

# Setting tool use within the context of animal construction behaviour

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**Tool use and manufacture are given prominence by their rarity and suggested relation to human lineage. Here, we question the view that tool use is rare because cognitive abilities act as an evolutionary constraint and suggest that tools are actually seldom very useful compared with anatomical adaptations. Furthermore, we argue that focussing on animal tool use primarily in terms of human evolution can lead to important insights regarding the ecological and cognitive abilities of non-human tool users being overlooked. We argue that such oversight can best be avoided by examining tools within the wider context of construction behaviours by animals (such as nest building and trap construction).**

## Introduction

In this article, we begin by arguing that there is little biological justification for the separation of tool use from construction behaviour according to the most popular definition of tool use; we then discuss the ways in which research can be disadvantaged by such an arbitrary separation. Research on tool use is generally focussed on exploration of the underlying cognitive processes, and we argue that the level of underlying cognitive complexity is diverse in both tool behaviours and other construction behaviours and that there is no reason why underlying cognitive processes should be more complex and interesting for tool use than for some other construction behaviours. We end by arguing that tool behaviours are uncommon in the natural world not because they require complex cognitive underpinning but because situations in which they are advantageous compared with anatomical adaptations are uncommon.

## The definition of tool use

Defining tool use has a long history [1,2]. However, the definition provided by Benjamin Beck [3] has subsequently become the standard used in recent publications. The key features of his definition are that to be a tool, an object must: (i) not be part of the animal itself; (ii) not be attached to the environment; and (iii) be manipulated to achieve some beneficial outcome. Thus, a bird that uses a thorn to extract an insect larva from under the bark of a tree is a tool user, but another that uses its beak to peel back the foil top of a milk bottle to access the contents is not. The thorn is not a part of the animal itself but the beak is. Another bird that drops stones on an egg to break it is a tool user, but if it were to carry the egg up then drop it on the ground

it would not be a tool user. The stones are not attached to the environment but the ground is. A primate that throws branches at a pursuer would be considered a tool user, but another primate whose flight from pursuers through the trees dislodges weak branches and foliage would not (because the behaviour lacks obvious manipulation and perhaps also benefit).

Authors of papers on animal tool use continue to adopt Beck's definition; however, it is clear that many researchers [4–7] now fail to recognize the qualifications that Beck attached to his original definition. Beck warned about mistakenly seeing tool use as biologically distinct from construction behaviour, such as nest building. He said: 'There seems to be no biological dimension on which external constructions differ fundamentally from tools', but continued: 'Nonetheless, constructions are excluded as tools because they are not held or carried during or just before use. . . without such an exclusion virtually any [construction] behaviour could be considered tool use' [8]. His definition of a tool was, therefore, one of convenience rather than biological distinctness.

To clarify the boundaries of his definition, Beck provided a detailed discussion of 'borderline' cases. These borderline cases confirm that the boundaries of Beck's definition are arbitrary. For example, his definition denies outright recognition of tool use by any spiders. Orb web spiders are excluded because their webs are not held by the spider but are attached to the substrate; bolas spiders *Mastophora*, which swing a large sticky blob at the end of a single thread to capture moth prey, are discussed as a borderline case. However, it seems likely that, had Beck known that the ogre-faced spider *Dinopis longipes* makes a small web that it holds in its legs before bringing it down on passing ant prey [8], he would have classified it as both a tool user and tool maker. However, this spider first makes the web in the normal way (attached to the substrate) and then detaches it from its anchor points. It seems difficult to justify logically why a spider becomes a tool user (and a tool maker) after making its web in the conventional way, simply because it then picks up its web and holds it. Under Beck's definition, caddis larvae building shelters that are attached to the substrate are excluded, whereas those building portable cases are 'borderline'. As Beck himself says, this makes '... the distinction between tools and external construction hazardedly arbitrary'. See Box 1 for a definition of construction behaviour and a comparison with Beck's definition of tool use.

