Lonely Neanderthal: Neurochemical Hypothesis for the Domestication of Animals and Plants

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Abstract

Domestication in essence represents a set of interactions of humans with other species, in which behavior has a leading role. At the same time, recent findings from neurochemical research highlight the importance of opioid system to such interactions. The combination of these neurochemical mechanisms and the peculiar social behavior of Neanderthal males could facilitate interactions between humans and wild species, and this type of behavior could be adopted by our ancestors in Eurasia from Neanderthals. These facilitative interactions could later lead to domestications. We propose that domestication is an artificial, social and personal system of the repeated use of results from the behavior and existence of specific representatives of animal and plant species, often obtained by means of genetic selection, with the initial aim of producing a greater amount of endogenous opioids and related neurohormones in the human organism. The new perspective can help generate empirically testable predictions. First, it predicts that interactions with plants, similar to interactions with animals, will launch cascades of neurochemical changes in the opioid system and establish certain patterns of our behavior; this prediction can be tested with the same experimental approach as used in the case of animals. Second, significant differences can be found in the ethnographical records on the interactions with animals between the shaman sub-cultures of Africa and Eurasia.

Keywords: *Domestication, Neanderthals, opioid system, pre-history, social behavior*

Domestication theories

The current theories of domestication can be classified into two groups. The first mostly considers the ability of animals to adapt to human behavior (hereafter behavioral theories). According to one such popular theory, there exist animals with specific behavioral and social structures who can be subjected to domestication, and it is precisely these who have been domesticated throughout the history of mankind (Diamond 1997): this perspective lists the exclusive traits of domesticable animal species according to which they should be characterized by a social hierarchy (so that they would be subservient to humans) and their feeding should be easy (e.g., they should not have an exclusively carnivorous diet). According to another behavioral theory, animals domesticated themselves over millennia while observing the advantages of living in close proximity to man (an easy life, protection and food) (Wrangham 1999; 2009).

The other group of domestication theories considers that, owing to the increase in the human population and the corresponding difficulties in sourcing food, human societies were forced to move to a system of permanent settlements and to begin the domestication of plants and animals to satisfy the need for food and other necessities (hereafter populational theories). The Destiny-Equilibrium Theory (Binford 1992; Binford 2008) can be called a clearly expressed representative of this group, according to which growth in the human population upset the environmental balance (owing to the overlap of suitable hunting and foraging grounds), as a result of which humans were forced to move from a hunter-gatherer to a farming-domestication lifestyle to restore the balance. Other theories of this group likewise observe that a food-producing society formed in regions where food was scarce (Bar-Yosef 1995; Rindos 1980; Zohary, Hopf 2012).

Apparently, the above theories of domestication are based on right-minded thinking, the interpretation of paleontological data, and knowledge of human as well as of animal relations (both domesticated and wild/tamed). It is also clear that a human need underlies the domestication of animals. Nevertheless, these theories show considerable weaknesses too. For the behavioral theories this is the geography of domestication centers. If we look closely at the domestication 'map' we see that not a single animal or plant was domesticated in Africa's central and southern parts. In the northern part of Africa, from 33,000 years BC (the time dogs were domesticated) to the beginning of the first millennium AD, only the domestication of the ox (*Bos primigenius taurus*) has been confirmed, yet, most probably, it arrived already domesticated from the Near East (McTavish 2013). It is difficult to find animals satisfying the criteria of behavioral theories in Australia, southern South America or western North America, and this may explain as well the lack of domesticated animals from these regions. However, against this background, some African animals satisfy behavioral theory criteria rather well, but their domestication has not occurred. The hyena is one of these, with very acceptable 'natural' character for domestication. Fully-grown individuals easily make contact with humans and it is even possible for them to learn certain actions (Holekamp, 2007). For the time being it is difficult to say why humans did not domesticate the hyena. The reason cannot be that no use was found for it, since the hyena is primarily an eater of carrion, rather than a hunter. Recent research has shown that this opinion is far from the truth (Cooper, 1999; Lansing 2009). It is noteworthy, that according to the social memory of African societies, the Hyena is presenting as almost first enemy of humanity (Glickman 1995), contrary to e.g. the image of the wolf in Eurasia and Americas. The same difficulty is encountered when explaining the example of the African wild dog (*Lycaon pictus*). This in practice satisfies all the criteria for domestication, and when hunting it teaches its offspring (Creel 1995). The lack of domestication in this candidate is truly surprising, especially since, in the area over which it is spread, humans have from time immemorial lived and have supported themselves by hunting, in which a domesticated lycaon would have truly proved useful to them. Of the non-domesticated African animals, also worthy of mention is the zebra, the close relative of domesticated horses and donkeys. Behavioral theories (e.g., Diamond 1997) explain the zebra's non-domesticability by its caution and tendency to panic. This is not a strong argument if we take into account that the wild horse is notorious for just these reasons (Bendrey 2012; Hayes 2003). We may assume that the domestication of the horse on the Eurasian continent required a long time compared to other animals because of the difficulty of domesticating horse-like animals. But this difficulty, as we see, is not insurmountable. Europeans began attempts at domesticating the zebra relatively late and progress was indeed really slow, but probably by using the classical method of domestication – reproducing desirable individuals through artificial selection – bringing domesticated zebras into being over millennia should not have been impossible. At the same time, how to break in a zebra is well known today, and there are several well-documented precedents of zebras harnessed to two-wheeled carts (Hines 2003; Hartwell 2013; Messy 2012).

