond universal concepts.

In this approach, the body of a tetrapod is moving all the time, even in sleep. Multiple kinds of movements occur at the same time; and different kinds of movement have independent means of production. Eyes, neck, limbs, fingers, mouth, gut, heart and lungs can all operate independently, within limits and with a supporting body and environment.

Muscular movements of a human being include whole-body movements such as walking, dancing and gardening; and also movements of body parts that often occur while the body is in a stationary position such as adjustments in posture, handling objects, speaking and gesturing, working at a desk. Movements of body parts can be coordinated through synchronized operations, e.g., movements during dinner of two hands, eyes and mouth. Whole-body movements are often based on innate or habitual forms such as sitting down or changing clothes.

Bodily feelings include: itch, stretch, heavy, ouch, ache, numb, limb positions, resting, relaxed, upright, unbalanced, tense, queasy, riding, working, hungry and tired. Bodily feelings occur inside the skin while objects outside the skin are perceived through sensory detections. Skin both feels inside and also perceives outside objects. In the mouth and throat, outside objects end up inside; surfaces in these body parts have high densities of multiple detectors that generate complex images. Closing the eyes in a quiet room can help to bring bodily feelings into the foreground of a person's consciousness. In ordinary life, during activities directed at external events, bodily feelings often fade away from a focus of awareness.

Each movement has a brief duration. Many activities involve functional repetition of movements, achieving a single purpose over and over, e.g., in tooth-brushing; but exact repetition of movements requires environmental constraints and training (e.g., movements of a pianist). More often in actual life, unique movements supersede each other during the ever-changing moment of now.

Bodily feelings that accompany ever-changing muscular movements generally have a brief duration. An original domain of actual life is thus constituted by a multitude of transient events occurring inside an animal body that is producing many kinds of movements and generating many kinds of feelings.

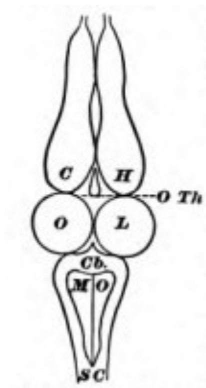
In this approach, external objects, persons, relationships and situations become part of actual life by gradually modifying and enlarging the original domain. This approach resembles that of psychologist Jean Piaget (1896-1980), who studied the development of intelligence in children beginning in infancy, as discussed below.

In many activities, movements and feelings are interactive — e.g., grasping, holding and carrying a water bottle; touching objects and self-touching. Pivotal examples revolve around itching and scratching. Feelings can cause, prevent, guide and otherwise influence movements. I suggest that primitive ***exercises of freedom*** occur during movements that are influenced by bodily feelings. In sum, the body of a tetrapod produces movements, generates bodily feelings and exercises freedom. I suggest that principles of freedom are grounded in the actual life of an animal body and extend, by means of modifications and enlargements, into mental life and social life.

2. First investigations: wiping reflexes in decapitated frogs.

William James (1842-1910) wrote a famous treatise, *The Principles of Psychology* (1890) (available free online). As a starting point for his investigations, James reported on experiments with frogs that focused on movements of the spine alone.

The adjacent image shows James' diagram of the frog brain. There is an ordered array of "different nerve-centres" in which the bottom parts are foundational.



The "SC" (spinal cord) stands at the bottom of the nerve-centres. The first step up leads to the "MO" (medulla oblongata); next comes the "Cb" (cerebellum). Above the cerebellum are the "OL" (optic lobes) and the "O Th" (optic thalami). At the top are the "CH" (cerebral hemispheres) that extend up to olfactory sensors.

In a series of experiments, frogs suffered a cutting off or removal of certain upper nerve-centres while leaving the lower nerve-centres untouched. Some frogs were reduced to spines while others suffered only the loss of the cerebral hemispheres. Frogs manifested changes in behaviors depending on the location of the cut. Intact frogs were also observed.

James concluded: "***The acts of all the centres involve the use of the same muscles.***"

> The same muscle, then, is repeatedly represented at different heights; and at each it enters into a different combination with other muscles to co-operate in some special form of concerted movement. At each height the movement is discharged by some particular form of sensorial stimulus. Thus in the cord, the skin alone occasions movements; in the upper part of the optic lobes, the eyes are added; in the thalami, the semi-circular canals would seem to play a part; whilst the stimuli which discharge the hemispheres would seem not so much to be elementary sorts of sensation, as groups of sensations forming determinate objects or things.

Frogs that have been reduced to spines, without any of the higher nerve-centres, demonstrate ***wiping reflexes.***

> If, to take the stock instance, the right knee of a headless frog be irritated with acid, the right foot will wipe it off. When, however, this foot is amputated, the animal will often raise the left foot to the spot and wipe the offending material away.

> If we suspend it by the nose, and irritate different portions of its skin by acid, it performs a set of remarkable 'defensive' movements calculated to wipe away the irritant. Thus, if the breast be touched, both fore paws will rub it vigorously.
>
> . . .
>
> The most striking character of all these movements, after their teleological appropriateness, is their precision. They vary, in sensitive frogs and with a proper amount of irritation, so little as almost to resemble in their machine-like regularity the performances of a jumping-jack, whose legs must twitch whenever you pull the string.
>
> . . .
>
> The spinal cord of the frog thus contains arrangements of cells and fibres fitted to convert skin irritations into movements of defence. We may call it the centre for defensive movements in this animal. We may indeed go farther than this, and by cutting the spinal cord in various places find that its separate segments are independent mechanisms, for appropriate activities of the head and of the arms and legs respectively. The segment governing the arms is especially active, in male frogs, in the breeding season; and these members alone with the breast and back appertaining to them, everything else being cut away, will then actively grasp a finger placed between them and remain hanging to it for a considerable time.
>
> . . .
>
> The spinal cord in other animals has analogous powers. Even in man it makes movements of defence. . . . Robin, on tickling the breast of a criminal an hour after decapitation, saw the arm and hand move towards the spot.

James appears to discern "***conscious intelligence in the frog's spinal cord***."

> In a similar way Goltz ascribes intelligence to the frog's optic lobes and cerebellum. We alluded above to the manner in which a sound frog imprisoned in water will discover an outlet to the atmosphere. Goltz found that frogs deprived of their cerebral hemispheres would often exhibit a like ingenuity. . . . Goltz concluded from this that the hemispheres are not the sole seat of intellect in frogs.

"Important new features of the [wiping] reflex" were observed in the mid-twentieth century by a group of Moscow physiologists. [Mark L. Latash, *Fundamentals of Motor Control* (2012) at 183.]

