Cover Page

Title: "A Theory of Marks and Mind: the effect of notational systems on hominid brain evolution and child development with an emphasis on exchanges between mothers and children."

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A Theory of Marks and Mind: the effect of notational systems on hominid brain evolution and child development with an emphasis on exchanges between mothers and children.

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Summary

A model of human language requires a theory of meaningful marks.

Humans are the only species who use marks to think. A theory of marks identifies children's scribbles as significant behavior, while hypothesizing the importance of notational systems to hominid brain evolution. By recognizing the importance of children's scribbles and drawings in developmental terms as well as in evolutionary terms, a marks-based rather than a predominantly speech-based theory of the human brain, language, and consciousness emerges.

Combined research in anthropology, primatology, art history, neurology, child development (including research with deaf and blind children), gender studies and literacy suggests the importance of notational systems to human language, revealing the importance of mother/child interactions around marks and sounds to the development of an expressive, communicative, symbolic human brain.

An understanding of human language is enriched by identifying marks carved on bone 1.9 million years ago as observational lunar calender-keeping, pushing proto-literacy back dramatically. Neurologically, children recapitulate the meaningful marks of early hominins when they scribble and draw, reminding us

that literacy belongs to humankind's earliest history. Even more than speech, such meaningful marks played --- and continue to play --- decisive roles in human brain evolution.

The hominid brain required a model for integrative, transformative neural transfer. The research strongly suggests that humankind's multiple literacies (art, literature, scientific writing, mathematics and music) depended upon dyadic exchanges between hominid mothers and children , and that this exchange and sharing of visuo-spatial information drove the elaboration of human speech in terms of syntax, grammar and vocabulary. The human brain was spatial before it was linguistic. The child scribbles and draws before it speaks or writes.

Children babble and scribble within the first two years of life. Hands and mouths are proximal on the sensory-motor cortex. Gestures accompany speech. Illiterate brains mis-pronounce nonsense sounds. Literate brains do not. Written language (work of the hands) enhances spoken language (work of the mouth).

Until brain scans map the neurological links between human gesture, speech and marks in the context of mother/caregiver/child interactions, and research with literate and illiterate brains document even more precisely the long-term differences between these brains, the evolutionary pressure of marks on especially flexible maternal and infant brain tissue that occurred 1.9 million years, radically changing primate brain capabilities, requires an integrated theory of marks and mind.

Background

The Theory of Marks and Mind

Once bipedalism and upright posture created the reverse blood flow necessary for cooling and, thus, enlarging the primate brain, marks of meaning --- from doodling in the dust by solitary toddlers to notational systems devised by female and male hunter/gatherers for keeping track of natural cycles and periodic events and processes --- placed substantive visual/attentional pressure on the proto-hominid visual cortex, the dexterous, expressive hands, the vocalizing mouth, and the motivational/emotional limbic system, to drive brain growth in terms of the lateralization as well as the synchronous unification required for the complex, symbolic, multi-modal, multi-literate communication systems

we identify as human, in a brain with special quantum advantages and requirements.

Two Broad Categories: primates who make marks to think, and those who don't

Research with children's scribbling and drawing (1-16), including mappability onto recurring designs in art history (15), attests to the importance of marks as invariant behavior.

An evaluation of brain endocasts (17), as well as a re-interpretation of pre-Ice-Age marks incised in bone (18), brings into sharp relief two broad categories of brains: primate brains with increased vascular/cooling systems which use meaningful marks to think, and primate brains which lack such systems, and do not.

We hypothesize that the primates who used using meaningful marks to communicate found themselves in a quandary. On the one hand, marks drove the development of symbolic language, changing one group of primate brains dramatically. On the other, this kind of information processing was energy-costly, with a potential for over-heating the brain (19). Improved meaning-making systems required improved cooling systems (17). Brains capable of talking and writing needed a new kind of vascular system.

Literate brains *learn* phonological processing from alphabetic written language. Auditory-verbal and written language interact. Literate and illiterate brains differ in attention, working memory, and articulatory organization of verbal output (19, 20). These are significant, non-trivial differences (20). How did the verbal, literate human brain evolve? What drove the connections between marks and mind?

Anthropology.

Missing links: brain-casts and scribbles.

Skull fossils of bipedal hominins show that blood started to leave the skull in ways that differed from the way blood circulates in ape brains. By counting the numbers of holes in the skull which allowed major vessels to dump their coolant (blood) all over the surface of the brain, it became clear that the special placement and number of foramina increased

dramatically in *Homo* (17, page 25). Brains and veins evolved together (17, page 26). Cooler brains became bigger brains.

