ϕ-Features in Animal Cognition

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This paper argues that the core ϕ-features behind grammatical person, number, and gender are widely used in animal cognition and are in no way limited to humans or to communication. Based on this, it is hypothesized (i) that the semantics behind ϕ-features were fixed long before primates evolved, (ii) that most go back as far as far as vertebrates, and (iii) that some are shared with insects and plants.

Keywords: animal cognition; gender; number; person

1. Introduction

Bickerton claims that language is ill understood as a communication system:

> [F]or most of us, language seems primarily, or even exclusively, to be a means of communication. But it is not even primarily a means of communication. Rather, it is a system of representation, a means for sorting and manipulating the plethora of information that deluges us throughout our waking life. (Bickerton 1990: 5)

As Berwick & Chomsky (2016: 102) put it recently "language is fundamentally a system of thought". Since much of our system of representation seems to be shared with other animals, it has been argued that we should "search for the ancestry of language not in prior systems of animal communication, but in prior representational systems" (Bickerton 1990: 23).

In support of this, I provide evidence that all the major ϕ-features are shared with primates, most with vertebrates, and some with plants; and that there are no ϕ-features whose semantics are unique to humans. Specifically human categories, including all things that vary across human cultures, seem to

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be expressed by nouns, verbs, and adjectives, never by function words or affixes. Specifically, I hypothesize:

(1) The semantics of grammatical categories are not unique to humans.

But this is a much broader claim than can be argued for here, so I limit the present work to a subset of what Zwicky calls direct features, those "associated directly with prototypical, or default, semantics" (Zwicky 1992: 378). I leave aside his indirect features—case, declension, conjugation, and finiteness—which do not seem to have any analogues in animal cognition and are probably unique to grammar; I focus on the features behind grammatical person, number, and gender. I present evidence elsewhere for the use in animal cognition of the verbal categories tense, mood, and aspect, and for the use of θ-roles (Golston 2018), though the argument here for ϕ-features stands alone and in no way relies on those efforts, or vice versa.

The specific features I will be concerned with here comprise the traditional categories of person, number, and gender:

(2) *ϕ-features we share with other animals*

Person:	*first, second, third*
Number:	*singular, dual, plural; comparative, superlative*
Gender:	*masculine, feminine, neuter; animate*

These constitute the ϕ-features that play a central role in language (see articles in Harbour *et al.* 2008) and are involved in agreement, an important phenomenon in language that is likely unique to humans. I argue here that all of the semantics of person, number, and gender are shared with vertebrates, that many are with insects, and that some are with plants.[1]

The findings presented here argue against the idea that there is something uniquely human and communicative to the categories grammar regularly makes use of. Mithun claims that:

> It is now generally recognized that grammatical categories develop in languages through use. Distinctions made most often by speakers as they speak tend to become routinized over time in grammatical markers. Many grammatical categories recur in language after language, no doubt because they reflect common human interests. (Mithun 2015: 131)

The data I present here suggest that ϕ-features at least did not develop in grammar through language use but are part of the innate cognitive structures we share with other living things. It seems that ϕ-features reflect common living interests and are part of the faculty of language in its broad sense (FLB), which includes "a wide variety of cognitive and perceptual mechanisms shared with other species […] in more or less the same form as they exist in humans, with

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[1] A reviewer raises the issue "whether there is something like a language-specific semantics on the one hand and a language-independent semantics on the other hand". I assume that the semantics of ϕ-features are language independent, though I cannot speak past that to semantic issues more generally.

differences of quantity rather than kind" (Hauser *et al.* 2002: 1573). Person, number, and gender do not seem to be part of the faculty of language in its narrow sense (FLN), the discretely human part of language, and do not reflect interests specific to humans. Most people never think or care about person, number, or gender in the grammatical sense.

There is a split among some linguists between more formal approaches that see language as mostly representational and innate and more functional approaches that see it as mostly communicative and learned. This paper partially supports the more formal view by arguing that grammatical categories are shared with animals that do not use them for communication at all and only use them for cognition (humans use them for both). Also, most of the ϕ -features have clear neural and genetic bases that suggest they are innate rather than learned.