On the other hand, there are animals, which do not satisfy behavioral criteria, yet they became as a common domestic animal as the cat *Felis silvestris catus*. This case truly sits uncomfortably in the behavioral theory scheme. The cat was domesticated despite the fact that its wild ancestors were not social animals and the fact that domestic cats pay little heed to their owner's commands, not recognizing his leadership and higher hierarchical status (Bradshaw 2013; Faure 2009). It is possible that yearning for cats' domestication was very strong, which is indicated by the very rich tradition of sacralization seen in past civilizations (Egypt, China), where quite strong cat cults and even deification have been confirmed (Driscoll 2007). Finally, the geography of plant domestication centers shows generally the same pattern and it is a strange coincidence that from Ethiopia southwards not a single plant was domesticated, just as was the corresponding case with animals.

As regards to populational theories of domestication, the first objection that strikes one is the time necessary for the artificial selection of an animal trait beneficial to man and for its reinforcement. An experiment by the Russian geneticist Dmitri Belyaev and his pupils confirmed that the development from canids (in this case, the Siberian fox) of a breed friendly to man needs forty years at the very least (Trut 1999; Trut 2009), and that is when there is a supporting selection programmed. Belyaev and his pupils sorted foxes according to strengthening friendly traits towards humans. Forty years later, the foxes participating in the program had curly tails, mottled coats and hanging ears. Overall this experiment shows that obtaining a domesticated animal demands difficult, prolonged and tiresome work and, also, that beginning the domestication of an animal by man could answer the challenge presented by a shortage of food only from a long-term perspective. Operation of such long-term strategic programs is improbable in early societies.

Historical geography of our ancestors and domestication centers

The paleontological data suggests that the basic wave of domestication began about 10,000 years ago on the Eurasian continent (Zeder 2008). We know that, unlike the Eurasian continent, there is no trace of Neanderthals interbreeding with *Homo sapiens* on the African continent (Sankararaman 2014; Seguin-Orlando 2014). Or in other words, according to data from paleontological and genetic research, it is known that among the 'human factors' the difference between the continents of Africa and Eurasia is one of the existence versus the non-existence of Neanderthals. We hypothesize that the existence of domestication versus non-domestication on these continents is somehow connected to the Neanderthal population.

Theories and hypotheses abound about the Neanderthals. These hypotheses range from the so-called 'earlier stage' idea, according to which Neanderthals were representatives of less developed hominids (Boule 1920; Hammond 1982), to the 'identical development' idea, according to which the Neanderthals had developed a society with modern features (speech, burial of the dead, medicine, applied art, weaponry (Condemi 2013; MacErlean 2012; Riel-Salvatore 2009; Rohrer 1980). However, in recent years, especially after it had been established that interbreeding between *Homo sapiens* and Neanderthals had occurred, an ever increasing number of paleontological facts is in favor of a developed Neanderthal society (below).

