studied in a specific gene. The available technology makes such studies possible. Similar studies can be carried out in various age-dependent neurodegenerative conditions whenever such material is available, in order to pinpoint precisely the genetic defect in such disorders and to launch therapeutic measures at the genetic level or through transplantation of normal cells into the brain area.

Since the chromosomal localization of a number of genes has been established and also cDNA probes are becoming available for many genes, it should be possible to study in a specific gene the conformational state, the damage that is present and the repair of that damage.

What is needed, however, is the establishment of appropriate infrastructural facilities and continued encouragement by agencies like DST and DBT to places where such work is already initiated and there lies promise for meaningful achievements.

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Concept formation

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IN general, a concept is an abstract idea. The Oxford English dictionary also defines it as a rough draft of an idea. In the context of our essay, let us define our concept as an abstract understanding of the external environment and of the development of the manner in which we should react to this environment.

Concept as defined above will encompass several parameters:

1. Abstract analysis of a theoretical situation.
2. Sensory inputs regarding the external environment.
3. Processing and consciously interpreting this sensory information.
4. Storage of this information.
5. Abstract organization of the required motor response.
6. Generation of the motor response and correction of any errors that may be present.

Abstract analysis of a theoretical situation can be a very real part of our understanding of the environment and of the development of the manner of our reaction to it. This is because prior experience enables us to imagine a theoretical situation. We can endow this theoretical situation with the physical properties that we expect it to possess and formulate the necessary reactions. Even if a

particular environment is totally unfamiliar, we can imagine the properties that it should possess. Therefore, we can create a theoretical environment within our minds and formulate the appropriate reactions. For all practical purposes then the external environment exists within the abstract framework of our minds. Hence, one can develop theoretical models regarding the manner in which our minds will analyse a given environment, based on our knowledge of the way in which our bodies will behave. This type of theoretical analysis is very important, because it can help the experimental worker to interpret experimental data. Again, based on theoretical analysis, experiments can be designed to prove or disprove plausible hypotheses regarding the functioning of the mind and the generation of concepts. This idea will be developed later.

Sensory inputs regarding the external environment

Sensory inputs range regarding the external environment include a wide range of parameters, such as the interface between the external world and the animal body, the conscious interpretation and understanding of the nervous phenomena which encode the information regarding the external environment. We may generally subdivide these under the following headings:

1. *Study of sensory receptors*. This includes histology, physiology, membrane phenomena, molecular biology and biochemistry of the receptor membrane.
2. *Understanding the transformations* of sensory information that take place at various levels along the sensory pathway. This may include:

(a) Treating the sensory receptor as a black box and studying its input–output properties, thereby defining the transformations that take place within the receptor.
(b) Tracing the sensory pathways in order to understand the way the sensory input is interpreted as a conscious sensation or, alternatively, is reflected at various levels of the nervous system so that reflex reactions are generated.
(c) Studying the function of various relays along the sensory pathways.
(d) Studying the nature of the transmitter substances that are involved.
(e) Histologically reconstructing a particular nucleus that is involved in this pathway, in order to understand the way the nucleus functions.
(f) Studying the integrative activity along the sensory pathway.
(g) Studying the input–output relations of the pathway.
(h) Studying the behaviour of any particular neuron along the pathway, in order to understand the manner in which any given sensory input is transformed for it to be interpreted as some particular quality of a given sensation.
(i) Construction of models in order to understand the various points listed above. These models may be physical or abstract.

Processing and consciously interpreting the sensory information

Again, this can be studied by a variety of techniques:

1. Analysing the responses of a sensory neuron at the cortical levels in order to understand the manner in which some physical input is interpreted as some particular quality of a sensation.
2. Psychophysical studies relating the stimulus to the sensation. The results of such studies would then be used to understand the manner in which a given physical input is interpreted as the quality of a conscious sensation.
3. Studying and attempting to understand the behaviour of conditioned animals.
4. Studying the way brain activity evolves in newborn infants, using topographic brain mapping and evoked potentials.
5. Studying and attempting to understand the behaviour of children, particularly at very early stages of life. Teaching and education will come under this heading.
6. Studying and attempting to understand the behaviour of mentally or physically handicapped people. Rehabilitative training like physiotherapy and occupational therapy will come under this heading.