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**Box 1. What do we mean by construction behaviour?**

Construction behaviour is relatively easy to define: something must be constructed and it must necessitate behaviour. This is the definition used by Hansell in previous publications [24,44]. Thus, the secretion of a snail shell and a coral reef are both excluded by the definition because their creation does not involve behaviour. The making of a termite fishing tool by a chimpanzee is included because, although material is removed, a new structure is created by that behavioural process. By this reasoning, the sculpting of the environment to create a burrow is also included, as is nest construction by chimpanzees and birds. We believe that this definition makes a biologically coherent subject for study and is not as unmanageable as Beck asserts [3]. Inevitably, this definition does reveal some borderline cases. However, there are far fewer and for a much larger category than under Beck's definition of tool behaviour, not least because many of Beck's borderline cases are ones of obvious construction behaviour. However, construction behaviour is not simply a category into which all of Beck's tool behaviour examples can be absorbed, so it is helpful to see just how the two differ.

**Excluded by Beck [3] and Hansell [44]**

A gull dropping a mollusc shell on hard ground; a chimpanzee climbing a fence to get food; an elephant rubbing itself on a tree; a moth secreting a pheromone to attract a mate; and rhinoceros wallowing in mud.

**Included by Beck [3] and by Hansell [44]**

All tool-making behaviour (e.g. a woodpecker finch making a stick tool and a chimpanzee making a termite-fishing tool).

**Excluded by Beck [3] but included by Hansell [44]**

All vertebrate nest building; beaver dam building; bowerbird bower building; all solitary insect home building (portable caddis case is a Beck 'borderline' case); all social insect nest building; spider web building (Bolas spider is a Beck 'borderline' case); and a bridge or nest made of linked ants.

**Borderline cases for Hansell [44]**

The example of an *Ammophila* wasp using a stone hammer to seal its nest burrow [32] is included because the hammer is used in the completion of a structure. However, a chimpanzee using a hammer and an anvil to crack a nut does not involve making a tool or making something with a tool, so a strict definition of construction behaviour suggests that it is excluded. However, objects are being manipulated and the environment is being altered as a result. These factors invite inclusion.

This leaves cases of even simpler tool use that are not used to make anything. These are examples that are included by Beck: a hermit crab adopting a gastropod shell as a home; an archer fish squirting water to catch insect prey; a heron using bait tools (e.g. berries or insects) to attract fish prey; and a chimpanzee waving a stick as a threat.

We suggest that the approach here should be pragmatic. For example, in looking at construction behaviour by chimpanzees, it would seem helpful to consider stick waving alongside more complex object manipulation, such as making a termite fishing tool or a night nest. By contrast, in a general consideration of construction behaviour, little will be lost by excluding reference to hermit crabs or archer fish. Construction behaviour is a simple category defined by observable behaviour. It contains no presumption of cognitive abilities, but provides a useful framework for studying them.

**Consequences of treating tool use as separate from all construction behaviour**

The discovery of the manufacture and use of tools by wild chimpanzees *Pan troglodytes* by Jane Goodall in 1968 [9], and later in other primates (e.g. capuchin monkeys *Cebus libidinosus* [10]), offered living models for the study of the

possible ecological context of tool use in early hominids [11,12] and of their cognitive abilities [13,14]. More recently, studies of tool-using bird species, in particular the New Caledonian crow *Corvus moneduloides* [15], have also been invoked by some as appropriate models to understand human evolution better [16,17].

Although non-human tool users might be appropriate models for investigating aspects of human behaviour, regarding Beck's definition as truly biological rather than arbitrary leads to two unfortunate distortions in the interpretation of the results of such research. The first is that evidence from construction behaviour other than that of tool behaviour (such as nest building) has tended to be excluded from the debate on the evolution of human intelligence and ecological dominance. The second is that the potential value of studies of tool behaviour to the study of other construction behaviours (and non-human evolutionary ecology more generally) has not been given sufficient attention. We discuss these issues further in Box 2, but now turn to consider the power of tool use and other construction behaviours for shedding light on animal cognition.

**Cognition and tool use***Cognition and construction*

One of the merits of the study of tool behaviour in non-human animals has been the opportunity to reveal underlying cognitive processes. However, tool use by itself carries no implication of cognitive abilities. This is explicit in Beck's [3] definition of tool use, which is, in his words: '...free of any dependence on or reference to cognitive processes'.