> In particular, the hindlimb of the frog produced a series of wiping movements targeting the same area of the back (where the stimulus was placed); individual movements within the series produced wiping

> of the back in different directions. This means that the movements were organized to wipe the same spatial location but at different angles. In other words, the spinal cord was able to organize a multi-joint coordinated action that preserved the location of the spot to be wiped…while allowing the direction of the wiping movement to vary.
>
> Another important observation was made with the stimulus placed not on the back of the body but on a forelimb. Accurate wiping was observed for various positions of the forelimb . . . This implies that the spinal cord is "aware" of changes in body configuration and is able to use this information for movement production.
>
> . . .
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> In [] loading studies, a heavy (lead) bracelet was placed on one of the distal joints of the hindlimb, thus changing dramatically the inertial properties of the limb. Movement kinetics was changed. Nevertheless, the hindlimb was able to wipe the target successfully at the first attempt. Successful wiping was also observed, also at the first attempt, when one of the hindlimb joints was blocked mechanically.

The experiments show that the spine acting alone produces complex repertoires of movements — called "wiping reflexes." Attempts to model wiping reflexes with physical processes of nerves and muscles encounter formidable difficulties. A spot of acid on the skin presumably generates nerve signals that trigger other nerve signals that cause muscular movements of limbs. The movements specifically target the affected spot on the skin. Accurate targeting occurs despite a huge number of possible configurations of body parts and even when a secondary limb must be used or when a limb is burdened with weights.

I suggest that wiping reflexes manifest primitive operations of a physical principle of freedom called ***location selection***. The principle of location selection is a foundational component in more highly developed kinds of freedom, e.g., picking a snack from a rack of many snacks in a food store. The principle is vaguely stated, serving as a starting point. This project investigates the principle in diverse situations tethered to actual life. I presume that what is actually happening may be beyond our capacities for understanding.

In the first reflexive example of location selection, a multitude of similar locations could have been targeted by a multitude of movements, but one particular location and movement were selected. The process of selection was triggered by signals from the acid spot at the location. During the selection process, many possible movements changed into a single actual movement. This is the germinal concept of freedom in this project, the beginning step in a course of development.

3. Progressive investigations of bodily freedom start with wiping reflexes, lead to itching and scratching and extend to habits in the home.

In the following investigations, I presume that my own spine produces repertoires of wiping movements, which are then adapted for itching and scratching. The principle of freedom (location selection) that was attributed to wiping reflexes is extended and developed for itching and scratching. Next, principles are further extended to habits in the home.

To start: guided by the feeling of an itch, my body first moves a finger to a location just above the targeted spot on my skin; and then the finger extends and performs scratching movements on the skin at that spot. Perhaps while I sit on a couch, a small elbow movement brings a hand to the face or to the chest; some small movements resemble wiping reflexes, apparently effortless and thoughtless.

Involuntary reflexive events often generate feelings that carry signifiers of external causes, e.g., a feeling of sharp pain or heat or an impact. Awareness or consciousness of the feeling arises after the movement has started, with a delay. The feeling does not cause or influence the reflexive movement; rather an external event causes both the movement and the feeling.

Suppose that a skin irritation causes an itch and that I feel the itch prior to actual movement. The feeling of an itch ***intervenes*** between the irritation and the movement. Alerted by the itchy feeling, my mind might stifle the scratching movement. "Nurse says do not scratch." As an advancement from an inalterable wiping reflex, an itchy feeling provides a point in the process where mind can control movement. This more advanced freedom might be called "free will."

Similar intervening feelings alert us to try to stifle a sneeze or to relocate to the nearest bathroom.

Wiping reflexes manifest a physical principle of freedom that operates on its own. The addition of feelings provides many opportunities for development. The itch is an example of a ***desire*** and scratching it provides ***satisfaction*** of the desire, sometimes at least. Reduced to a primitive psychological form, a feeling of desire causes the movement. A different feeling would cause a different movement. Different movements are caused by different feelings during exercises of freedom.

According to William James, “the mind is at every stage a theatre of simultaneous possibilities” and on “our mental stage Feeling always selects.” I suggest that similar selections occur in the body before they occur in the mind and that all selections occur in biological materials regardless of location. (Quotation from a magazine article by James "Are we automata?"; see the free-will puzzles project.)

An important ***residential/remote distinction*** guides further investigations in this domain and in the whole project. The distinction states that there are two different kinds of muscular movements and two different kinds of control systems, which are based in different regions of the central nervous system.

Residential movements are based in nervous structures that reside in and about the spine, progressively extending up through the brain stem and the cerebellum. ***Remotely-controlled movements*** are based in the cerebrum. Residential movements arise from and depend on physical properties and conditions of living bodies while remote movements can be controlled by principles of reason.

As discussed in the free-will puzzles project, the residential/remote distinction was originally articulated by William James and is congruent with his description of the frog brain that has different kinds of muscular control at different nerve-centres.

I suggest that the residential/remote distinction illuminates independence of mind and body in certain situations. At the gym, the body toils on a treadmill while the mind discusses social events on a cellphone. In connection with Habit, James related that "A musical performer will play a piece which has become familiar by repetition while carrying on an animated conversation" and that the innovative magician Robert-Houdin trained himself to read books while juggling balls.

Limited investigations of residential movements begin with a spinal focus, e.g., in movements of locomotion. Extended residential investigations involve the cerebellum, which contains most of the brain's neurons, about 70% by some estimates, while occupying only about 10% of the brain's volume. These imbalances are especially impressive since movement control is the sole function of the cerebellum while the minority of neurons in the cerebrum perform many diverse functions.

Neuronal groups in the cerebellum interact through multiple circuits with neuronal groups in vertebrae. I suggest that, metaphorically, a vertebral unit by itself is like a musical instrument called "panpipes" — a rudimentary harmonica made of a set of tubes of different lengths, each producing a musical tone. The cerebellum and spine together are like a pipe organ with multiple ranks of pipes, a variety of keyboard controls and many combinations of tones organized in flowing streams. I suggest that "training" and "practice" in athletics and music occur chiefly in the cerebellum and spine and that certain bodily consciousness practices discussed in part E occur in a "theater of bodily awareness" generated in the cerebellum.

Cerebral exercises of freedom in actual life, in contrast, commonly involve external events in a spatial field, permanent (or stable) objects, persons and forms. Parlor games provide many examples, e.g., game boards, dice and playing cards.

Investigations in this section (§ 3) and the following section (§ 4) are based on residential movements and controls. In § 5, certain mental or remote controls are added incrementally as cues, commands and choices. Final developments in § 6 lead to a holistic view of unified controls ("integrity of freedom") that produce movements of a competing athlete, performing musician or yoga practitioner.

Thus, investigations of bodily feelings beyond reflexive appearances depend on residential/remote distinctions. Functions of ***awareness of feelings*** are attributed to residential operations in the spinal cord, brain stem and cerebellum. Functions of ***consciousness of feelings*** are attributed to remote operations in the cerebrum. Holistic activities are attributed to unified residential and remote operations and unified consciousness and awareness. These attributions might be criticized as arbitrary and categorical; they are also provisional and modifiable.