A note about animal cognition. The main line of research here is in how animals process information related to what biologists call the four Fs—feeding, fighting, fleeing, and reproduction. It is not in how animals think about the information they process; i.e., none of the claims here involve animal metacognition (for which, see Kornell 2014). The issue in this paper is *Do animals think **using** person, number, gender?* It is not *Do animals think **about** person, number, gender?*

Two notes about what I do *not* claim. First, the semantics of grammatical categories like number are quite specific and meager: The grammatical features singular, dual, and plural do not have anywhere near the depth of meaning that humans enjoy in lexical items like *single, twin, fifteen,* π, etc. Claiming that guppies process singular, dual, and plural like humans do does not mean that they possess all of our numerical skills, nor that they use their mathematical skills as we do ours. The claim is much more restricted: *singular, dual, and plural are used by animals in their natural settings*. Second, I do not claim that what is shared with other animals is necessarily derived from a shared common ancestor; other animals have eyes but many are the result of convergent evolution. The argument for inheritance has to be made on a case-by-case basis and I will indicate where this has been done below. The claim is just that *person, number, and gender semantics are not uniquely human.*

I begin with the features behind the category *person* as it unfolds in grammar and in animal cognition (section 2), then turn to *number* (section 3) and *gender* (section 4), before briefly concluding with some broader concerns (section 5).

2. Person

All human languages mark grammatical person, usually in pronouns like *I, you, he, she, it*, and it is common to see person features copied onto a verb or other predicate, as we see in a language like German, where verbs agree in person and number with their subjects:

(3) *German*

Ich geh–e	Du geh–st	Sie geh–t
1SG go–1SG 2SG	*go–2SG*	*3SG.F go–3SG*
'I go'	'You go'	'She goes'

Person lies behind the notions speaker (1P), hearer (2P), and other (3P), but there is reason to see it as based more deeply on the concept *self*. The idea goes back over a century:

> Le point de départ est le moi psychologiquement; du moi, on passe au non-moi. Mais le fait du discours introduit un troisième élément et divise le non-moi; on ne parle pas sans interlocuteur; cet interlocuteur se détache du groupe du non-moi et prend une importance particulière.
>
> Celui qui parle divise ainsi les êtres en trois groupes: 1° soi qui parle, 2° celui à qui il parle, 3° ce dont il parle. (Grasserie 1888: 3)

Person is linked specifically to *self* as early as Boas: "Logically, our three persons of the pronoun are based on the two concepts of self and not-self, the second of which is subdivided, according to the needs of speech, into the two concepts of person addressed and person spoken of" (Boas 1911: 39). The grammar of the Papuan language Urama codes this distinction of self and not-self overtly:

> There are only two overt person markers in Urama. One of them marks the first person of all numbers. The other one marks the second and third person of all numbers and as such is a 'non-speaker' form. (Brown *et al.* 2016: 27)

Thus a verb agreeing with 1P has the prefix *n–* (glossed 1 for 'first person'), while a verb agreeing with 2P or 3P has the prefix *v-* (glossed N1 for 'non-first-person'):

(4) *Urama*

a. Nimo nahua=i n–abodo ka=umo.
1PL song=DEF 1–sing PRES=PL
'We are singing the song.'

b. Rio hatitoi v–odau du=mo?
2PL whither N1–goTENSE=PL
'Where are you all going?'

c. Ni raisi itai a–v–o'ou du=mo doutu?
3PL rice cook Q–N1–DFUT TENSE=PL tomorrow
'Will they all cook rice tomorrow?'

(Brown *et al.* 2016: 28–29)

The importance of the notion *self* for 1P and 2P generally is treated in Bobaljik (2008: 224ff.) and Wechsler (2010), who argues convincingly that "first- and second-person pronouns are not grammatically specified for reference to speaker and hearer" (p. 362), based on evidence from typology, acquisition, and autism (to which the reader is referred). Mizuno *et al.* (2011) likewise argue that pronoun-reversal in autism (generally *I* for *you*) is the result of a failure to shift the "deictic centre from another person to oneself" (p. 2433). As Wechsler points out, the autistic data make no sense if 1P and 2P mean 'speaker' and 'hearer', concepts which autistic individuals should have no difficulty with.