In the 1980s works by Lewis Binford (1983), one of the founders of modern archaeology, were published, in which he argued that Neanderthals' social life differed from that of *Homo sapiens*. It followed from an analysis of fossil data made by Binford that, in Neanderthal society, females and males lived in sharply divided groups: the females and adolescents separately (in groups of ten to fifteen individuals); the males separately, in yet smaller groups, who from time to time went to the female society (it may be assumed mostly for sexual intercourse), just like certain social animals (for example, elephants and most ungulates, many species of dolphin, and some primate species). This theory provoked much opposition: Binford was for the most part blamed for excessive extrapolation (Mellars 1996).

The earlier part of the Neanderthals' existence coincided with a quite cold period (Finlayson 2005; Jordan 2013): the end of the Pleistocene, the time of a great ice age which began 110,000 years ago, and ended 12,000 years ago (Spielhagen 2004). It is natural for us to suppose that Neanderthals coming from the relatively warm region of the African continent had to adapt to unfamiliar and hostile climatic conditions: an environment where it was cold and where finding food must have been more difficult than in the Neanderthals' 'historical homeland' (Finleyson 2005; Power, Sommer 2013). If Binford's theory is correct, it is entirely possible that Neanderthal males lived apart for reasons connected with finding and storing food: strong males could easily appropriate all the food by which they could significantly weaken the group's viability. The absence of males in the women/offspring community would not create big problem: hunting and gathering should be collective business in these prehistoric communities. As a consequence, it is possible for us to ascribe the coming into operation of populational and survival mechanisms to the Neanderthals' social structure, where males lived separately from females and offspring.

It is possible that it is precisely in this social structure and behavior – which differs from 'African behavior' – that the difference will finally be found which will bring us to the domestication of animals.

Neurochemical drivers of behavior

Ever increasing attention is being paid in modern science to the importance and influence of social links and systems to both emotional balance and also to mental health (Cohen 2004; Maulik, 2009). During relations (whether between two or more people or groups) specific opioid compounds are produced in the human body at that moment, which for their part facilitate relaxation, and neutralize the operation of substances provoked by stress (Drolet 2001). As a consequence, a specific social interaction (showing affection, touching, group entertainment or the like) is one which not only turns man into a social being, but also protects him from the stress which he would otherwise experience without this interaction. Social interaction activates an endogenous opioid process in the human body which, for its part, is responsible for the production of those biologically active substances (dopamine, oxytocin and others) which are fundamental for keeping us mentally healthy (Eisenberger 2012, Valentino 2015).

The opioid system plays a central role in the perception of pain (nociception) and in its relief (Holden, 2005). Besides this, the system in question participates in various physiological bodily processes such as the response to stress, the operation of the pulmonary and digestive systems, the working of the endocrinal and immune processes, in the formation of a hedonistic mood and character, and in the formation of the phenomena of a euphoric state and of habit (Keley 2004; Keley 2002). Opioid peptides and their receptors are widely distributed in the peripheral and central nervous systems and are the subject of intense study.

Thus the opioid system, especially in those brain centers located in the ventral tegmental area, participates in the functioning of all those basic mechanisms that are linked to the reinforcement of behavioral reactions and obtaining positive results (Khachaturian, 1993). At the same time, it is possible that opioids of various types may work in contrary ways depending on the anatomical peculiarities of nervous circuits and of the nature of those receptors that are activated in one or another specific behavioral process; for example, opioids which work on μ- and δ-receptors give us a feeling of pleasure, creating a positive reinforcement phenomenon and increasing the chances of repeating the behavior, whilst opioids working on κ-receptors cause aversion, negative moods, hallucinations and malaise, which lead to a process of negative reinforcement (Le Merrer 2009).

The functional activity of the brain's opioid system underlies such behavioral processes as social behaviors, mother-child relations (Burkett 2012; Nelson 1998), relations between partners, play, and others (Le Merrer 2009). During such types of relations, social information is expressed through the so-called 'loyalty' phenomenon (Burkett 2012), which differs in its essence from the habit phenomenon. In the development of a usual habit (for example, one concerning narcotic substances), a reinforcement of behavior is dependent on elementary positive feedback located in the adjacent nucleus between the existing opioid and dopamine systems (Wise 1987). The formation of the 'loyalty' phenomenon, (for example, relations with partners, between mother and child) is considerably more complex and is essentially social in character and based on sensory information (contact, conversation, appearance, odor, voice, behavior, etc.) in which, besides dopamine and the opioids, other types of neurohormones (oxytocin, vasopressin and others) also participate (Burkett 2012; Nelson 1998). Following on from this, it is clear that the endogenous opioid system produces substances which are essential not only for our psyche but also for our functioning as social beings.