In this view, awareness is internal, body-centered and self-centered, often with a whole-body character. An animal in a stationary position, alert and ready — a dog at home awaiting the owner's expected arrival — may have awareness even if no object engages its attention. Awareness can expand to include the environment. Stationary awareness may be tethered to external objects but the foundational bodily feelings arise internally on their own.

Consciousness, in contrast, is generally directed at or interacting with external objects, events and persons. Externally-directed consciousness constructs and re-constructs an individual's reality of people, places and things.

Consciousness can also be directed at internal bodily feelings that appear in awareness. Feelings are thereby objectified. Examples appear throughout the project, especially in practices of bodily consciousness discussed in part E. As a general method of investigation, I objectify feelings in this project.

In the following experiments, a person investigates residential/remote distinctions by means of different kinds of self-touching. In the experiments, the tip of one index finger touches the tip of the other index finger.

First experiment. In remotely-controlled fingertip touching, the eyes focus on a stationary left index finger. Then a moving right index finger enters into the field of view; and then the right fingertip approaches and touches the left fingertip under visual control.

Second experiment. In residential fingertip touching, movements are similar to those in the first experiment but the eyes are closed. The moving right fingertip approaches and touches the left fingertip under the control of functions called "proprioception," based in muscles and joints and configurations of body parts.

After practice, my chief observation is that remote and residential fingertip touching have distinctly different kinds of associated feelings. Feelings in the remote case are centered about the fingertips and eyes, which focus on the fingertips and follow their movements; eyes also generate the images used for control. Feelings in the residential case are grounded in the back of my body and extend through shoulders and arms with a culmination in the fingertips.

In the remote case, the controlled speed of movement slows down as the fingertips approach. A steady speed can be more easily maintained in the residential case.

Accurate touching is chancier in residential cases, compared to more assured accuracy in remote cases. This occurs even though my capacities for residential movements and feelings have been developed through various disciplines.

Further experiments. Change roles of right and left fingertips. Try various bodily configurations. Have both fingertips move. My conclusions: Much the same, right or left. Accuracy does not change much as configurations vary. Experiments with two moving fingertips present little added difficulty.

The foregoing observations are applied to whole-body itching and scratching that involves influential feelings. For example, a whole-body movement directs a finger to an itching foot — perhaps the foot participates by lifting to meet the finger. Accurate placement is achieved when the targeted spot is accessible to a finger regardless of the postural configuration of arms, legs, pelvis, chest and head.

I attribute the original start of a whole-body movement to a reflex; then, continuation of the movement takes place under more extensive controls that are activated by a wave spreading from the spinal origin through multiple spinal regions and extending over the entire spine. Perhaps scratching the face is entirely reflexive and operations are confined to thoracic vertebrae; but scratching the foot requires whole-body involvement and extensions of movement.

I suggest that, as more vertebrae become involved in a continuing movement, feelings arise and take on functions of guidance to the target. Complete execution of a whole-body scratching movement by a human being involves a wave of activity through the spine that spreads from the region of origin and culminates in the brainstem and cerebellum.

Recall that residential fingertip self-touching included feelings that reached from the back through the shoulders to the fingertips. Much the same kinds of feelings appear in whole-body itching and scratching. A ***feeling of fingertip leading*** stands out. In a whole-body scratching movement, a moving trajectory of fingertip feeling is aimed at the itch. Such a feeling of directed leading of a movement is a manifestation of an exercise of freedom that re-appears in diverse situations.

Next, the investigation extends to exercises of freedom performed by the body during simple self-touching movements with objects — such as scratching the back with a wooden stick, using a towel to dry off after bathing and tooth-brushing. In each case, an object is moved in specific ways at specific locations on body surfaces so as to generate specific feelings and produce specific effects.

In self-touching with objects, feelings of fingertip leading may be relocated to the part of the object that touches the body, e.g., to the tip of the backscratcher or the bristles of the toothbrush. Relocation of leading feelings to objects is an echo of what presumably occurs in the body, where operations of neurons in and about vertebrae and the brain are felt at fingertips.

Freedom of location selection is similarly exercised when a person puts cleaned dishes away, each dish in its reserved location in the cupboard. Conscious attention may be required to manipulate an object in a crowded space. Securing a dish in its proper place in the cupboard is like scratching an itch.

Extending the principle of freedom exercised during location selection, there are thousands of objects in the home, each with an assigned location. A person takes objects out of assigned locations for use and returns them afterwards. A person can put their fingers on nearly all the objects in their assigned locations, needing only the thought of an object to recall its assigned location and to direct the movement. Location selections in the domain of the home resemble those that occur in the domain of bodily feelings. Each domain is a domain of freedom. The home domain is enlarged and has greater capacities. A person can re-organize assigned locations of objects in the home. While living in the home, a person acquires objects that require new movements, further expanding the domain of freedom.

4. In initial psychological models, bodily habits are described by forms of movement that are based on properties of materials.

a. Psychological models

Definitions. In a ***bodily domain***, movements of an animal are influenced by an environment and conditions of the body such as cold or sleep, by interactions with external bodies, and by internally-generated nerve signals and ***images***. "Images" is used to model "subjective experience" and consists here of internal bodily feelings and external objects. Bodily feelings and objects have common features, e.g., location and duration. Here, objects are constructed elements in a developing mind but they are not yet part of a coherent "reality." There are no objects in initial constructions; they appear incrementally in § 5 as cues, commands and choices.

For purposes here, a ***psychology*** is a ***model*** of movements of an animal body. The model is constructed in a ***mental domain*** resembling a chalkboard. The elements of a psychological model can be verbal, symbolic or designs for devices. The mental construction domain of the model is distinct from the physical domain in which the body moves and from any mental domain of the organism. Certain movements of the model are ***representations*** of movements of the body.

A psychological model includes ***forms of movement.*** The simplest form of movement is a ***beat***. A beat is a flow of repeated movements. Each beat has a ***tempo*** or rate of repetition, e.g., 85 repetitions per minute. The repeated movement in a beat is called the ***schema***, plural "schemata." A schema can be a single stroke or a more complex pattern. Rests can intervene between ***separate iterations*** of the schema. Or the schema can repeat continuously in a ***cycle***. Initially, the tempo and schema of a beat are fixed and then variations are used in development.

Representational movements of the model are controlled by the forms of movement. The forms can also control movements of the body; movements of the body that can be produced by use of the forms are thus based on the model. A body controlled by a beat repeats movements incessantly. The set of forms is readily expanded but can never reach all possible movements of the body.

Each psychology is restricted to a specific ***situation***, which is an environment for movements with a defined space that contains certain fixed and movable objects and is otherwise unobstructed. Examples of situations are kitchens, sports fields, game boards, music rooms and exercise rooms. Only limited classes of movements are performed in a particular situation.

The foregoing definitions are my inventions. They are based on Piaget's psychological concepts and are also adaptable to engineering designs.