I follow Wechsler's claim that "ALL PRONOMINAL REFERENCE TO SPEECH-ACT PARTICIPANTS takes place via SELF-ASCRIPTION" (Wechsler 2010: 349, his caps), also known as reference *de se* or *self-reference*. When speakers say 'I' they refer to themselves, and when addressees hear 'you' they refer to themselves. For him,

> SELF-ASCRIPTION EXHAUSTS THE PERSON SEMANTICS OF THESE FORMS. [...] These pronouns indicate self-ascription, but there is no additional specification that they must 'refer to' or 'be anchored to' the addressee and speaker. [...] For every speaker, *I* translates as a self-notion, and for every addressee, *you* translates as a self-notion. (Wechsler 2010: 348, his caps)

3P translates as everything else, occasionally to other actual people but much more commonly to animals, plants, rocks, dirt, clouds, warmth, situations, events, hypotheticals. The referents of 1P and 2P form a remarkably small set of usually human *selves* compared to the referents of 3P which cover the rest of the world and everything in it: all nouns are 3P in every language.

2.1. First Person

If 1P actually denoted speakers, a sentence like *I am not speaking* would be logically false or interpretable only metaphorically, which it clearly is not. 1P need not coincide with someone who is speaking and *I am speaking* is not a tautology in any language. Nor does 2P need to coincide with an addressee: *You are speaking*, where the speaker is 2P, is perfectly grammatical and need not be interpreted metaphorically to be true. Nor are *She is speaking* or *She is listening* logically false or semantically anomalous in any language. Speakers need not be 1P and 1P need not include speakers. Everyone uses 1P to refer to themselves when they speak, but the intended referent is *self*, not *speaker*. People with associative identity disorder have multiple *selves*: the referent of 1P shifts from one personality to another, not from one speaker to another (schizophrenia might be similar, see Gallagher 2000: 15ff.).

That said, what 1P encodes *grammatically* is incredibly spare and utterly devoid of content in the languages of the world, as discussed in the philosophical literature:

> 'I' seems to lack descriptive content entirely. Importantly, there is no need for the speaker to 'know who' he is, i.e. who is uttering 'I', in order to successfully refer by its use. The speaker may have entirely false beliefs about himself or no identifying beliefs at all. None the less, when the speaker utters a sentence containing 'I', he refers to himself. By the use of 'I' one refers to oneself without any further characterization.
> (Röska-Hardy 1998: 3)

Gallagher distinguishes a rich *narrative self* from a lean *minimal self*:

> Phenomenologically, that is, in terms of how one experiences it, a consciousness of oneself [is] as an immediate subject of experience, unextended in time. The minimal self almost certainly depends on brain processes and an ecologically embedded body, but one does not have to know or be aware of this to have an experience that still counts as a self-experience.
> (Gallagher 2000: 15)

1P is essentially what Descartes (1641) argued was the one thing he could not doubt:

> Sed quid igitur sum? Res cogitans. Quid est hoc? Nempe dubitans, intelligens, affirmans, negans, volens, nolens, imaginans quoque, & sentiens.
> [But what then am I? A thinking thing. What is that? Surely doubting, understanding, affirming, denying, wanting, refusing, imagining too, and feeling.] (*Meditations* 2.8)

In some languages, persons combine to form ‘inclusive’ or ‘exclusive’ duals and plurals. Wikchamni Yokuts, for instance, contrasts *inclusive our* (1P and 2P) and *exclusive our* (1P and 3P) in both duals and plurals. The inclusive forms are built on a 2P root (*m–*), while the exclusive forms are built on a 1P root (*n–*):

(5) *Wikchamni*

Dual	Plural		
m–akʔan	m–aːy’in	‘our (1P and 2P)’	*(includes you)*
n–imkin	n–imik’	‘our (1P and 3P)’	*(excludes you)*

(Gamble 1978: 101)

Bobaljik (2008) notes that no language distinguishes 1P duals or plurals in terms of [1P +1P] vs. [1P +3P], that is, no language has a special morpheme for ‘true 1P’ or ‘true 2P’.