Studies on captive birds and mammals, in which tool manufacture or use is required to solve artificial foraging tasks, have sometimes demonstrated that animals can perform satisfactorily despite having low levels of understanding of the task [14,18]. Such studies also sometimes demonstrate significant genetic influences in the development of tool behaviour [19,20]. However, differentiating tool use from construction behaviour can encourage the assumption that tool use requires high levels of cognitive complexity. The making and use of a spear by chimpanzees [21] is a convenient illustration of this. Chimpanzees break off a branch, trim off side branches, adjust the length of the resulting stick and sharpen its point with their teeth, a progression described as 'crafting'. There appears to be some variation among tools in their final form because of variation in the sequence of behaviours used in their construction. The lack of stereotypy in the manufacturing behaviour is interpreted by the authors as 'special' and requiring high cognitive faculties [21]. However, this lack of stereotypy could be compared with that shown by orb web spiders in the establishment of attachment, frame and radial threads, in which the structure emerges from a non-stereotyped sequence that includes not only the progressive building up of the structure by thread addition, but also its 'editing' by thread removal [22].

Complexity and flexibility in construction behaviours can be connected with elaborate patterns matching those of tool making. Consider the nest building of the red-headed weaver bird *Anaplectes rubriceps* [23]. To make its nest of

### Box 2. Two distortions

We argue that the literature on tool behaviour suffers from two distortions. First, tool behaviour has been interpreted primarily in terms of hominid evolution. Second, tool behaviours have been isolated from other construction behaviours in the same species.

The context for the study of tool manufacture and use by monkeys and apes has been primarily seen as one of human evolution [45,46]. A recent paper on the manufacture and use of a specialized stick as a spear-like tool by chimpanzees hunting bushbabies *Galago senegalensis* [21] stresses that the type of tool behaviour observed had previously been considered uniquely human. This paper provides evidence of the complexity of the tool-making behaviour and includes observations on the hunting technique and the social context of the behaviour, before discussing these in the context of hominid evolution. This pattern of presentation can also be seen in several publications on the manufacture and use of hook tools by New Caledonian crows. The initial description of the tools made by these crows compares their attributes with those of: '...early humans after the Lower Palaeolithic, ...' [15]. Other key publications on New Caledonian crows [16,17] also stress the human-like attributes of the tool behaviour of these crows: such as regional variation being potentially associated with repeated innovation and the potential for social learning. Further examples of the human perspective adopted in publications on tool use include the steady stream of observational or experimental studies of tool use in animals that are published in *Journal of Human Evolution* [47,48].

An example of the other distortion that concerns us, the isolation of tool behaviour from other construction behaviours, is provided by a recent paper entitled 'First observation of tool use in wild gorillas' [7]. In considering factors affecting the incidence of tool use, this paper makes no reference to a construction behaviour that is prevalent in this species: nest building has been documented as a daily activity in about half the population of western lowland gorillas *Gorilla gorilla gorilla* in some sites [49] and by >90% at one site in particular [50]. Why should relatively simple tool use be so worthy of attention in a species in which it is already well documented that most adults construct a substantial nest structure every day? Is it really clear that tool use is ecologically more important or cognitively more challenging than nest building in this species? There have, for several years, been a few primatologists who have continued to point out the lack of a biological distinction between nest- and tool-making. This position has been adopted by McGrew [46] who embraces both nest building and tool behaviour within a more general category that he terms 'material culture'; Fruth and Hohmann talk of nest building and '... other forms of tool use' in the great apes [34,51] and draw attention to the possible significance of these to human evolution. Although we feel these publications deserve wider attention, our emphasis is also rather different. First, to us, tool behaviour is a form of construction behaviour, rather than the reverse; second, our concern is with the biological context of construction behaviour, rather than just its relevance to human evolution.

fresh 'green' twigs, this weaver bird first trims the leaves from a twig, then breaks it away from the main stem in such a way as to include a long, flexible strap of bark projecting from the broken end. This strap is then wound round the end of a narrow tree branch so that, on drying, the twig is firmly attached. Drying bark straps are the principle by which the whole nest is held together. The bird now attaches more twigs to form a stout nest attachment hanging below the branch. Below this a globular nest chamber and a downward-directed entrance tube are added. In the light of this, we see no reason to suggest that as a generality tool use will require higher levels of cognition than other construction behaviours shown by the same or closely related taxa. As we argue in the next

section, it is important to avoid the presumption that all construction behaviour (and indeed all tool use) requires a similar level of cognitive complexity.