Repetition. In human infancy "there is a tendency toward repetition, or, in objective terms, cumulative repetition." (Piaget, *Origins of Intelligence in Children*, p. 33.) According to Piaget, a kind of pattern — the "Primary Circular Reaction" — appears in the first stage of development and includes behaviors that "are ordinarily called 'acquired associations,' habits or even conditioned reflexes." "The repetition of the cycle which has been acquired or is in the process of being acquired is what J. M. Baldwin has called the 'circular reaction.' " (47 - 49.)

Sometimes, desire not having been satisfied, completion of one cycle starts the next cycle. Movements may become self-perpetuating. "The sucking reflex . . . lends itself to repetitions and to cumulative use, is not limited to functioning under compulsion by a fixed excitant, external or internal, but functions in a way for itself. In other words, the child does not only suck in order to eat but also . . . ***he sucks for the sake of sucking.*** " "The object sucked is to be conceived not as nourishment for the organism, but, so to speak, as aliment for the very activity of sucking, according to its various forms." (35, emphasis added.)

I suggest that, beginning in infancy, movements are often self-perpetuating and performed for their own sake. After three or four years, bodies that repeat movements for their own sake may be accompanied by minds that construct other reasons for such movements. An older child or adult will engage in lifestyle, social and mental activities in self-perpetuating ways and will sustain and deepen an activity by means of repetition — "doing it for the sake of doing it." I suggest that acting on one's own, deepening performance skills through repetition and "doing it for the sake of doing it" identify activities that manifest freedom.

The repetition element provides content for activities in domains of freedom. A kitchen routine incorporates linked sequences of repetitive circular actions in peeling, slicing and dicing a carrot. A musical composition is a highly repetitive structure of beats, rhythms, melodies and harmonies. Musicians and athletes repetitively practice movements in preparation for public events. In sports with perenniel leagues, a single contest gains significance as one of a series of repetitive events. Likewise, series of contests in courts and in electoral politics acquire governmental significance. Repetitive movements in yoga, taijiquan and karate nourish growth of seeds of consciousness.

Schema. Piaget sometimes uses the word "schema" and sometimes the word "scheme." I use the word "schema" and restricted definitions. The starting point is from Piaget & Inhelder, *The Psychology of the Child* (1969) at 4: "A scheme is the structure or organization of actions as they are transferred or generalized by repetition in similar or analogous circumstances."

Here are examples of simple schemata: drying the hands with a towel after washing; serving the ball in a game of tennis; singing the opening motif from Beethoven's Fifth Symphony (dit-dit-dit-dah); a forward bend in a yoga routine.

Piaget & Inhelder conclude that the presence of schemata ("action-schemes") in young children demonstrates the "existence of an intelligence before language."

> Essentially practical — that is, aimed at getting results rather than at stating truths — this intelligence nevertheless succeeds in eventually solving numerous problems of action (such as reaching distant or hidden objects) by constructing a complex system of action-schemes and organizing reality in terms of spatio-temporal and causal structures. In the absence of language or symbolic function, however, these constructions are made with the sole support of perceptions and movements and thus by means of sensory-motor coordination of actions, without the intervention of representation or thought. (p. 4.)

b. Psychology of bodily habits, with an application to tooth-brushing.

In tooth-brushing, an exemplar of bodily habits, a larger purposeful course of action includes a series of location selection processes, each such process targeting particular tooth surfaces. Perhaps the person's operative arm and hand are holding the toothbrush so that the bristles are rubbing against one particular tooth. The arm and hand are also engaged in a small cyclical movement that pushes the bristles in a repetitive brushing pattern. After a while, the arm and hand exercise freedom of location selection and shift the bristles to rub the next tooth in line, using the same cyclical movement.

As described by James, the nature of such habits is based on physical properties of materials. "The moment one tries to define what a habit is, one is led to the fundamental properties of matter." He quotes from a philosophical account on

> how a garment, after having been worn a certain time, clings to the shape of the body better than when it was new … A lock works better after being used … It costs less trouble to fold a paper when it has been folded already … The sounds of a violin improve by use in the hands of an able artist [giving] inestimable value to instruments that have belonged to great masters … Water, in flowing, hollows out for itself a channel, which grows broader and deeper.

Development of habits recalls events "when a bar of iron becomes magnetic or crystalline … or plaster 'sets.' " Habits are possible because of *Plasticity*, which "means the possession of a structure weak enough to yield to an influence, but strong enough not to yield all at once." Such plasticity accounts for strengthening of habits that are used daily, for variations of habits among animals of the same species and for changes in habits of an individual at different stages of life.

James concludes that "habit simplifies the movements required to achieve a given result, makes them more accurate and diminishes fatigue" and that "habit diminishes the conscious attention with which our acts are performed." Through practice, "habit economize[s] the expense of nervous and muscular energy." "Dr. Carpenter's phrase that our nervous system grows to the modes in which it has been exercised expresses the philosophy of habit in a nutshell."

In a simple case, "the impression produced by one muscular contraction serv[es] as a stimulus to provoke the next, until a final impression inhibits the process and closes the chain."

> In an action grown habitual, what instigates each new muscular contraction to take place in its appointed order is not a thought or a perception, but the *sensation occasioned by the muscular contraction just finished*. A strictly voluntary act has to be guided by idea, perception and volition throughout its whole course. In an habitual action mere sensation is a sufficient guide, and the upper regions of brain and mind are set comparatively free.

James' observations are readily incorporated in my psychological model of residential habits. Guidance of movements is by means of residential feelings based in the spine, brain stem and cerebellum, rather than by ideas, perceptions or volition based in upper regions of brain and mind. In primitive bodily habits, causation is presumptively muscular, with sensorial linkages.

I would add "engines" to the philosopher's list of things that operate more smoothly and economically after steady use during a "break-in period." Engines are devices and processes that convert energy from one form to another, including steam engines, internal combustion engines in automobiles and the biochemical engines that power animal muscles and nerves. Engines produce cyclical movements described by a beat.

In a psychological model of tooth-brushing, something like an engine produces a repetitive brushing movement, or ***stroke***, e.g., up-and-down, side-to-side or round-in-a-circle. Movements of the arm and hand performing the stroke embody the schema of a beat in the model.

Unlike the strokes of an automobile engine, strokes of the tooth-brushing engine manifest individual exercises of freedom, e.g., as to the pressure of the bristles against the teeth and gums. With sensitive feelings, a range of possible pressures changes into a single actual pressure. A different kind of freedom is triggered by a feeling akin to satisfaction, which causes a shift of the brush from tooth to tooth. And then, yet another kind of freedom — the familiar freedom of location selection — is exercised when the muscles holding the brush actually perform the shift from tooth to tooth and when, in yet another version of the same freedom, the brush relocates to a different set of tooth surfaces, e.g., from outside surfaces to inside surfaces. Although the beat may be interrupted when the brush relocates, the beat quickly resumes at the new location.