Most animals use the *self* as a reference point to function in their natural environment. Spada *et al.* (1995: 194) define this kind of biological *self* as the “ability of a living organism to be an active agent in its physical and social environment by means of a continuous monitoring of its position in relation to any environmental situation, i.e., danger, hunting, attack, etc.” *Self* also includes all interoception—hunger, thirst, cold, fatigue, arousal. Spada *et al.*’s notion of *self* for animals is, like Descartes’, a thing that sees, hears, feels, and thinks.

Bekoff & Sherman (2004) argue that *self* is too broad a term when discussing the animal world and distinguish three levels of *self* for animal minds. Two of these, *self-referencing* and *self-awareness,* are said to be shared with other beings, while the third, *self-consciousness,* is thought to be unique to humans. They define *self-referencing* as a simple dichotomy of *me* vs. *others* that “can be reflexive and noncognitive, even occurring in the immune system and in creatures without brains, such as tunicates [commonly known as sea-squirts, invertebrate marine filter-feeders with no sense organs—CG] and plants” (p. 177). If a plant or animal’s immune system cannot tell itself from other things, it will attack the plant or animal it is meant to defend: in this very basic sense *self* is a general notion that requires no cognition at all. I take Bekoff & Sherman’s *self-referencing* to be a biological pre-cursor to the categories 1P and 2P, one that is shared among eukaryotes, bacteria, and archaea, all of which have immune systems; *self-referencing* probably traces back to the last universal common ancestor (LUCA).

Bekoff & Sherman’s notion of *self-awareness* includes *self-referencing* but also distinguishes things like *my body* vs. *others’ bodies*. I would argue that *self-awareness* in this sense is 1P in its grammatical sense and is widely shared among animals (including humans), but not by single-cell organisms:

> A sense of 'body-ness' is necessary for most animals to function in their social and ecological milieus, i.e. to find mates, to evade predators, or to avoid bumping into each other. A brain is required for this level of self-cognizance, although the actual discrimination can be conscious or unconscious.
>
> (Bekoff & Sherman 2004: 177)

Bekoff & Sherman's *self-awareness* is clearly meant in a 1P sense: An animal is immediately aware of itself. De Waal (2016: 241) points out that when two monkeys play, they bite *each other* (2P) rather than *themselves* (1P); they can only do so if they distinguish 1P from 2P. The details of all this are less important than what these conceptions of animal self share: They are meager and include little or nothing of substance, for example, no knowledge of *self* in a biographical sense. They seem to be the exact homologues of 1P *self* in grammar.

Some such notion of *self* is required not just for locomotion in animals, but for the spatial mapping that guides it. A core element of such mapping is *egocentric* mapping, the use of neural spatial reference frames that include the *self*:

> It is well-established that neurons in many brain regions, especially parieto-frontal cortex, represent the spatial location of objects in egocentric spatial reference frames, centered on various body parts such as the eye (retina), the head, or the hand. […] [Egocentric frames are involved] whenever the observer invokes the position or orientation of the present, remembered or imagined (e.g., mentally rotated or translated) self, as opposed to an external landmark, to represent the location of external landmarks.
>
> (Filimon 2015: 1–2)

Navigation in all animals is thought to involve egocentric representations. Anderson & Oates (2003) conjecture that prelinguistic animals can have *only* these and Filimon (2015) argues that all spatial mapping is egocentric for humans as well. Most of the field, however, assumes a healthy mix of egocentric and allocentric mapping: "[B]oth allocentric or 'survey' strategies, based on the manipulation of map-like representations, and egocentric or 'route' strategies, based on path integration or on sequences of stimulus-response associations, contribute to human navigation" (Galati *et al.* 2010: 113). Visual navigation in water mazes by rats (Harvey *et al.* 2008) shows both egocentric (e.g., keeping a visual cue in the center of the retina) and allocentric navigation (discussed below under 3P). Recent work with moving ferrets shows this for auditory cortex as well (Town *et al.* 2017). Even insect navigation relies on where the *self* has been (Collett *et al.* 2013).