Endocasts showed that Broca's area - one of the two cerebral areas we associate with language- was present in the brains of hominins that lived about 1.9 million years ago. It is still present in chimpanzee brains today. This means that language was being selected for and lateralized 2 million years ago (17, page 27). As the dividing and sharing of mental tasks into two general categories, the spatial and the linguistic, lateralization was a huge jump forward in hominid brain morphology and capabilities. Still, the question remains: why did some primates develop spoken and written languages while others did not?

The Motherese Thesis

Bipedal, upright posture selected for smaller pelvises. Smaller maternal pelvises selected for immature neonates. Immature neonates put pressure on mothers' vocalizations for reassuring sounds (17, page 28), as well as on infants' signaling systems (21).

Bipedalism, improved brain-cooling systems, smaller pelvises, premature births, infant dependence eliciting maternal comforting and admonishing sounds increased mother-child interactions, generating, over time, the slower, more carefully articulated, higher-pitched speech called "motherese" (17, 21). "Motherese," plus the solitary marks-based play of the hominid toddler set down in the dust, became important components in a constellation of pre-adaptive conditions necessary for human speech.

It was not the descent of the hyoid bone that achieved human language. The hyoid bone descends in the organization of the throats of modern day chimps as they mature (23). It was the complex interactions between mothers and children around sounds and signs that proved especially pre-adaptive for speech (24), with marks-based communication as the key to the sophisticated oro/facial controls as well as to the neural networks necessary to transform vocalizations (25) into elaborated speech beyond simple (as opposed to complex) sentences.

Primates and Language: the great debate

Linguists do not believe primates can acquire language as humans do (26, 27) Some primatologists believe they can (28-32, 74). After eighty

years of research with apes and chimpanzees, it is unclear whether highly trained primates understand the *meaning* of the signs and symbols they use, let alone grammar or sequencing rules (33-35). Because they tend to interrupt their trainers, failing to take turns conversationally or to provide new information, never lengthening their sentences past six or seven signs, chimpanzees' use of human language is very different from a child's (35). Bonobo tool use (36) might bridge the linguistic gap if it included mark-making. The fact that bonobos mark their trails with smashed plants, which they evidently use as road signs at trail intersections, means that some primates can "write" and "read" visual cues (29).

The major difference between human children and chimpanzees as language-users is that children invent new sentences, while chimpanzees sign the sentences they've learned from their trainers (with a few reported exceptions). Another major difference between child and chimpanzees is that chimpanzees use language to ask for things, rarely, if ever, to "chat" (35). On-going research with apes shows that they can learn to use language in human-like ways with mechanical assistance (including computers and voice synthesizers), and that, more importantly, apes demonstrate the importance of co-regulated interactions between teacher and learner, speaker and spoken to (40). Whether gestured, vocalized, signed, or spoken, the enterprise of language depends upon two items: dynamic dyadic communicational exchanges, and especially susceptible infant brain tissue (40). Ape language research suggests that the primate group that used a digging stick to make intentional marks more than 1.9 million years ago opened a visual and verbal dialogue which would select out one group for the long adventure of spoken and drawn and written languages --- an adventure in which mothers and children would play central, dramatic roles.

Primates can learn to use hundreds of signs. The more signs a chimpanzee knows, the greater its chances of responding to a novel demand, even to making a novel statement like Kanzi's "Give the dog a shot." Kanzi had never heard this sentence. (This observation about chimpanzees argues for the importance of an expanded vocabulary in children if we expect them to think creatively.)

One researcher suggests that primate research should focus on gesture rather than speech to see if primates have something like a natural sign language (39, 41-39). Should this prove true, then some of the conditions for language as speech *as gesture* (if not as sound) would

have been met before hominins split off from other primates. Since chimpanzees will scribble with trainers, another line of research might focus on whether chimpanzees in the wild make marks. For instance, when gorillas drag branches to indicate that the group is going to move to a new nesting site (22, 51), does the rest of the group follow the noisy, branch-dragger or the visible marks the branches make on the ground? Is the function of branch-dragging creating an attentional audio-visual display or a map? If the marks are followed by members of the troop who follow at a distance, out of sight and hearing of the branch-dragger, then this might be where scribbling, drawing and literacy began.