Rejecting social relations (for whatever reasons) gives rise to a process during which something akin to physical pain begins ('Theory of social pain', Eisenberger 2012). According to the theory of social pain, a consequence of social and physical 'pain' is that adaptive/compensatory mechanisms given rise to are similar, and are expressed in the activation of the endogenous opioid system (Hsu 2013). The changes in question are expressed especially clearly in those areas of the brain that are responsible for motivation and mood (Trezza 2011). It is to be noted that in children positive social behavior and games are dependent on the activation of existing opioid neurotransmission in the adjacent nucleus, the disruption of which, supposedly, leads to the formation of the symptoms of autism, depression and schizophrenia (Trezza 2011).

Lonely Neanderthal: in quest of neurochemical balance

It is especially relevant to our hypothesis that, as a consequence of social pain, the activation of the opioid system creates an inclination towards investigation: at this time the human organism 'seeks' something to substitute for those opioids and other neurohormones which are produced in its social system during social relations (below).

The formation of the phenomenon of investigative activity and its reinforcement follow from natural physiological processes by means of opioids: obtaining food and water, relations with potential partners, and other positive physiological stimuli result in a reinforcement of behavior (Bodnar 2004). This reinforcement implies searching and investigative activities, which we can see on the example of feeding. The physiology of feeding can be divided into two parts: the first is the so-called homeostatic feeding necessary to sustain life, and the second is hedonistic, pleasure-inducing feeding, which is revealed after taking excessive and pleasant food (Bodnar 2004). In both cases, the opioid system plays a part; this system comprises specific areas of the brain that reinforce the phenomenon of positive reinforcement in which, besides the opioid system, a second important motivational and emotiogenic system plays a role: the dopaminergic system (Kelley 2004; Khachaturian 1993). Two of these systems (the ventral tegmental area and the so-called adjacent nucleus) participate in almost all those phenomena connected with opioids and which participate in the process of the formation of habit/reinforcement and pleasure/euphoria (Kelley et al. 2002, Le Merrer 2009). It is in this particular system that the μ- and δ- positive reinforcement opioid receptors are located, the activation of which increases the chances of repetitive behavior (e.g., searching for food). Besides this, the activation of the opioid receptors located in the adjacent nucleus (nucleus accumbens), facilitates a hedonistic mood (Kelley 2004; Le Merrer 2009). It should be noted here that another important neuropeptide, oxytocin, has a similar area of spread in nervous tissue, and whose interaction with opiates frequently appears to be coordinated (Dölen 2013). Oxytocin's potential as a neuromodulator becomes apparent in the structures determining the brain's social, adaptive and emotional behaviors (Carter 2014), which by its corresponding nervous paths gives rise to changes in the operation of the central nervous system: feelings of empathy, sympathy, belief and hopefulness (Bethlehem 2014).

The same thing happens when a person suffers from a lack of social interaction (Le Merrer 2009). Activation of the endogenous opioid (and related neurohormonal) system forces him to undertake investigative and/or search activities: to seek what will replace for him the opioids received through social interaction. We suspect that this physiological mechanism could have been the basis of the beginning of the taming/domestication of animals. If we suppose that Neanderthal males lived at a distance from groups of women and children, their endogenous opioid system should have forced them to seek out what would substitute for the opioids they had obtained from social interaction. It is also clear that, among the 'evicted' males, the survivors would be those successful in the search for the factors that gave rise to the production of 'external opiates' and opioids, and reinforced this behavior.

