

**Table 1.** Conceptual and pragmatic definitions of learning surveyed from different disciplines

<b>CONCEPTUAL DEFINITIONS: LEARNING AS THE PROCESSING OF INFORMATION OR EXPERIENCE</b>	
<b>Psychology</b>	
“We can divide all learning into (1) learning by trial and accidental success, by the strengthening of the connections between the sense-impressions representing the situation and the acts—or impulses and acts—representing our successful response to it and by the inhibition of similar connections with unsuccessful responses; (2) learning by imitation...”	Thorndike 1911/2000 [1]
“Learning is a relatively stable unspecified change within an organism that makes a change in behaviour possible; that is due to experience; and that cannot be accounted for in terms of reflexes, instincts, maturation, or the influence of fatigue, injury, disease or drugs”	Chance 1979 [2]
“Learning refers to the process by which an animal (human or non-human) interacts with its environment and becomes changed by this experience so that its subsequent behaviour is modified”	Hall 2003 [3]
“The process of acquiring new and relatively enduring information, behaviour patterns or abilities characterised by modification of behaviour as a result of practice, study or experience”	Breedlove et al 2007 [4]
“In a representational theory of learning, the brain computes a representation of the experienced world, and behavior is informed by that representation. By contrast, in associative theories of learning, which dominate neurobiological thinking, experience causes a plastic brain to rewire itself to make behavior better adapted to the experienced world, without the brain’s computing a representation of that world”	Gallistel 2008 [5]
<b>“[...]learning is a process of change that occurs as a result of an individual's experience”</b>	Mazur 2013 [6]
“Learning is a process by which an organism benefits from experience so that its future behaviour is better adapted to its environment”	Rescorla 1988 [7]
<b>Cognitive Psychology</b>	
“Learning is any process that modifies a system so as to improve, more or less irreversibly, its subsequent performance of the same task or of tasks drawn from the same population.”	Langley and Simon 1981 [8]
"...learning is conceived in terms of the storage of information in memory as a consequence of any experience the individual might have had.”	Medin 2001 [9]
"Learning and memory involve a series of stages. Processes occurring during the presentation of the learning material are known as "encoding" and involve many processes involved in perception. This is the first stage. As a result of encoding, some information is sorted within the memory system. Thus, storage is the second stage. The third (and final) stage is retrieval, which involves recovering or extracting stored information from the memory system."	Eysenck and Keane 2010 [10]

"The [incidental] acquisition of knowledge about the structural properties of the relations between objects or events."	Buchner and Wippich 1998 [11]
<b>Neuroscience</b>	
"Learning is the process of information input and processing as well as storage, and, on the other hand it is a product which changes in the behaviour of an animal due to experience"	Korte 2013 [12]
"We define memory as a behavioral change caused by an experience, and define learning as a process for acquiring memory."	Okano, et al. 2000 [13]
"Learning is the process by which we acquire knowledge about the world, while memory is the process by which that knowledge is encoded, stored, and later retrieved."	Kandel, et al. 2000 [14]
"Learning is the process of acquiring new information."	Rudy 2008 [15]
"[...]learning is the capacity to change behaviour as the result of individual experience in such a way that the new behaviour is better adapted to the changed conditions of the environment"	Menzel 2013 [16]
<b>Behavioral Ecology</b>	
"that process within the organism which produces adaptive change in individual behaviour as a result of experience"	Thorpe, 1943 [17]
"The process which produces adaptive change in individual behaviour as the result of experience. It is regarded as distinct from fatigue, sensory adaptation, maturation and the result of surgical or other injury."	Thorpe 1951 [18]
"[...]learning can be defined as a process by which long lasting changes in behaviour are acquired by experience"	Sitter 1999 [19]
"[...]learning involves the acquisition, storage and retrieval of information that can potentially affect behavior"	Bekoff 2004 [20]
<b>Machine Learning</b>	
"The capacity... to acquire or develop new knowledge or skills from existing or nonexisting examples for the sake of optimizing performance criterion."	Alpaydin 2004 [21]
"A system is said to learn if it can acquire (synthesize) declarative knowledge from data and/or it displays performance/competence improvement through practice".	Neri and Saitta 1997 [22]
"[Learning is] the acquisition of structural descriptions from examples."	McQueen and Holmes 1998 [23]
"[Learning is] the process of forming general concept definitions by observing specific examples of concepts to be learned.	Haglin et al 2005 [24]