Bekoff & Sherman's third level, *self-consciousness,* involves thinking about oneself and one's relation to others:

> Being self-conscious implies that an individual is self-aware, and that it can use self-referent phenotype matching. We hypothesize that self-consciousness evolves when individuals benefit from analyzing and revising their own behavior in light of how specific members of their social group, including actual or potential mates, responded to their behavior in the past.
>
> (Bekoff & Sherman 2004: 177)

They do not speculate on which animals have self-consciousness in this sense, but this need not deter us here. Grammatical 1P is based on *self-awareness*, not the much richer notion *self-consciousness*.[2]

A related trichotomy in neuro-science is the distinction between mental states arising from the *protoself*, the *core self*, and the *autobiographic self*, associated with Damasio (1998, 1999, 2010). Mental states of the last kind "are generated when individuals retrieve memories for historical aspects of their lives, and thus are dominated by biographical information, including simple facts of one's identity (e.g., date and place of birth), personality traits (e.g., honesty), as well as specific life events and episodes (e.g., one's high school graduation)" (Araujo *et al.* 2015: 2). These may well be unique to humans and an autobiographical sense does not seem warranted in the cognition of most animals; nor is it warranted in grammatical 1P. What grammar codes is the mental states of the *core self*: "Such states allow individuals to form an account of their ongoing body states, and may relate to interoceptive body changes (e.g., hunger, thirst, or fatigue), and to a class of exteroceptive changes caused by the interaction of the body with the outside world (e.g., pressure exerted on one's arm)" (Araujo *et al.* 2015: 2).

Damasio takes the *protoself* to be a biological precursor to the core self.

> The protoself is the stepping-stone required for the construction of the core self. *It is an integrated collection of separate neural patterns that map, moment by moment, the most stable aspects of the organism's physical structure*. The protoself maps are distinctive in that they generate not merely body images but also *felt* body images. These primordial feelings of the body are spontaneously present in the normal awake brain. (Damasio 2010: 201, his italics)

The neurological *core self*, biological *self-awareness*, and philosophical *I* seem to be describing the same thing from slightly different angles. My claim here is that the notion 1P in grammar describes the same biological mechanism.

Summarizing, 1P behavior is widespread among animals and involves a stripped-down notion of *self* essentially identical to the one that grammatical 1P encodes.

2.2. *Second Person*

Still following Wechsler (2010), the referent of 2P is again the *self*; the difference between 1P and 2P is that 2P references the *self* for an addressee, while 1P references the *self* for a speaker. Since we cannot profitably use terms like *speaker* and *addressee* when discussing animal behavior (they don't speak), separating 1P from 2P in cognition is less obvious than it might seem. The general picture, however, is that 1P indicates a *self* that is *me,* while 2P indicates a distinct *self* that I am engaged with. This 2P *self* is generally human for us, though it can be extended to animals that function as humans in some way (e.g., pets and farm animals). As pointed out by a reviewer, I can and do address my dog as *you*, though I doubt he responds to it with self-ascription; when I address my (adult) daughter as *you*,

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[2] Whether animals recognize themselves in mirrors is sometimes taken to be relevant to the notion *self* as well; the issue strikes me as tendentious and I will not address it here.

self-ascription goes through as planned. So the relative propriety of addressing my daughter > my dog > my car as *you* is well-modeled as a function of how well each of them can self-ascribe the notion *self*: my daughter does so fully, my dog less so, my car not at all.

With this caveat, I assume that grammatical 2P involves close interaction of the *self* with a conspecific, where each is usually aware of the actions of the other and the actions are coordinated in some way. Although most humans invest much more than this in interpersonal interactions, grammatical 2P encodes just this and no more.