### From simple to more complex construction

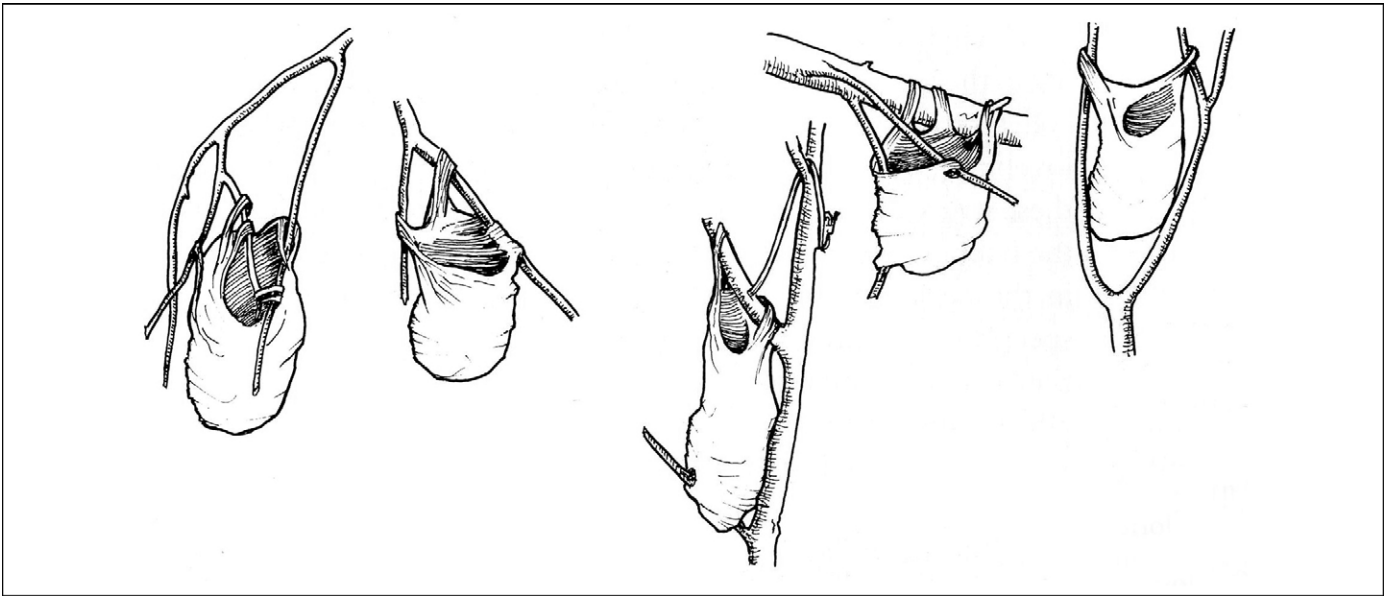
There is a tendency to assume that nest building by birds involves little or no learning, implying low cognitive requirements for the task, but there is too little evidence to know the extent to which this is true [24] (Figure 1). In some weaver species, there is experimental evidence of a significant learning component to nest building [25]. There is also good circumstantial evidence of a learned component in bower construction by male bowerbirds (Ptilonorhynchidae). Juvenile males of the golden bowerbird *Prionodura newtoniana* habitually visit the bowers of mature males and observe their behaviour over a period of five or six years [26]. The same is true of satin bowerbirds: the immature males have been observed to practise bower construction [27].

One consequence of the assumption that tool use is a sign of higher cognitive abilities is a desire among some researchers to seek admittance for a species into the apparently exclusive club of tool users. Tool-user status has been claimed for a variety of mammalian species other than primates, including elephants *Elephas maximus* [5] and North American badgers *Taxidea taxus* [6]. It has also led to some species that are notable builders being accorded some additional recognition for also being tool users. This is the case for the beaver *Castor Canadensis*, which has been observed to create a step to enable it to cut a tree higher up the trunk [28]. Why should there be special emphasis on such simple tool use in a species that is already justly famous for the scale, complexity and flexibility of its construction behaviour?

We are not suggesting that all construction behaviours arise from similar levels of underlying cognitive processing. Indeed, we strongly suspect that such a viewpoint would prove incorrect. Some construction behaviours show strong levels of stereotypy without evidence of learning or flexibility that cannot simply be explained by interaction with the environment. For all the impressive size and complexity of some termite mounds, it would not surprise us if the building behaviours of the termites are driven by very simple genetically determined rules. However, not all building is the same. Among the invertebrates, individual spiders have been shown to modify the structure of a sequence of webs, in reaction to the type of prey caught and variation in the position of captured prey within the web, in ways that can be understood to tailor the web to its setting [29].