In such a habit, movements depend on properties of bodies and materials, e.g., masses of parts, limb lengths, muscle strengths. Movements also depend on momentary positions and variable operations. Proposed engineered organisms discussed in part C illustrate the foundational character of material properties in primary definitional operations of devices. Variable operations are secondary and also depend on material properties. I suggest that, likewise in animal bodies, properties of materials participate in control at all levels of movement. Changes in material properties drive changes in operations.

There is also an accumulative character like that observed in well-played violins, in clinging garments, in grooved water channels and in well-worn engines. Such accumulative character or memory resides in moving parts of the organism.

The grooves of movement are definite but they are not determinate or fixed. An underlying readiness for change is the essence of original freedom. The grooves, like meandering rivers, will shift in time. In the next section, movement production is switched from one groove to another groove by means of signals from a mental domain — specified as cues, commands and choices.

5. Extended psychological models include mental images that influence exercises of freedom during routines of food preparation, changes in locomotion gaits and a choice of dinner from a restaurant menu.

a. routines of food preparation in a kitchen.

A new kind of control is introduced in which one kind of repeated movement is replaced by another kind of repeated movement when a ***mental cue*** occurs. A series of mental cues controls production of a series of different repeated movements. The series adds up to a new kind of movement called a ***routine***. A routine has a specific purpose and pre-arranged sets of repeated movements and cues. The description of a routine usually includes one or more of these features, e.g., peeling, slicing and dicing a carrot; performing eight repetitions each of six exercises prescribed by a physical therapist.

The course of development is thus progressing from wiping reflexes to itching and scratching to tooth-brushing to a routine in a kitchen or exercise room.

Such development involves simultaneous growth of complexity in two domains, the external domain where the results of new movements appear and the internal domain where new movements (schemata) are produced. As stated in Piaget's *The Construction of Reality in the Child*: "the increasing coherence of the schemata thus parallels the formation of a world of objects and spatial relationships, in short, the elaboration of a solid and permanent universe." (Introduction, p. xii.) The "universe" in Piaget's approach is a mental image that is being constructed.

An extended development begins with the beat form of movement, in which a single schema repeats incessantly. Development proceeds to construct structures of schemata. Suppose that a bare beat (a "click") continues for a number of repetitions and then stops — call that number "m." A circular movement (schema) immediately follows each beat. It repeats m times and then stops. After the first schema is stopped, a second beat and schema start, repeat a number of times and then stop — call that number "n." And so forth.

As part of development, the class of "schemata" is expanded to include the bloc of m repetitions and the bloc of n repetitions; they become identifiable movements. An original schema that follows clicks is called an ***elemental schema***, while a larger schema made of elemental schemata is called a ***compound schema***. Both an elemental schema and a compound schema are confined to a time period. Like an elemental schema, each compound schema has a production cycle that is independent from other production cycles. In a first-level compound schema, elemental schemata follow each other in a series. Then compound schemata follow each other in a series to make up a model of a habit, e.g., tooth-brushing.

In a routine, changes between compound schemata are triggered by signals, feelings or objects that are noticed mentally. A mental action of noticing and triggering is called a ***cue***. The person notices the cue and responds by changing the compound movement. This model applies to a routine of peeling, slicing and dicing a carrot. This routine of food preparation can be developed to fit into larger routines, such as: first dice onions, then dice carrots, then dice celery.

> Get cutting board from assigned location and put it in workspace. Get knife and peeler and put them on cutting board. Get carrot from refrigerator, wash and put on cutting board. Cut off top and root tip of carrot and discard pieces. The carrot is now ready for the routine. (This is a cue.)
>
> Peeling proceeds in two halves. For the first half, hold the carrot by the top end and peel the root end. Thus, holding the carrot in the left hand, stroke the surface of the carrot from middle to end with the peeler held in the right hand. Between successive strokes, the left hand rotates the carrot. There is a beat of stroke-rotate-stroke etc. Each stroke and each rotation require exercises of freedom as to location selection. Rotations and strokes aim to remove all of the skin and also to minimize any unnecessary removal. Another aim is to minimize the number of strokes needed to peel the carrot.
>
> When skin at the root end has been completely removed (cue), flip the carrot and hold the root end with the left hand. Then, for the second half of peeling, repeat the first-half movements directed at the top of the carrot.
>
> After the skin has been completely removed (cue), hold the carrot down on the cutting board with the left hand. Take the knife and slice the carrot lengthwise into narrow strips similar in size, stroking the main piece of the carrot with the knife to separate strips. Each succesive stroke involves exercises of freedom, including location selection. Depending on the carrot and on slicing patterns, initial strips may be cut into smaller strips.
>
> When the carrot has been reduced to strips of the desired size (cue), proceed to dice. Gather the strips into a bundle held in the left hand and adjust strip ends near the left thumb to even up the stubs. With the knife held in the right hand, dice with successive forceful strokes by cutting off pieces of carrot from the bundle of strips, which are held down on the cutting board by the left hand, which also squirms backwards during the cutting so as to present fresh carrot to the advancing knife. Diced carrot pieces should be similar in size. Deposit them in the cooking pot or pan. Wash knife, peeler and cutting board and return them to their assigned locations.

Such a routine can be acquired by way of imitation, or verbal instructions via teacher or via recipe. or invention. In this routine, the situation is my kitchen in which I have made many meals and where I keep objects in assigned locations, more or less. Having habitually diced carrots for many years, my body exercises freedom like an engineer — efficiently and economically. Although a verbal description of an action might specify only the end state and disregard details of posture or adjustments during performance, this is sufficient since the body has lots of practice and exercises freedom to complete the task. Each stroke of the peeler or the knife is an exercise of freedom with location selection as a foundational component.

Comparison of the carrot-dicing routine with tooth-brushing illustrates continuity of freedom from one stage of development to the next. Both activities are specific tasks. Both incorporate repetitive circular motions and linkage by steps that carry out a sequence of collective movements. Carrot-dicing proceeds by peeling, slicing and dicing; tooth-brushing proceeds tooth surface by tooth surface. In each case, there is a definite succession of movements that are produced according to a pre-existing form. Production according to the form fulfills the purpose of the task. Each elemental circular motion and larger motions too require exercises of freedom that include location selection, tempo selection and pressure selection. Complete performance of the task can also be viewed as an exercise of freedom.

Contrasting features of the two tasks show development of freedom. In tooth-brushing, an orderly succession of movements can proceed solely by way of habit, without conscious attention. In contrast, careful visual attention is required when handling a sharp peeler or knife close to fingertips. As noted in experiments with fingertip touching, visual control is more accurate than control by bodily feelings.