Interestingly, a comparative transcriptome analysis of prefrontal cortical brains from tamed versus wild silver foxes (see above) detected significant, at least two-fold differences in the expression of 335 genes pointing to massive neurochemical changes associated with domestication (Kukekova 2011). These differences were further validated for nine genes, and one of them appeared to be the gene of the 5-hydroxytryptamine receptor 2C (HTR2C) with greatly higher expression in the tame foxes. This can be important support to our hypothesis as HTRC2 represents a G-protein-coupled receptor expressed in the forebrain (Stam 1994), and is implicated in the numerous aspects of physiology and behavior (Heisler 2007a,b). In particular: (a) HT2C receptor is a significant modulator of the hypothalamic–pituitary–adrenal axis, which is the main controller of acute sympathetic stress responses related to fight-or-flight response (Heisler 2007); (b) HT2C receptors increase dopaminergic circuitry, especially in the nucleus accumbens that have been implicated in stress, anxiety, and pain (Mickey 2012); (c) mice with knocked out HTR2C are hyper-responsive to repeated stress (Chou-Green 2003); (d) male humans with schizophrenia are characterized with decreased expression of HTRC2 functions (Lee 2015). These findings together suggest that the elevated expression of HTRC2 gene in tame foxes provides increased comfort and easily adaptable behavior of these animals thus allowing them to become more receptive to interactions with humans.

If our hypothesis is correct, it is clear that Neanderthal men could find in animals external factors that gave rise to opioids and related neurohormones – something that would be the beginning of familiarity. Some of the first findings on physiological mechanisms induced by the relationship between man and domesticated animals appeared in 1983 (Friedmann 1983), in which it was shown that relations between people and dogs were accompanied by a reduction in blood pressure on both sides. More detailed study showed that during positive relations between man and dog averaging fifteen minutes were accompanied not only by a reduction in blood pressure but also a whole range of biochemical changes: in representatives of both species there was a convincing rise in the level of plasma β-endorphins, oxytocin, prolactin, phenylacetic acid and dopamine; (Odendaal 2003). We can conclude that the relationship between man and animal for the two species is positive for both their mental and physical health, and also reinforces mutual familiarity and, in the same way, is followed by reinforcing physiological and biochemical changes.

As already mentioned above, the positive effects of the interactions with animals are a result of the growth of neuropeptide oxytocin, which, through corresponding neural paths induces changes in the mental processes and evokes feelings of empathy, hope and believe. The effect of oxytocin is overall mediated by that opioid- and dopaminergic systems, which take part in the formation of basic mechanisms of "awarding" and positive social interactions (Bethlehem 2014). The secretion of opioids by plants and fruits is a fact and we can observe it in our everyday life. It is important for our hypothesis that the plants domesticated first are those from which producing alcohol is easy: with the grapes and figs next we see rice, barley and wheat (Patrick 1952: 676-686). Easier access to alcohol could add motivation for domesticating these plants by the first homos' societies.

Discussion and synthesis

Wolves were most probably the first tamed by our ancestors (Friedman et al. 2014). Not only for the reason that we know the dog was the first buried domesticated animal (Larson et al. 2012), but for the reason that wolves over a long period must have been satellites around human dwellings (Russell 2012), especially, one may assume, those wolves who had lost hierarchical fights within the pack, and therefore easily acknowledged man as master. In the same way, it is entirely plausible that a step was taken on the part of the animals towards familiarity with man (Derr 2011; Paxton 2000). An animal, who is alone and not in a social group, also needs opioids and its organism is similarly oriented towards seeking out opiates, as is the physiology of man (in our case, that of the Neanderthals). Thus we surmise that the first tamed animals were either still undeveloped offspring or isolated animals who were still 'seeking' the provocative phenomena of endogenous opioids in the same way as Neanderthal men. If so, we must state that the first taming of an animal by a Neanderthal seeking the rise to endogenous opioids, was a bilateral process. Such relationships can be described as mutually positive or facilitative (Baenninger 1995), and their emergence is very probable from the point of view of ecology: in relatively severe environmental conditions (such as in the range of Neanderthals) usually the frequency of positive interactions among species increases – a fact well established in plant community ecology (e.g., Brooker 2008), but which can readily be generalized (Kikvidze 2009).

Nowadays it is already taken for granted that relations between man and animals have a positive impact on both sides: on social attentiveness, social behavior, relations among people, and on mood (Archer 1997; Derr 2011; Smith 2014). Much data indicates that in this relation we are dealing with a reduction of stress-related factors: the levels of epinephrine and norepinephrine are reduced, the functioning of the immune system improves, and pain is reduced (Beetz 2011; 2012). Similarly, aggression is reduced, there is an increase in empathy, trust towards the other side, and an improvement in learning skills (Beetz 2011; 2012; Dölen 2013; Handlin 2011; 2012; Miller 2000). Nowadays, an ever-increasing number of articles appear appealing to us to investigate using animal therapy as an essential and not as an ancillary intervention mechanism (Hart, 2006; Maujean 2015; Palley 2010).