As well as asking whether chimps can speak or sign grammatically, with understanding, it might be more fruitful to ask if chimps can learn to draw, and then try to "bootstrap" (27) signed speech onto drawing. This approach would place the emphasis on acquiring visual literacy before verbal literacy. This educational order of events makes sense developmentally, at least from the human child's point of view; children draw before they write.

The question still goes begging: *exactly how* did our CA (common ancestor), the one who bridged the gap between great apes and humans, map spoken language onto existing gestural/vocalization communication systems?

Putting the Baby Down: Exploring infant solitude in connection with scribbling and drawing and the lateralization of the human brain.

"Infant parking " was rare in anthropoids because predators were everywhere (22). Still, bipedal mothers occasionally put their dependent toddlers down upon the ground, freeing up their hands for survival tasks like gathering, gardening, and hunting small game. Presumably, as hominid society became more organized, child care-like support was provided by allomothers (52), allowing supervised infant parking to become more common.

Brain casts suggest that hominid mothers' gestural and vocal repertoires would have been sufficient to comfort and control babies who were too immature to cling to their mothers' bodies (22), while pre-toddlers' communicative gestural/vocal skills would have been sufficient

to making their needs known to caregivers who were not actively holding them (22). Hominid mother/child communication became multi-modal (22, 53), designed to communicate at a distance, from several feet to much farther away.

In a theory of marks and mind, maternal vocalizations and notations and toddlers' vocalizations and scribbling must have been, and remain to this day, mutually influential, following parallel courses, with the result of creating marks-based (as contrasted with a gestural or sound-based) communication systems. These early, multi-modal sound and marks-based systems encouraged the evolution of the abstract aspects of speech, as well as the range of symbolic marks we identify as literacy (as literacy includes drawing, writing, mathematics, and musical notation). This parallel developmental course for marks and sounds drove the mother/child dyad's communicative repertoire. If novel behaviors are transmitted youngster to youngster, trickling up to older females and siblings, and then, as fixed behavior, to adult males (54), we can attribute the invention of elaborated speech and literacy to young hominins.

Ambiguity, mimicry and the solitary independence of the "parked" child: more conditions for speech and literacy.

If manual gestures exchanged by mothers and children were often ambiguous (22), requiring the invention of words to make communication clearer, and if our hominid mothers taught us to copy her images (which is likely, given the instructional nature of mothers and the imitative nature of children), then both speech and drawing would have been dividends of mother/child interaction, and hominid mothers emerge as humankind's first, best speech *and* literacy teachers. Contrary to one scholar's position that maternal linguistic influence including "motherese" is "folklore" (27, p.39), modern mothers and children continue to co-invent language and literacy.

In fact, it is probable that the prosody, or sing-song cadence of motherese (which babbling reflects), is reflected, in the "prosody" of scribbling, increasing the influence of low-frequency organizers on the young brain. It is also probable that the "social syntax" (54), or learned call-and-response behavior in mother/child communication (also called turn-taking) was reinforced by scribbling and drawing, encouraging

hemispheric turn-taking in a newly lateralized hominid brain. Theoretically, this bihemispheric turn-taking included the neural circuitry necessary for translating verbal information into visual information, as well as visual into verbal information, making possible the multiple literacies humankind uses to communicate.

Just as it is possible to argue backward from how children currently learn to talk with their mothers, to how hominid infants must have learned to talk via exchanges with their mothers featuring the special prosody of "motherese," (55), so it is possible to argue backward --- not from modern mothers' marketing lists --- but from the fact that modern toddlers scribble, to the position that marks of meaning must have been part of the process of the acquisition of spoken as well as of written language in young hominids, perhaps from the time of *Homo habilis*. In fact, the mental move from *Homo habilis* to *Homo sapiens* may depend upon scribbles.

Brain Science.

The Sensory-Motor Cortex: closely connected hands and mouths

The contiguity of the hand and the mouth on the sensory-motor human cortex supports a synergistic relationship between the action of the hands and speech (56-72). Hand and mouth areas on brain cortices are close, too, in other primates (73). Still, some confluence of behavior and environmental pressures connected the work of the hands with work of the mouth in the service of human language. A special, synergistic relationship between hands and mouth persists in the life of child whether sighted or blind, hearing or deaf (75-83). Gestures, signing, scribbling, babbling, speech and literacy are connected.

It is this paper's position that not only gestures and speech (41-50), but speech, scribbling and drawing are neurologically linked in the human brain as multi-modal extensions of the dopaminergic SEEK and PLAY mammalian survival systems (34). It can be argued that the evolutionary rationale for such a linkage is not language *per se*, but emotionally-driven, energy-conserving *understanding*.