Similarly, flexibility can be found in some tool manufacture [30] and some tool use [31]. Yet, while learning and development over time has been extensively demonstrated in laboratory studies of tool use [18], it seems likely that tool use can sometimes arise from processes no more complex than those operating in termites. The *Ammophila* wasps use a stone hammer to pack down the material used to seal its nest burrow, but there is no evidence that the underlying cognitive processing in this phase of nest construction follows anything other than the simple genetically controlled rules that appear to govern the rest of the





**Figure 1.** Birds' nests can show a great deal of complexity and flexibility. The hanging nests of the Baltimore oriole *Icterus galbula* illustrate the behavioural flexibility shown by some bird species in accommodating the attachment of the nest to the local twig topography (Adapted, with permission from Cambridge University Press, from [11]).

nesting process in these species [32]. Within the vertebrates, there is ample evidence of laboratory experiments that demonstrate effective tool use without understanding of the underlying problem, and thus without the ability to adopt behaviour effectively to changed circumstances [18]. Thus there is no reason to expect all tool use to reflect similar underlying cognitive complexity, and no reason to expect tool use to be necessarily more cognitively complex than other construction behaviours.

### The significance of the relatively few tool-using species

If tool making and tool use are no more complicated than other building behaviours, then why are there so few bird tool users in comparison with bird nest builders, and so few invertebrate tool users in comparison to the houses and nests of solitary and social insects and the webs of spiders? The conventional explanation for this is that tool-using behaviour is difficult to evolve owing to constraints on cognition [33]. We propose an alternative explanation: that tools are often not useful, and the small number of species of tool makers and users across the animal kingdom results from the lack of ecological contexts in which tools are superior to the already evolved anatomy of the animal.

Two strands of evidence lend support to our hypothesis: first, tools are generally not a substantial part of the ecology of species identified as tool users; and, second, tool use has had little evolutionary impact as a driver of speciation, especially in comparison with species that show construction behaviour more generally.

### Tools are generally not a substantial part of the ecology of species identified as tool users

Chimpanzees in the Gombe site in Uganda use tools shaped from grass stems to 'fish' for termites by inserting the stems carefully into holes made in the termite mounds. However, this is a behaviour shown only during ~15% of waking hours and only for three or four months of the year

(W.C. McGrew, personal communication) by chimpanzees that engage in fishing. All chimpanzee groups studied in the wild use tools to some extent, yet at Kanyawara in Uganda, tool use represents <1% of feeding activity over the year (R.W. Wrangham, personal communication). So tool use seems important as a foraging method only to some chimpanzees at some times of year. However, contrast this with their nest building: essentially every weaned member of a troop constructs a new nest on a nightly basis and might also make a day nest as well [34,35], incidentally demonstrating what a potentially rich source of research material chimpanzee nesting behaviour offers for the study of other construction behaviours (see Figure 2) as well as the evolution of human material culture.

In the study of Pruetz and Bertolani's on the use of spears by chimpanzees [21], the chimpanzees observed



**Figure 2.** Chimpanzee nests are very impressive structures. A researcher sitting in the nest of a chimpanzee in Senegal illustrates that these nests are neat, compact and sturdy structures. Should the making of a stick tool be regarded as cognitively more complex than the making of this nest? (Photograph by permission of F. Stewart).

using the spear were females and juveniles. The authors' interpretation is that these are individuals that, when deprived of access to meat by more competitive individuals, developed tool use as an alternative. This conclusion is placed in the context of chimpanzees and the evolution of human tool use. By our reasoning this observation should be set in the context of animal construction as a whole, which would make its significance very different: the juveniles and females might only have found it necessary to make tools when deprived of a more conventional method of obtaining meat. Pruetz and Bertolani [21] mention a study in which a related group of female bottlenose dolphins *Tursiops truncatus* have been observed to use sponge tools on their snouts to protect them when foraging on the sea bottom [36]. The 'tools are not often useful' hypothesis predicts that, in this habitat, males are denying the females access to easier foraging sites that do not require tools. This behaviour is certainly not widely reported in studies of dolphin feeding and thus invites further study.