## LEARNING DEFINED AS BEHAVIORAL CHANGE

### Psychology

“[...]the acquisition, maintenance, and change of an organism's behavior as a result of lifetime events”	Pierce and Cheney 2008 [25]
“[...]more or less permanent change in behaviour that occurs as a result of practice”	Kimble 1961 [26]
“[...]change in behavior that occurs as the result of practice”	Dewsbury 1978 [27]
“[...]specific and only partly reversible change [in behavior], often related to a positive or negative outcome”. “Experience can change behavior in many ways that manifestly do not involve learning”	Staddon 1983 [28]
“[...]changes in the behavior of an organism that are the result of regularities in the environment of that organism”	De Houwer et al. 2013 [29]

### Neuroscience

“[...]any fairly persistent change in behavioral attributes produced by the action of experience on the central nervous system”	Krasne 1976 [30]
“[...]a change in the behavior of an animal as a consequence of the animal's experience”	Delcomym 1998 [31]
“Learning is a change in an organism's behaviour as a result of experience”	Kolb & Wishaw 2011 [32]
“[...]a relatively permanent change in behavior that results from experience”	Kolb & Wishaw 2014 [33]

### Behavioral Ecology

‘[...]a change/modification in behaviour with experience’	Shettleworth 1984 [34]; van Alphen and Let 1986 [35]; Szentesi & Jermy 1990 [36]; Vet et al. 1990 [37]; Stephens 1993 [38]; Barron 1999 [39]
“a reversible change in behaviour with experience”	Papaj & Prokopy, 1986 [40]

**No longer willing to define learning. Instead, offer criteria to specify learning**

- 1. The individual's behavior changes in a repeatable way as a consequence of experience**
- 2. Behavior changes gradually with continued experience**

Papaj & Prokopy, 1989 [41]

### 3. The change in behavior accompanying experience wanes in the absence of continued experience of the same type or as a consequence of a novel experience or trauma

“Learning is the adaptive modification of behaviour based on experience”	Alcock 2005 [42]
“a change in state due to experience”	Shettleworth 2010 [43]
“Learning is the modification of behaviour due to stored information from previous experience”	Breed 2012 [44]

#### Machine Learning

<b>“A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E”</b>	Mitchell 1997 [45]
“Things learn when they change their behaviour in a way that makes them perform better in the future.”	Witten and Frank 2005 [46]

### LEARNING DEFINED AS CHANGES IN BEHAVIORAL MECHANISMS

#### Psychology

“[...]the process by which a relatively stable modification in stimulus-response relations is developed as a consequence of functional environmental interaction via the senses”	Lachman 1997 [47]
“[...]an enduring change in the mechanisms of behavior involving specific stimuli and/or responses that results from prior experience with those or similar stimuli and responses”	Domjan 2010 [48]
“[...]a long-term change in mental representations or associations as a result of experience”	Omrod 2012 [49]

#### Neuroscience

“[Learning is] either a case of the differential strengthening of one from a number of more or less distinct reactions evoked by a situation of need, or the formation of receptor-effector connections de novo; the first occurs typically in simple selective learning and the second, in conditioned-reflex learning”	Hull 1943 [50]
“Learning is a manifestation of the malleability of the nervous system because it is a change in the behavior of an animal based on experience. Memory refers to the stored experience and to the process by which it is stored. Memory is a requirement for learning.”	Delcomyn 1998 [31]
<b>Offer no definition of learning – rather provide mechanistic definitions of specific learning subtypes, e.g. habituation.</b>	Carew 2000 [51]; Schwartz, et al. 2002 [52]; Kalat 2007 [53]; Reznikova 2007 [54]; Squire, et al. 2008 [55];

Gluck, et al. 2008 [56]

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**Behavioral ecology**

“[...]the acquisition of neuronal representations of new information”

Dukas, 2009 [57]

“Learning is a change in the nervous system manifested as altered behavior due to experience”

West-Eberhard 2003  
[58]

“Learning is a specific change or modification of behaviour involving the nervous system as a result of experience with an external event or series of events in an individual’s life”

Grier 1992 [59]

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## Table References

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