In clarifying relations between man and animal, enabling the endogenous opioid system shows a new aspect of the domestication hypothesis: it is known that these hormones are created during social relations (Beetz 2012; Bethlehem 2014; Carter 2014; McGregor, Callaghan 2008; Nelson 1998). Correspondingly, those who have had experience of these hormones must again reach a situation where these neurochemicals will be secreted, that is to say: they must interact socially with those similar to them. We think that this perspective explains why the wolf was the earliest to be domesticated. Alone, defeated in a hierarchical struggle, thrown out of the pack – a young wolf was the best candidate to form a bond with a similar lone man (in this case, Neanderthal). Both of them are looking for a link that will bring their organisms the desired neurochemicals.

Generally, existence of pets directly confirms the neurochemical theory: the objective of their domestication apparently is the secretion of opioids and other neurohormones such as oxytocin that improves psychological health by providing emotional support and dispelling feelings of depression, anxiety and loneliness (Hines 2003; Holden 2005; Staats 2008). Indeed, modern research shows that their ability to provide companionship and friendship are common reasons given for owning pets (Jones 2007), and that interactions with them may improve health and reduce blood pressure (Erwin 2003).

Apparently, taming animals and then domesticating them was based on just this process: owing to the difficulty of obtaining food and to its scarcity, Neanderthal males were driven out from the society of women and children and they were forced to live alone. This probably happened 100,000 – 120,000 years ago, at the time of the first emergence of Neanderthals onto the Eurasian continent. As a result of this expulsion a mechanism was enabled in Neanderthal males that compelled them to investigate/seek out opioid-secreting stimulating factors, which they found in the taming/training of animals and in the discovery in plants of characteristics useful to them. When *Homo sapiens* came to Eurasia they, we may suppose, were met by Neanderthal men with tamed/trained animals. We can assume that folk tales about magicians living all alone in the forest, who know the languages of animals and plants date from this time. Such characters are common to the folk tale repertoires of all peoples, but given the fact that Neanderthals were not in contact with our ancestors in Africa, we might suggest that the presence of such lonely magicians will be less conspicuous in the folklore of this continent (below). Later, when Neanderthal and *Homo sapiens* societies mingled, the custom of familiarization and domestication must have become generally accepted. This is something entirely possible, at a time when the great ice age ended (12,000 years ago), which had become one of the stimulating factors for the appearance of permanent settlements. It is for this very reason that we 'see' domesticated plants and animals in paleontological fossils starting from ca. 8000 AD: the Neanderthal legacy had brought its result. Changing these omesticated/familiarized/trained animals into a source of food must have been a later phenomenon, by continuing this process jointly with *Homo sapiens*.

We may also suppose that this aspect of Neanderthal society made a lasting impression on *Homo sapiens*. To the present day the skill of familiarization/training of animals is considered special and almost magical. We say nothing of that cultural fact that in the myths and tales of almost all traditional societies, animals are the assistants of magicians and evidence of their supernatural power (Propp 1968).

Conclusive remarks

On the basis of what has been said above, we can establish a definition of domestication: 'Domestication is an artificial, social and personal system of the repeated use of results from the behavior and existence of specific representatives of animal and plant species, often obtained by means of genetic selection, with the initial aim of producing a greater amount of endogenous opioids and related neurohormones in the human organism.' Although at this stage it does not seem easy to immediately test this hypothesis, future research based on the advances in molecular biology that emphasize the importance of epigenetic mechanisms to the evolution of our brain (Krubitzer and Stolzenberg 2014) and behavior (Cox 2013; Meloni 2014; Rozanov 2012) can certainly help vindicate, modify or refute this new perspective.

The new perspective can also help predictions that are already testable empirically. First, we may expect that interactions with plants, similar to interactions with animals, will launch cascades of neurochemical changes in the opioid system and establish certain patterns of our behavior; this prediction can be tested with the same experimental approach as used in the case of animals. Second, the ethnological records can show significant difference between the shaman sub-cultures of sub-Saharan Africa and other continents in their interactions with animals and plants.

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