Storage of this information

Basically, this involves the study of memory. This will include:

1. Studying conditioned animals and analysing memory functions in such preparations.
2. Studying the structure and function of areas of the brain that are known to be related to memory, such as the hippocampus. This would lead to an understanding of the neural organization of the hippocampus, so that one can formulate theories regarding its behaviour, based on histology, connectivity, electrical activity, types of neurotransmitters that are released by the neurons, and membrane phenomena and molecular biology of the membrane of the relevant neurons.
3. Modelling the behaviour of the central nervous system as relevant to memory, using data that are derived from the studies listed above. These models could be abstract or based on computers forming networks.

Abstract organization of the motor response

One has to accept that we possess the ability to project our concept of the physical environment on to the

physical basis of the mind. That is, elements of our nervous system will behave as if they are homologous to elements of a theoretical environment. These same elements of the nervous system would behave similarly if they received inputs from the elements of a real environment. In other words, the physical elements of the nervous system that form the physical basis of the mind can interface with the physical world or, alternatively, with a simulated world that exists solely within the mind.

Investigating this link between the abstract and the physical requires:

1. The psychologist to design experiments that can evaluate the formation of abstract concepts in (i) children of various ages, particularly, very young children, (ii) mentally retarded subjects and (iii) gifted children, whose mental ages are well above average.

2. The teacher to formulate lessons to teach concepts to (i) children of various ages, particularly, very young children, (ii) mentally retarded subjects and (iii) exceptionally gifted children. The teaching methods used would be evaluated with respect to their ability to actually get the subject to form concepts. From this some understanding of concept formation can be derived.

3. The computer scientist to design and evaluate artificial nervous systems based on computers, to teach these artificial nervous systems and evaluate their learning.

4. The biologist to design and evaluate studies on conditioning of animals. By recording from various specific nervous elements before and after conditioning, the biologist can make inferences regarding the physical nervous elements that constitute the mind.

It must be emphasized that in all cases the results of the studies listed above must be used to formulate tenable theories regarding the nature of the relationship between the physical nervous elements and the mind. Otherwise, these studies will be meaningless.

The generation of the motor response and correction of any errors that may be present

In this case, the motor response that has to be evaluated is generated by the concept of an environment, this environment being formulated within the mind. Hence, one studies this aspect by presenting the subject with the desired environment and observing the motor response. Such studies can be done using humans or animals as subjects. In the case of human studies, the subject is presented with a given environment, e.g. to reach out and grasp a cylindrical rod. The motor response, or some parameter of the motor response, is studied using appropriate techniques. In the case of animal experiments, the animal is presented with the environment, e.g. the same cylindrical rod, and taught to respond to it in the manner desired, i.e. to grasp the rod. The various parameters of the motor response can then be studied. Various elements of the nervous system that belong to the relevant pathway can be studied.

Similar studies can be done on handicapped subjects. In the case of animal studies, such handicaps can be artificially produced in a controlled manner. In the case of humans, the handicap might be a birth defect, or can be due to an accident.

Robotics can also be used to model the motor response to a given theoretical environment.

Methods of investigation

As discussed above , there are numerous ways in which this whole problem of concept formation can be studied. All these would have one common objective, viz. to understand and define the link between the abstract and the physical. This is because our ability to explore, understand and respond to the environment in which we live is based on our ability to assimilate the physical properties of the environment and endow these physical properties with some abstract qualities. For instance, we can assimilate some wavelength of light and endow it with a quality of colour. The ways of studying the various aspects of this problem are variegated:

1. Morphological aspects of the nervous system.
2. Connectivity patterns within the nervous system.
3. Membrane phenomena and molecular aspects of the relevant nervous elements.
4. Physiological, biochemical and pharmacological aspects of the relevant nervous elements.
5. Psychological and psychophysical studies.
6. Teaching.
7. Modelling.
8. Robotics.