In casual tooth-brushing, completion of a step is decided by a subconscious feeling of satisfaction. Completion of a step of carrot preparation is subject to visual cues, e.g., placement of the peeler to prepare for a stroke. Visual cues also control slicing and dicing movements so that resulting bits of carrot are uniform. In carrot preparation, perceived locations of cues and controls are in objects in the kitchen rather than feelings in the mouth, as in tooth-brushing. The new features participate in an external reality that extends to the grocery store and merchants of kitchen utensils. Potential for future development of freedom is much greater in the kitchen.

b. changing gaits of locomotion

The capacity of an animal body to move from location to location — the ***power of locomotion*** —is a chief source of freedom. In human life, a world opens up for an infant who is learning to crawl; the world enlarges as the child learns to toddle, walk and run. Animal bodies try to escape or overcome ***confinement*** that restricts freedom of bodily locomotion.

For an adult, freedom of locomotion develops into walking tours of big cities and wilderness adventures. Many people walk for the sake of walking. I first became conscious of freedom during backpacking trips in the California Sierra.

From a perspective of the residential/remote distinction, it appears that primary drivers and controls of locomotion movements operate in the spine and that secondary controls operate in the head. In experiments with quadrupeds whose spinal cords have been severed above the lumbar vertebrae, coordinated locomotion movements of the rear legs can be maintained without control from the higher parts of the brain. The animal may need support to maintain an upright position; the rear legs cycle on their own on a treadmill.

Scientists conclude that:

> many aspects of locomotor movement are achieved by unconscious control via local sensorimotor circuits operating at spinal (vertebrate) or thoracic ganglion (insect) levels.
>
> Control … is thought to be mediated by networks of neurons called *central pattern generators* (or CPGs). Central pattern generators represent clusters of nerve cells located within the spinal cord of vertebrates or nervous system ganglia of insects that have *rhythmic* burst-generating properties. … The evidence for CPGs rests largely on experimental observations of animals in which coordinated movement patterns of the limbs (cats, turtles, cockroaches and locusts have been studied) or undulation of the body axis (lampreys and dogfish) can be initiated and maintained independently of any functional link to higher brain centers.
>
> Andrew A. Biewener, Sheila N. Patek, *Animal Locomotion* (2018) at 183.

Undulating locomotion movements of lampreys and eels have the character of waves that travel along the spine. The whole spine operates as a unified system. Movements depend fundamentally on physical properties of the animal's body parts (masses, elasticities, viscosities) and interactions with the watery medium.

I suggest that movements of quadrupeds also have a whole-spine character in the coordination of forelimbs and hindlimbs in various gaits.

For purposes of a model, an animal's locomotion is made of cyclical whole-body movements with an accumulative result of transportation. Exercises of freedom occur during each cycle and in an ongoing way. Perhaps a quadruped stepped directly forward during its most recent locomotive cycle. The animal can repeat that cycle. Alternatively, in the next cycle, it can turn to the right or to the left. Forward steps can be bigger or smaller, faster or slower. The animal can stop, turn around and go back. Multiple possible routes to home may be available. Variations in terrain may require momentary adjustments of foot position.

Suppose that a first model of a swimming organism has only a single kind of wavy locomotion movement. A ***start-stop control*** is conveniently installed as the first working part in a separate ***command center*** located remotely in the head. A start command sends a trigger signal to the motor system; a stop command sends a halt signal. Start/stop signals resembles cues that switch from one repetitive pattern to another repetitive pattern. This resemblance suggests a further development in which a model has 3 different ways or modes to produce wavy movements (lazy, active, frenzied) and cue-like signals from the remote system trigger changes. Such commands are ***mode shifters*** and resemble gear shifts in motor vehicles.

A ***speed control*** and a ***steering control*** are added in the remote domain. The tempo of movements or speed is controlled by a signal with a certain rate of pulsations. Faster pulses are converted into faster locomotion movements, and the reverse for slower pulses. The steering control has two pulsational signals, left and right. No more than one steering signal appears at any moment. If the left steering signal is active, steering is pulled to the left by an amount that depends on the rate of pulsations. Conversely for the right steering signal. If both steering signals are silent, locomotion proceeds in the forward direction.

The command center resembles the driver's seat of a motor vehicle. From another perspective, the driver's seat of a motor vehicle resembles the remote system in a brain that controls locomotion. A mind that directs legs in self-movement easily learns to drive an ***automobile*** if the controls have similar purposes.

In models of locomotion, one function drives repetitive cycles and other functions select variations between the last cycle and the next cycle. The driving function is chiefly residential but subject to remote controls; selective functions can be residential or remote. Every cycle involves exercises of freedom. Foundational freedoms exercised by the driving residential system involve forceful interactions with the environment. Higher-level freedoms are exercised in the mind.

Foundational exercises of freedom appear as ***motoric causes*** of movements while remote exercises of freedom appear as ***selective causes***. (Residential selections occur but are not noticed, e.g., adjustment of a foot to a foothold.)

A ***motor/selector*** distinction appears in many domains. In a ping pong game (part B), the motoric cause of a stroke by a player is the need to move the paddle to meet a ball that is flying through the air — while the selection of a particular return stroke depends on mental judgment and skill. Technology models (part C) aim for a rhythmic motor cycle that includes a critical moment of Shimmering Sensitivity during which influences select an actual movement from multiple possibilities. The beat in music (part D) is a steady motoric movement that is foundational for varying artistic movements that depend on it. Deep breathing provides the motoric beat in nataraja yoga (part E) while pelvis and shoulders move spontaneously.

A construction of a rudimentary psychology for locomotion focuses on walking and jogging, examples of a class of ***gaits*** that also includes sprinting and skipping. Walking is a smooth or steady movement while jogging is a choppy or saccadic movement. Saccadic movements have a discontinuous character and appear in quick glances of eyes and fingers of typists. A stroke of a knife slicing a carrot is a steady movement; a stroke of a knife dicing a carrot is a saccadic movement. Investigations in parts C and E further explore steady and saccadic movements.

In walking, at least one foot is always on the ground; sometimes two feet are on the ground. Feet on the ground are stabilizing. In jogging, there is never any moment when two feet are on the ground; there is, at most, one foot on the ground and it does not hold to a stable position. Jogging is generally faster than walking but a fast walker can pass a slow jogger.

In this approach, the body has an equal capacity to produce either gait. I presume that the body is used to long jogging sessions. Transitions between gaits can occur in multiple ways. Walking after jogging involves a reduction in energy level accompanied by a feeling of easing. The transition can also be caused by a mental signal, including a cue in an internal script or a command from another person.

The reverse transition, from walking to jogging, usually involves an increase in energy level that requires a mental operation. A feeling of mental effort is converted into an increase in bodily energy consumption and bodily effort.

Suppose that the model is applied to an athlete who is building stamina on a self-powered treadmill with an inclined pitch. The coach stands nearby and issues commands to the athlete: "faster," "slower," "walk," "jog." The athlete interprets and obeys each command. There is no pre-arranged order of schemata, as in the case of cues. Anticipating future development, there might be a large number of different commands that the coach can issue at arbitrary times.

c. choosing a dinner from a restaurant menu

In a simple model of an exercise of freedom, the body maintains a structure of balances and it can easily move in multiple ways. The selection of a particular movement can be determined by a tiny influence, such as a feeling.

