MUSCLE ALONE IS NOT ENOUGH

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Irritability, the property of response to the forces in the environment, is present in even the more primitive living cells. If a weak electric shock or touch is applied to an amoeba, it will immediately respond with a movement exemplified by a flow of its protoplasm. It will also respond to temperature, oxygen, pH, and various other environmental stimuli. Yet this primitive single-cell organism has no observable specialized “sensory” system. It is “all sensor”.

This state of affairs has become incredibly refined as we move up in the evolutionary scale. Nevertheless a fundamental principle has remained the same: there is an enormous ratio of sensory input capability relative to motor output capability. For humans, it probably is not feasible to estimate with any precision, but it is compellingly evident that the sensory side is many-fold greater than the motor side, perhaps even in ratios of billions or trillions to one.

The philosophical question is: what is the function that nature has achieved by providing such a rich sensory capability, and what is its role in relation to patterns of behavior? I would like to speculate a bit on this matter, particularly on how sensory feedback relates to rehabilitative engineering.

Experimentally, it has been demonstrated many times that various sensory responses are coordinated into a whole that provides a multidimensional “solid” image of the environment. This image permits all the processes of survival to take place by focusing needs and coordinating them with environmental resources, the global expectation being optimal fulfillment for the living system.

Loss of one sense, or even of more than one sense, in higher living forms does not necessarily destroy this environmental image, though
the total amount of inflowing information may be enormously re-
duced. For example, some well-trained congenitally blind and even
deaf-blind persons have developed a great enough idea of their spa-
tial involvement using touch, kinesthesia, and their other remaining
senses to be able to draw representations of objects without visual
feedback. A fairly accurate concept of dimensionality has been de-
veloped. Yet we do not expect people with such handicaps to perform
appropriately in dimensions for which their lost senses are primary;
for example, color. Clinically, we are helpless in such circumstances.
We cannot give back what genetic circumstances have taken away at a
primary level. But we can give back degrees of functions in propor-
tion to that level of technology which we have achieved and, through
use, have satisfactorily evaluated. Rehabilitation requires ingenuity in
adapting available technology to bypass the missing sense.

Each time a new event of fundamental importance takes place in
technology, there seems to be a mad rush to see how it can be applied
to the problems of humankind. Both government and industry sup-
port such efforts, often with the help of dedicated and ingenious
individuals. Such is the case with current development in the area of
manmade sensors. On a more and more microscopic level, it is becom-
ing possible to sense virtually all the energies of interest to survival in
biological systems. Light and sound are only the beginning! Specialized
differentiation of various chemical and thermal compo-
nents at a micro level is becoming more feasible each day. Of course,
display of such information in real time, in a way requiring minimal
conscious attention for interpretation, and with low-cost, low-power,
compact, portable equipment — is largely unsolved today.

However, the implication for humans is that detailed recognition of
environmental factors influencing decisions regarding immediate be-
havior, with refined display systems, is a reasonable technological
expectation. In the broadest terms, the whole behavior of a living
organism becomes a matter of its own parts being continuously influ-
enced by each minute change in the local environment to supply a
mass of information which is processed in a secondary order of neural
synapses. Decisions are reached that, in turn, are transmitted to a
primary order of processors which control coordinated changes in the
ultimate effector (muscle) forces, and thus cause an appropriate
movement. In contrast, even though microprocessor technology is
rapidly developing, present devices are far below the level of sophisti-
cation of the nervous system.

The hierarchical nature of natural sensory input, from the micro-
identification of events in the environment to the refinement of data
into macrocommunication and control events, is evidently why sensory
systems exist. With multimodal senses more information is obtained,
hence complex relations within the environment can be developed. A
simple reach and grasp can be converted into a refined movement representing the skill of a musician, artist, or master craftsman.

In the world of prosthetics, direct attention to sensory feedback has been minor compared with attention to motor activity. Sensory feedback systems possess great potential for definition and for refinement of the information flow for "fine tuning" at the micro level, which, in turn, makes possible the seemingly smooth transition to macro movements. Traditionally, utilization of this potential has been an area of little clinical concern, and "successful" rehabilitation has generally accepted standards that are far removed from fully normal performance. This tolerance is quite understandable. Some regain for improvement in function is better than none at all. It is simply not practical to wait for "perfect" technology.

Nonetheless, while we struggle to obtain deeper understanding of the mechanism of the structural functional relationship so exquisitely designed in natural products, each small step, whether in concept or in practice, becomes an increment, a building block, whose values goes beyond cost/effectiveness and the urgency of immediate general application. Though even modest improvement in artificial sensory feedback can be helpful, understanding in detail how to use it in the most general and efficacious manner must necessarily remain an area for advanced research and development, with low expectation for a prompt breakthrough revolutionizing day-to-day use.

Basic science in the area of sensory feedback moves ahead at a rate commensurate with the quality of talent as well as the resources applied toward it. Substantial progress then depends on dedication and persistence. Living creatures had to get beyond the amoeba's protoplasm flow before muscle could evolve.

In my view, the promise is great but cannot be taken for granted.