In a marks-based (as opposed to a speech-based) theory of language, scribbling and drawing act like thermostats, heating/speeding up brain frequencies for easy word-retrieval in speech, as well as for

reading and writing, then cooling/slowing down brain frequencies to achieve efficient resting states via marks-based resolution/understanding.

Exactly how the praxis and practice of speech and literacy and emotional self-regulation co-evolved in hominid history and continues to unfold in today's child is unclear, but brain research with children and mothers engaged in play and conversations around scribbles and drawing will extend the existing research connecting speaking mouths and gesturing hands, providing support for the theory that dyadic mother-child interactions once constructed and still construct the kinds of integrated neural processing and callosal transfer necessary not only for descriptive, analytical, inferential and metaphorical speech but for the multiple literacies on which such complex symbolic language depends.

Infant Decentration and mirror neurons

A theory of Infant Decentration (55) suggests that, once infants no longer clung to the tummies or backs of their mothers, the mother/child unit was split. Mothers' and the infants' points of views about everything diverged. The infant had to learn to read its mother via her gestures, sounds, facial expressions: ditto, the mother vis a vis the infant. Since mirror neurons form substrates for understanding motor actions in others, it is likely that another pre-adaptive condition for language was an increased number of mirror neurons in sensory-motor, emotional, and language areas as additional cognitive dividends generated by hominid mother/child interactions.

Vision and Attention

Vision and attention are connected operations (6-8). We propose that sustained visual attention is necessary for speaking, too, as well as for drawing, reading, writing, and other marks-based expression. Arguably, the work of the hands *as marks* extended the attentional capabilities of the visual cortex for language. The first four tenets of The Scribble Hypothesis (10, 11) anchor this position:

• One: Very young children's scribbling trains the brain to pay attention and to sustain attention, setting up self-organizing feedback loops between the eye/hand/ear/mouth and the inter hemispheric brain.

• Two: Very young children's scribbling stimulates individual cells and clusters of cells in the visual cortex for line and shape.

• Three: Very young children's scribbles help them practice and organize the shapes or patterns of verbal and visual symbolic thought.

• Four: Very young children's scribbling encourages an affinity, or love for marks, preparing the mind for its determining behavior: literacy.

How affective neuroscience connects emotions with a theory of language: the strategies SEEK and PLAY.

Toward a Quantum Theory of Scribbling.

By connecting a marks-based evolutionary theory of literacy with emerging theories about the importance of emotions to brain function and human thought (84, 85, 88, 89), and by focusing on the mammalian SEEK and PLAY strategies described by affective neuroscience (84), literacy becomes a downstream ramification of ancient emotional circuitry associated with strongly positive motivational neurotransmitters designed to encourage humans to seek and play ---- in this case, with meaning, rather than exclusively for food, shelter or social and/or sexual advantages.

Seeking and playing with meaning makes human brains unique. Meaning is, of course, invisible. Meaningful marks are not. SEEKing and PLAYing inside the brain for the fun of it, and for the need of it, became a possibility and a priority for literate mammals. It is in this connection that it is useful to review tenets #5 and #6 of The Scribble Hypothesis, proposing a Quantum Theory of Scribbling:

- Five: Marks of meaning operate like "super-radiant surfaces," or mirrors, encouraging self-reflection, capable of producing consciousness states describable as self-induced transparency, or epiphanic consciousness (including understanding, wisdom, peace, transcendent at-oneness), rewarding the brain emotionally and neurochemically for its hard-won self-clarification (38), while, at the same time, allowing the brain to settle into minimal, coherent energy states (91-93). This resolution across

emotional/neural levels is energy-efficient, a highly desirable state in dynamic systems.

- Six: Marks of meaning including scribbling are not only critical to the neural development of visual, verbal, and emotional thinking in the child, but instrumental in the maintenance of healthy neurophysiology, including the visual, verbal, emotional, and memory/learning circuitry in the adult brain.

It is on these tenets that a theory of marks as transcendent consciousness designed to help the brain settle into energy-conserving states depends. (For a tentative explanation of the molecular biology behind such transcendent states, refer to "Scribbles: the Missing Links" papers, www.drawingwriting.com).