This is how 2P is used in most of the cognitive science literature, where it is not related to speaker/addressee but to perspective-taking, modes of social interaction, and the like. I follow de Bruin *et al.*, who

> propose that what distinguishes 2p from 3p modes of social cognition is their reciprocal nature. That is, 2p modes of social cognition feature agents who coordinate their actions with one another. (de Bruin *et al.* 2012: 8)

Evidence for 2P cognition in animals comes from *dyadic interaction*, what Hurford (2007: 198) calls "doing-things-to-each-other: aggression, sex, submission, feeding another, grooming, caregiving, and play". Dyadic interactions involving shared gaze and attention implicate the basic notions of 1P and 2P and "are commonplace in many species of animal; shared attention during social play with objects has been observed in some canid, psittacine, and corvid species" (Tanner & Byrne 2010: 592). "Jackdaws […] follow a conspecific's gaze toward the object of their attention concealing food, but only when the conspecific is their partner, not when unfamiliar to them" (Clayton & Emery 2015: 1337).

Mating displays in certain fish require coordinated 2P actions as well. Consider the following dyadic interactions of the mangrove killifish:

Tandem swim:	Fish pair up and move through the water column. Includes side-by-side swimming or one fish following closely behind the other.
Vertical rub:	Fish positions body vertically and uses entire body to make contact with opposing fish, which is suspended horizontally in water column.
Head rub:	Fish uses head to make contact with opposing fish; often, point of contact is underneath the vent of the opposing fish.

(Luke & Bechler 2010: 9)

Interactions like these require that a fish be aware of the actions of its partner and that the actions of both fish be closely coordinated. There is no indication that killifish communicate about any of this, suggesting that 1P and 2P are not fundamentally about communication, but about coordinating interactions with a conspecific.

When insect colonies relocate, individuals must be guided to the new area. Some species do this with a 2P method called *tandem running* (Franks & Richardson 2006):

> In brief, it is a behaviour involving two individuals walking one behind the other in tandem, maintaining physical contact. The individual in front has prior knowledge of the destination, be it the new nest or food source or nest of slave species, and is known as tandem leader. The follower or second individual in the pair is the recruit and she is led to the destination. The recruited member in turn can behave as an informed individual and recruit other colony members or be only a follower and stay at the destination. Throughout the journey, the follower maintains contact by tapping her antennae on the gaster of the tandem leader thereby forming a tandem running pair. In some species of ants, pheromones are said to play an important role in initiating and maintaining cohesion between the tandem pair. Studies in *T. albipennis* suggest that followers learn the destination and make independent explorations to navigate back to the old nest and become recruiters in turn. (Kaur *et al.* 2017: 2)

In some species, carefully coordinated *tandem calling* is used to initiate tandem running:

> When a successful scouting forager returns to the colony it first regurgitates food to several nest mates. Then it turns around and raises its gaster upward into a slanting position. Simultaneously the sting is exposed and a droplet of a light liquid extruded. Nest mates are attracted by this calling behavior. When the first ant arrives at the calling ant, it touches the caller on the hind legs or gaster with its antennae and tandem running starts.
> (Möglich *et al.* 1974: 1046)

All of this requires careful coordinated actions between reciprocating conspecifics, each aware of the actions of the other. Most ant species actually carry conspecifics to a location, which also requires a great deal of interpersonal interaction, especially as the ant that is carried has its head upside down and pointing backwards (Pratt *et al.* 2002: 126).

> The collective achievements of these colonies draw attention, not to a gap between the intelligence of workers and the colony as a whole, but rather to the difference in scale. Even when no insect possesses information on more than a small part of the colony's task, an adaptive global solution can emerge from their local interactions, guided by appropriate individual behavioral rules. Because these local interactions may themselves involve sophisticated information processing, a thorough understanding of colony cognition requires a full appreciation of the cognitive skills of individual insects.
> (Pratt *et al.* 2002: 127)

I submit that the cognitive skills of individual insects include a notion of 1P and 2P that bind with DUAL and PLURAL.