On Santa Cruz Island in the Galapagos, the woodpecker finch uses a stick tool held in its beak to extract insects from crevices. In the more moist forested part of the island, this behaviour occurs only during the dry season. In the more arid part of the island, the birds use tools more frequently and, in the dry season, increase their dependence on tools for food foraging to 50% [37]. The authors of this study show that prey extraction takes longer using a tool than using the beak directly but that the food value of prey obtained by tools in the dry season more than compensates for the cost in time. In their words: '...tools are only employed when and where foraging profitability is higher than that attained with alternative foraging techniques'. We note that the other celebrated avian tool user (the New Caledonian crow) is endemic to only one main island. As with the woodpecker finch, its habitat is devoid of competition from woodpeckers (see Ref. [38] for further discussion). The importance of tool use to its diet is unknown [39], but our prediction (strongly relating to that previously put forward in Ref. [38]) is that, similar to the woodpecker finch, tool use will function in this species to provide food during crucial seasonal periods when obtaining food by conventional means is restricted.

*Tool use has had little evolutionary impact, especially in comparison with species that show construction behaviour more generally*

Why should tool use generally be less preferred to foraging without a tool? Our suggested answer is illustrated by first considering a bird. To use a tool, the bird must hold it in its beak; thus in using a tool, the bird is sacrificing the use of the organ specifically adapted to foraging. There might be only a few contexts in which a tool is superior. Most examples of tool use do involve manipulation of the tool during use. It is therefore interesting to note that, although crows and finches provide the most numerous examples of tool use in birds, the parrots, noted for their general intelligence, provide few examples of tool use in the wild [40]. A possible explanation for this is that parrots, with their ability to grasp objects in their feet as well as to manipulate them with their beaks, find few circumstances in which a tool would offer an added advantage.

Unlike tools, nests and webs do not need to be held and manipulated to fulfil their function. Once built, these structures continue to perform their function without the involvement of the organs that made them. A scan across the animal kingdom reveals that (in contrast to tool behaviours) construction behaviour has had enormous evolutionary consequences. One obvious example of this is the influence of nest building on the evolution of social insects [41]. Furthermore, web building in spiders [42] and nest building in birds [24,43] have almost certainly been key drivers of habitat diversification and speciation in these groups.

### Concluding remarks

Despite Beck's considerable effort and intellectual rigour, he was unable to come up with a biologically satisfying definition of a tool. We have argued that striving for such a definition might not be fruitful, because there is rarely any advantage to be gained from separating tool use from animal construction more generally, and construction behaviour can be satisfactorily defined (Box 1). Under the construction behaviour definition, 'borderline' cases become a peripheral issue rather than the major preoccupation that they currently are in the consideration of tool use. This removes an obstacle to the investigation of cognitive processes used in complex object manipulation and construction behaviour.

We have further argued that tools are generally not particularly important to animals, in ecological or evolutionary terms, compared with other construction behaviours, such as nest building. However, this is not to suggest that studying tool use is unlikely to be rewarding; tools in general have the great benefit of being relatively simple. It is much easier to describe accurately the construction and use of the termite-fishing wand of a chimpanzee than that of even the simplest bird's nest. Construction behaviour is ecologically and evolutionarily important and has the potential to provide useful insights into the cognitive processes of non-human animals; the construction and use of tools could provide many of the most accessible entry points to such study. Those who feel that tools are 'special' might be correct – but they might be more special to researchers than to the animals that use them.

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## Free journals for developing countries

The WHO and six medical journal publishers have launched the Health InterNetwork Access to Research Initiative, which enables nearly 70 of the world's poorest countries to gain free access to biomedical literature through the internet.

The science publishers, Blackwell, Elsevier, Harcourt Worldwide STM group, Wolters Kluwer International Health and Science, Springer-Verlag and John Wiley, were approached by the WHO and the *British Medical Journal* in 2001. Initially, more than 1500 journals were made available for free or at significantly reduced prices to universities, medical schools, and research and public institutions in developing countries. In 2002, 22 additional publishers joined, and more than 2000 journals are now available. Currently more than 70 publishers are participating in the program.

Gro Harlem Brundtland, the former director-general of the WHO, said that this initiative was “perhaps the biggest step ever taken towards reducing the health information gap between rich and poor countries”.

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