In a brain which uses symbolic meaning to achieve equilibrium, there must be motivation for cooled-down states. It is arguable that the terms "self-induced transparency" and "super-radiance" associated with quantum micro tubular consciousness states (93) have relevance for the *emotional* motivation of special, higher-order "transcendent" brain states responsible for neural resolution, and, that, in fact, these terms provide apt descriptors for how such clarified higher-level mental states *feel*. A brain that has worked hard to figure out a major problem in life feels lightened (in the sense of being filled with light), even ecstatically clear. A quantum theory of scribbles suggests that multiple literacies, including art, literature, music and mathematics, are brain tools for resolving the over-heating consequences of problems encountered in a language-based life.

Child Development.

Extending the capabilities of multi-modal brain tissue with clues from the deaf and the blind.

The instinct to communicate using any available mode is innate; if a child can see but is deaf it uses signs; if a child is blind but can hear, it uses sounds. Still, all children babble and scribble *at first*. Their brains, despite their disabilities, are organized to communicate verbally *and* visually, in systematic parts-to-wholes ways using a combinatorial mechanism much deeper than language. Children instinctively build up

words with sounds, sentences with words. Children instinctively build up images and text with lines and dots, curves, spirals, and other geometric shapes.

Brain tissue dedicated to communication is open to environmental influence; it has multi-modal potential (53). We argue that this multi-modal potential owes a debt to the interactions between hominid mothers and children around gesture, vocalization (17, 55, 94), and marks of meaning. As significantly, mirror neurons in the brain most probably owe a debt to the affective exchanges between mothers and offspring across species.

By recognizing the importance of the dialogue between mothers and children around marks and sounds, we focus an evolutionary/developmental theory of human language on the connections between the work of the eye, hand, mouth, and ears achieved in emotionally positive exchanges with a primary care-giver. The neural substrates and requirements for human language, whether gestured, signed, spoken, drawn or written, requires the integration of major sensory systems in the context of love.

Babbling, scribbling, and motherese are robust, universal behaviors, and they constitute major links in a continuist theory of human language.

Literacy Research.

Adult illiterates mispronounce nonsense words, while literate adults do not. Learning a written alphabet in childhood changes the brain for a lifetime of *speech,* not just for literacy (20, 95). *Seeing* the letters of the alphabet, and learning to *read* them, teaches the brain to *say* them, even when the words are nonsense.

A look at the evolution of written languages, say Egyptian, shows us that pictographic writing paved the way for phonetic writing. A picture of a hawk came to stand for the sound that started the word "hawk." A picture of a thing became a picture of a sound. The brain *invented* consonants and vowels by *drawing* them. No one taught the solitary toddler in the dust to write and read consonants and vowels. Children and mothers invented them, along with vocabulary and grammar by drawing, and then by *talking about* drawings. Marks *changed* minds. Literacy changed, and still changes *speech*.

It is less likely that hominins invented speech first and *then* wrote it down, than that they invented rudimentary speech, drew what they could not otherwise communicate (which was almost everything), and *then* invented new sounds, new words, new organizations of words from looking at their drawings. Visuo-spatial complexity drove synactic and grammatical verbal complexity. A map of an edible plant drawn *behind* a mountain, *beside* a stream forces the invention of the prepositional phrase.

If we use the natural unfolding of children's drawings (13-16) as our model, holding to the rubric that ontology recapitulates phylogeny (while making room for the fact that ontology also modifies phylogeny), then early hominins scribbled first, drew schematically second, and then developed observational/representational drawing, thereafter inventing numbers, letters, algebra, calculus and musical notation.

We can hypothesize that speech mirrored this trajectory, developing from babbled sounds to the barebones of noun-verb sentences to more full developed *verbal* sentences representing more fully developed *visual* thought.

Recognition of the effect of the visual on the verbal is the keystone of to a new marks-based paradigm for human language (7, 10-12).

Gender Research

Research with rats shows that pregnancy has dramatic and long-lasting brain effects, These include improved spatial memory, and a reduced stress/fear response (86, 87, 96-100). A bolder, braver, more exploratory mother who had to forage afar to feed her children would have been selected for neurochemically. An improved spatial memory plus a kind of ingenious courage in brains changed by pregnancy for increased plasticity **(**99**)**, as well as the built-in flexibility of the mind of the very young child, combined with pressures for notational time-factoring systems and solitary self-amusement might have been the right mix for creating a new kind of mother and child: mother the notational time-and-space-binder; child, the world-draw-er. *Mark-Makers of Significance*.