A progressive series of tasks serves to develop such a simple model into processes suitable for uses of reason in a community. Development began with cues that trigger switches between schemata that have a pre-arranged order of performance. Each cue shifts performance from one schema to the next schema. With commands, there is no inherent order of performance and the next schema can vary among possibilities or within ranges. In a cue-controlled situation, the only next step is a pre-arranged step. In a command-controlled situation, the next step can occur in multiple ways that are specified by particular commands.

Development next proceeds to ***choices***: changes are subject to constraints and forms rather than to cues or commands. Instead of issuing from an external source, the next-step selection is based on an internal process that is tethered to one's own mental objects. In other words, multiple possible movements become objectified in multiple external objects, e.g., snack packages in a food store. You have a choice but it is subject to offerings of the store manager.

Choosing a snack is an example of ***selective eating***, a fundamental freedom that is observed throughout the animal kingdom and exercised by all of its inhabitants. Even amebae and paramecia absorb some organic matter they encounter and reject other such matter. Large domains of personal freedom feature selective eating and personal appetites for food, along with diverse rules and judgments about food.

Restaurant menus provide well-defined examples. In the simplest case, the menu lists a number of dinners and the customer chooses one dinner from the list. Different choices are manifested as different utterances, e.g., "spinach ravioli" or "pepperoni pizza." In the simplest case, the only possible utterances are listed on the menu. You expect to order one dinner and no more.

The possibilities are objectified as printed descriptions of various dinners. The description may specify ingredients and include words and phrases that aim at arousing desires. The diner's mind imagines the dinner and considers different dinners on the list as possible objects of desire.

The choice incorporates constraints and forms. The possible culminating utterances are restricted to a list of items, which correspond to objects of the choice. Uttering one dinner-name on the menu necessarily excludes uttering any of the other dinner-names on the menu. During the selection process, the list of possibilities changes into a single actual utterance. Then the menu is put aside.

In the simplest model, each possible movement or utterance stands equally with the others. Each movement or utterance would require about the same amount of energy and effort. Little energy or effort is required to shift from readiness for one possible movement to readiness for another possible movement. This aspect of the model is much the same for choices as for commands.

One difference is that, in the choice case, the change from possibility to actuality is triggered by an internal mental operation, rather than by an external event.

In other words, in the choice case, the selection between possible movements is caused by the person's feelings leading up to the change. The restaurant menu manifests the principle of freedom that different feelings cause different movements.

As an advance in development, the timing of a choice is innovative. In habitual tooth-brushing, the timing of a shift of the brush from tooth to tooth is presumptively based on physical properties and bodily feelings, e.g., a habitual number of strokes per tooth. Timing becomes objectified when cues are introduced — a movement is triggered by a sensation that is immediately noticed. The timing of a command also occurs in objective time. If objective cues or commands maintain a beat — e.g., an orchestra conductor's baton or commands of a drill instructor of a marching squad ("hup-two-three-four") — the body conforms to the beat and the body tends to maintain that beat during interruptions of the commanding beat.

A new kind of timing is introduced with the choice form. A choice is an exercise of freedom that often requires an extended period of time. Changes are quick during reflexes, cues and commands. In a restaurant, in contrast, the change from a list of possible utterances to a single actual utterance may require deliberation. There are various reasons to prefer ravioli or to prefer pizza. Perhaps a dinner companion might want to share? We are enjoying ourselves with clever remarks and the waiter is charmingly patient.

I call the new kind of timing ***detached timing*** and distinguish it from ***actual timing*** that is determined by properties and conditions of materials and by events in objective time. In detached timing, a variable amount of time changes into a specific amount of time — when the change occurs. The selection of an utterance, presumptively based on feelings, includes a selection of timing, also based on feelings.

Because a period of decision is often prolonged in a choice, it is possible to focus more sharply on the internal change. A cloud of mystery surrounds actual changes and productions of movement in animal bodies, beginning with wiping reflexes and becoming more complicated at each step of development. There has been no satisfactory explanation for the wiping reflex of the decapitated frog in which a skin irritation caused a targeted movement — in other words, for the exercise of freedom called "location selection." Investigations in the project have incorporated loction selection in more complex exercises of freedom but without insight into the original problem.

Observations of choices in actual life reveal a structure in time that helps to investigate location selection and more extensive classes of freedoms. The structure in time centers around a ***critical moment*** when the change occurs. Prior to the critical moment, multiple movements were possible; after the critical moment, one movement is becoming actual. The critical moment is much shorter than the period of time prior to the critical moment. Usually, changes occur so quickly that a person is not able to keep track of them, even if they desired to do so. According to William James, “The attempt at introspective analysis in these cases is in fact like seizing a spinning top to catch its motion, or trying to turn up the gas quickly enough to see how the darkness looks.”

In part B, dealing with contests such as games and sports, the time structure of a choice is applied to an external public event of an athletic competition. The beginning of the competition is like the beginning of a choice from a menu where multiple objects are presented. In the menu case, multiple possible dinners change into a single actual dinner. In the game case, multiple possible winners change into a single actual winner.

Evidence from actual athletic competitions reveals multitudes of ways to change from initial possibilities to the final result. The course of changes from beginning to end is "the game" that people come to see. I suggest that a similar course of events occurs in the mind of a deliberating diner. In part C, engineering designs investigate similar changes in proposed ***quadnet devices***. In anticipated operations of quadnet devices, a unique condition of ***shimmering sensitivity*** appears during a critical moment of change in a collective device — and illuminates the process of decision.

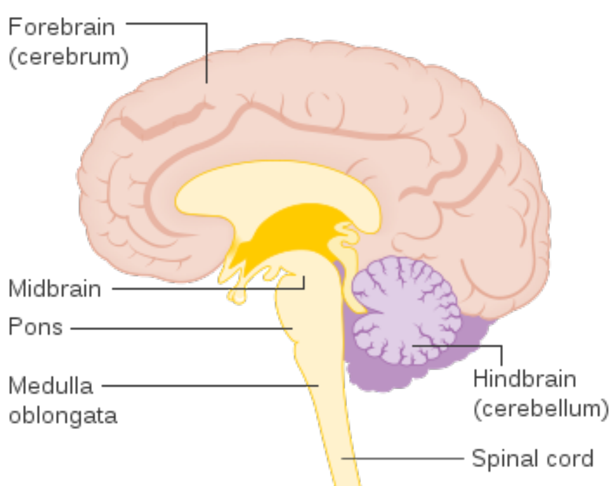
6. In operations of an idealized holistic brain, multiple kinds of imagery (feelings, awareness, consciousness) participate in exercises of freedom of a competing athlete, performing musician and yoga practitioner.

In the foregoing investigations of freedom in actual life, development followed a step-by-step approach, starting with wiping reflexes and progressively incorporating bodily feelings and mental objects. Exercises of freedom have been identified at every step, with a recurrent focus on location selection.