The one common factor in these ways of studying concept formation is the attempt to correlate the physical with the abstract, based on our understanding of real physical elements of the body. The primary need is that the investigator work continuously for a long period with some aspect of the problem. The investigator then correlates the results obtained with known values obtained from other works in order to develop a tenable theory that would explain the way concept formation takes place.

It is to be emphasized that several disciplines can lead to the formulation of theories regarding concept formation. These can range from teaching and rehabilitation to robotics and computer sciences, or from

abstract analytical logic to careful experiment with single neurons or fractions of single neurons.

Some particular techniques that should be noted

No one can profess to be competent enough to comment on all the various techniques that can be used to study concept formation. A few of the methods that can be used and which are not commonly used in India are:

1. *Histological techniques*. (i) intracellular marking of neurons by injecting the marker into the neuron using microelectrodes and (ii) image analysis techniques using computers.

2. Modelling and neural network analysis.

3. *Kinematic analysis of movements*. The subject is instructed to react in a given manner. He is then presented with a given environment. The subject's movement is recorded and analysed. From the results, one can develop ideas regarding the manner in which concepts are formed. One must make special mention of the work by Jeannerod. Again the study done at Queen's Square on a deafferented man requires a special mention.

4. *Teaching methods*. In other countries, there is a determined effort to develop techniques of teaching. Such teaching methods are developed and evaluated for exceptionally gifted children, mentally and physically handicapped children and normal children. In all cases there is an attempt made to understand the way concepts are formed and understood by the pupil.

5. Studying the development of the mind and brain in the new-born and very young children. This is done in other countries by studying topographic brain mapping or with appropriate psychological studies.

The Indian scene

Basically, the problem in India is that very few laboratories do sustained work on various aspects of the nervous system/mind, delving deeply into the relationship between the two. Secondly, we do not strive to publish our work in the best journals. Unfortunately, unless the Indian researcher publishes in first-class indexed journals, the work will go largely unrecognized. This is because the rejection rate of such journals is very high and, hence, one has to compete with researchers from all over the world to publish in these journals. This ensures that only excellent work will be accepted by these journals.

Perhaps no Indian laboratory has particularly studied concept formation. However, some laboratories have concentrated on aspects that are highly related to the subject. Various excellent studies on tracing pathways, both sensory and motor, have been done. This is an important step towards understanding the physical basis of the mind. Of special mention are the Department of Anatomy at the All India Institute of Medical Sciences, The Department of Animal Behaviour and Physiology at the Madurai Kamaraj University, The Department of Zoology of the Sri Venkateswara University, Post-Graduate Centre, Kavali, The Tata Institute of Fundamental Research, The Centre For Artificial Intelligence and The Neurophysiology Laboratory of The Department of Neurological Sciences, Christian Medical College and Hospital, Vellore. At all these places, some sustained work on some particular aspect of concept formation has been in progress. Unfortunately, none of these laboratories may claim to have had 'concept formation' as the primary subject of study. However, they have all contributed in some way to the understanding of the physical basis of the mind.

Neurobiology and drug abuse

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THE phenomenal growth in neuroscience research over the last decade has led to a better understanding of the biological basis of drug abuse and dependence. Contributions from various disciplines like neuroanatomy, neurophysiology, neurochemistry, molecular biology and behavioural pharmacology, along with technological advances, have helped us to achieve a holistic view. Interactions between biological, pharmacological and behavioural factors, rather than isolated defects in any one of the areas, are crucial to the understanding of the complex nature of the topic.

There are various chemical compounds, both natural and synthetic, which are addictive. This review will concentrate mainly on opiates, alcohol and benzodiazepines. The literature on nicotine and cannabis is very extensive and deserves attention separately and,