Shifting Paradigms

The stock psychological male model for fear and stress as a two-response, fight-or-flight system, is making room for a female, tend-or-befriend stress-model; the position that men are "cool under fire" while women panic has been overturned by research proving that motherhood produces a braver, more resilient and adaptable brain (51, 96-99): the anthropological paradigm for a sudden flowering of Paleolithic art and human consciousness is giving way to a more gradual pre-Ice Age model based on notational systems engraved on bone (18). The periodic lunar model for notational systems useful to male hunters is ripe for a shift to the gestational/seasonal roles of women gatherers and their children in hominid brain evolution in connection with a continuist position on language and consciousness (19, 20), focusing on the quotidian importance of mothers' care-giving, children's play, and shared speech around marks of meaning.

Proposing the tenets of an evolutionary theory of language in which meaningful marks played a major role among a constellation of other pre-adaptive pressures on the primate body/brain.

Bipedalism and upright posture created reverse blood flow, which cooled the brain allowing for a larger brain. Thereafter, marks of meaning --- including doodling in the dust by solitary toddlers and notational systems invented by hunter/gatherers (18), both male and female, to keep track of natural cycles and periodic events and processes --- placed substantial visual/attentional pressure on the proto-hominid visual cortex, the dexterous, expressive hands, the vocalizing mouth, and the motivational/emotional limbic system, driving brain growth in terms of:

- brain lateralization, allowing increased specialization, and thus, increased efficiency for spatial and linguistic tasks**;**
- brain de-lateralization, or *de novo* unification via the agency of scribbling and drawing, re-introducing spatial input (as visualization, imagination, plus the visual complexities of spatial relationships of drawn marks which contributed to verbal grammatical complexities) to spoken and, eventually, written language**;**

- bihemispheric, corpus collosal transfer, making it possible for the human brain to use drawn and written "alphabets" or marks-based literacies to modify speech in connection with attention, memory, articulation, semantics and grammar, as well as to translate meaning across systems of representation, for instance, changing a drawing into words, words into music, music into mathematics;
- the creation of awareness as attention in connection with a growing working memory (19, 20), appreciably expanded by new representations created by children's drawings and mothers' notational systems;
- emotional (endocrine-driven) motivation for thinking using symbols, off-setting the metabolically costly effect of brains which require so much information about humans and their doings (19, 20);
- cognitive motivation for inventing words to describe the range of marks early hominins produced to communicate around and beyond speech.

This marks-driven brain growth, in turn, created:

- adaptive pressure for increased prefrontal lobe capabilities with symbols;
- the possibility of increased synchronization via dyadic, call and response exchanges not only between mother and child, but between visual and verbal thinking (including the far-reaching effects of callosal transfer described above);
- increased levels of synchronization, which, in turn, increased levels of positive emotion, while conserving energy, which, in turn, made extra processing reserves available for images and words and other complex symbol systems;
- "mom-binding" and "time-binding" (18), as well as a "theory of mind" (19, 20) as additional dividends of the highly adaptive "displaced" capabilities of long-distance communication (19, 20) including infant crying (21), motherese (54),and youngsters' scribbling and drawing, along with other mark-making systems invented by hominid children and their mothers (100) to work with the seasons of their lives, as well as with the seasons of the plants and animals on which they depended.

Summary

Research in anthropology, art history, brain science, child development, literacy and gender studies, support the following propositions:

1) babbling, motherese and scribbling emerged from the song-like gestural/vocalizations of primates whose bipedal locomotion made possible a cascade of interrelated physical and mental changes around mothers' freed-up hands, and dependent (essentially premature) babies born early enough to allow the passage of the hominid head through the birth canal;
2) babbling, motherese, and scribbling functioned in the hominid brain as neural organizers for spoken and written languages;
3) humankind's earliest marks placed adaptive pressure on speech, creating the neural substrates for phoneme-to-grapheme (or sound-to-mark) correspondence, driving the invention of multiple literacies (art, literature, mathematics, music);
4) scribbling is an artifact of the evolutionary connections between speech and literacy;
5) the biological role of human language is the self-regulation of a biological system which tends to over-heat on three levels: emotional, linguistic, and quantum;
6) The human brain invented two cooling systems to deal with this problem of over-heating:

- a better vascular system, making larger language areas possible
- multiple marks-based systems for processing information, designed to resolve emotional conflicts, synchronize activity in multiple layers of brain tissue for language processing, and act as coolants, or energy pumps on biomolecular levels.

It is likely that the biological goal of both brain systems (the vascular and the linguistic) was and is the same: the conservation of energy in a dynamic system.

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