Investigations in subsequent domains in the project (contests, engineering, music, yoga) grow out of the prior development. Parallels between domains arise from the common origin and include unifying cross-references.

This section views anatomy as a guide to the physical (materials) foundation of all exercises of human freedom. The investigation relies on the following diagram of parts of the human brain with a focus on the residential nervous system.

Residential nervous system and other brain parts.



Source: Cancer Research UK/Wikimedia Commons

Presumptively, residential drives, controls and movements are based in the spinal cord, medulla oblongota, pons and midbrain — aspects of a single cylindrical body called the ***entire spine*** that operates in collective ways. Nerve fibers extend from the spinal cord into skeletal muscles and joints, participating with them in mutual adaptations. In further developments, operations of cerebellum and cranial nerves are integrated with those of the entire spine, greatly expanding repertoires of movement of the body.

This approach attributes wiping reflexes to nervous structures residing inside and around vertebrae. Similar resident structures produce locomotion movements in animals with severed spines, manifesting operations of central pattern generators. I suggest that vertebral structures, acting on their own, participate in a network that can operate in multiple ways as a whole or in independent parts.

At the bottom, a whole spinal cord produces large repertoires of movements prior to control by means of other brain aspects or parts. I suggest that ***beats*** are generated in a spinal cord, beginning with fish and eels and progressing through wagging dogtails, rock music drummers and qigong practitioners. ***The beat*** is a topic of investigation in part D, the domain of Music Practice and Performance.

Layers of development are built on the foundation of the spinal cord alone. Each layer contributes additional capacities and controls. The medulla oblongata, pons and midbrain are collectively called the *brain stem*, unified with the spinal cord to make up a whole body of nervous structures that I call the entire spine.

I suggest that the entire spine — on its own and prior to control by the cerebellum or inputs from cranial nerves — produces complex repertoires of sustained movements with variable strengths and durations. I suggest that rudiments of feelings generated in and around vertebrae are unified in the entire spine into whole-body feelings that lead a fingertip to an itching foot.

The entire spine lacks a capacity for habitual activity. It lacks connections to the head and is yet oblivious to external objects perceived by the head. Feelings and movements are brief. Memory is scant so as not to limit or distort the repertoire of foundational spinal movements.

Further layers of development are attributed to the cerebellum, beginning with habits, a "plastic" form of material memory, to use James' term. Simple models suggest production of repetitive movements that are steady for multiple cycles — and then change into different repetitive movements that are steady for multiple cycles. James observed that, in their adaptations to repetitive movements, habits resembled properties of material bodies. In furtherance of this approach, microscopic examinations of nervous structures in the cerebellum suggest that habitual movements are based in properties of cell bodies and variable adjustments in interconnections of nerve fibers.

From the perspective of residential/remote distinctions, the entire spine (spinal cord and brain stem) and cerebellum constitute the chief residential parts. I suggest that general awareness arises therein to maintain the body in readiness for movements that can be produced in diverse special ways — and then to produce appropriate movements. A body limited to residential parts and movements is sensitive to touch and has repertoires of aversion, such as wiping at an irritant or squirming away. It has locomotion capacities greater than those of a chicken with its head cut off. I suggest that, through cerebellar adaptations, such a body can learn and repeat on its own certain movements that are initially imposed by external forces; such adaptations appear as a primal kind of obedience. The body lacks, however, other sensitivities to external objects, such as smell, vision or hearing. Presuming a supportive environment, such a body has actual life but of a very primitive kind.

In prior steps, development of external influences involved mental objects called cues, commands and choices. Such a mental object is an isolated event which is tethered to movements. More development of mental objects will be required to construct separate domains of "reality" or "mathematics" or "music."

In anticipation of further development, I construct an overarching class called ***images*** that includes bodily feelings, awareness, sensations of smell and taste, sensations of sight and sound, visual objects, forms, memories, thoughts, plans, arts, sciences, etc.

Consciousness is presumed to generate images that are tethered to objects based in actual external events (e.g., music) or based in imagination (e.g., mathematics). Activities in these domains are attributed to the cerebrum.

Imagery also includes fantasies, whether generated on your own or from a screen and sound track. Anything you can name or imagine is an image. The class is open to new kinds of imagery.

Investigations in this project examine movements of a ping pong player, a pianist and a yoga dancer. Movements are presumed to require ongoing exercises of freedom that are sensitive to multiple influences, that occur in highly variable ways, that produce unified whole-body movements and that achieve difficult goals as a result of years of practice. Such culminating activities are presumed to occur in a ***holistic brain*** that is generating unified imagery —including feelings in the brain stem, awareness in the cerebellum and consciousness in the cerebrum.

The cerebrum and the residential region have multiple means of interaction. It appears that cues, commands and choices generated in the cerebrum are channeled through the motor region of the cerebral cortex to trigger directed movements of the spine. Without contributions from residential controls and habits, cerebrally-directed movements are brief and simple, e.g., movements of fingers on keyboards.

In holistic modes, additional interactions apparently involve the ***central region*** in the diagram of brain parts above, a region that is bounded by the cerebrum, the brain stem and the cerebellum. This region contains a variety of structures, e.g., the thalamus and basal ganglia. I suggest that, during holistic operations, separate controls in spine-based residential structures and in remote cerebral structures are absorbed into more powerful structures based in the center.

In *Neural Darwinism: The Theory of Neuronal Group Selection* (1987) at 219, in a useful chapter titled "Action and Perception," Gerald M. Edelman distinguished "the different evolutionary stages of what *appear* to be similar movements" and concluded that "movements of different body parts … have different evolutionary origins."

> Rhythmic movements can be carried out in amphioxus [a rudimentary eel] without a vestibular system or cerebellum. By the time that cyclostomes [another kind of eel] had evolved, a much greater axial flexibility and adapatability was accompanied by evolution of vestibular nuclei and the cerebellum.
>
> . . .
>
> Evolutionary changes in other areas involved in motor function far exceed those in sensory areas. … the largest single evolution change between therapsid reptiles and mammals is … in the relation of the basal ganglia to the cortex.
>
> . . .
>
> The data indicate that axial motions based on central pattern generators [] are combined later with vestibular and cerebellar developments, and with enhancements related to cerebellar control of appendages, and finally, with the development of basal ganglia and lateral cerebellum as well as cortical areas for fine voluntary motion. Motion can be based upon *any* combination of axial, appendicular, and postural components that can carry out a given gesture. This implies *varying* contributions of reflexes, central pattern generators, and feedback as well as feed-forward loops.

Edelman's approach, like those of James and Piaget, presumes a developmental path, namely, development of a succession of species in darwinian evolution, similar to development of a succession of partially crippled frogs into an intact frog, similar to the growth of an infant into an adult. Constructions in this project aim for similar successions that culminate in holistic exercises of bodily freedom.

Nov. 2022