There is evidence for 2P in animal *communication* as well, though that is not the focus of this paper:[3]

> Dyadic communication involves only two creatures: a sender and a receiver of a message. Such communication is not about anything external to the sender and the receiver. It is just a matter of one animal or person doing something to another, like greeting it, or threatening it, or submitting to it. This kind of communication is widespread in the animal kingdom.
> (Hurford 2007: 205)

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[3] See Schlenker *et al.* (2016) for a linguistic approach to communication in monkeys.

Sauerland (2016) argues that the semantics of a certain Colobus monkey call "explicitly mentions the addressee—i.e. *you*" and that "a Colobus monkey needs to attribute a mental state to the recipient" of its call (p. 151).

How far back in time 2P reaches is difficult to say, but it may be universal among social animals.

2.3. Third Person

3P reference in languages includes everything in the world other than the tiny number of *selves* referred to by 1P and 2P, a large map of everything with an x marking *you are here* and innumerable y's and z's marking everything else. We track our position among the y's and z's and navigate our way through them, through a maze of 3P places and things. Relatively few of the third person referents are *persons*; many are non-human (*dogs, cats, birds)* and most are inanimate *trees, rocks, roads, parks, attitudes, problems, events, situations*.

The psychology literature tends to use the term 3P for actual third *persons*, for example: "We experience our world from an egocentric (i.e. first-person) perspective and only later develop an ability to understand experiences from the perspective of others (i.e. third-person)" (Chisholm *et al.* 2014: 2). But this is not how the grammar of any language works: Grammar sees everything as 3P that is not 1P OR 2P.

The question at hand is whether animal cognition makes use of such a notion, whether animals distinguish things in the world (3P) from themselves (1P) and the selves they are currently interacting with (2P). Following Ungerleider & Mishkin (1982) and others, there are two visual processing systems in the brain, a ventral one that focuses roughly on *what* an object is and a dorsal one that focuses roughly on *where* it is. Goodale & Milner suggest that the ventral 'what' stream is more about the object itself (more 3P in grammatical terms), while the dorsal 'where' stream is about the relation between the object and the self (more 1P) and "would need to be largely 'viewer-centred', with the egocentric coordinates of the surface of the object or its contours being computed each time the action occurs" (Goodale & Milner 1992: 23). This makes sense if hapsis and navigation rely on spatial relations *vis-à-vis* the self, relations which object identification does not rely on. More recently, Manns & Eichenbaum (2009: 616) argue, based on neural data from mice, that the hippocampus may be where the map is located in mammals: "[T]he results suggest that objects were represented as points of interest on the hippocampal cognitive map and that this map was useful in remembering encounters with particular objects in specific locations".

Hurford argues that the dorsal/ventral stream distinction in perception is basic to the predicate-argument structure of logic and language:

> [T]he formula PREDICATE(x) is a simplifying schematic representation of the integration by the brain of two broadly separable processes. One process is the rapid delivery by the senses (visual and/or auditory) of information about the egocentric spatial location of a referent object relative to the body, represented in parietal cortex. The eyes, often the head and body, and sometimes also the hands, are oriented to the referent object, which becomes the instantiation of a mental variable. The other process is the somewhat slower

> analysis of the delivered referent object by the perceptual (visual or auditory) recognition subsystems in terms of its properties. (Hurford 2003: 273)

We look at the *where* first, and the *what* second in what follows, though it is important to note that they function together in parallel in neurologically intact animals.

2.3.1. Where

Clear evidence that animals have 3P representations of some sort involves spatial orientation and navigation in animals, which is generally taken to be partly egocentric (1P) and partly allocentric (3P)—to my knowledge, there is no biological literature on how we map our position to that of a conspecific we are interacting with (2P). The *locus classicus* for the idea that animals build cognitive maps is Tolman (1948), reporting on a number of experiments with rats in mazes. Arguing against behaviorist explanations, he says of 'field theorists' like himself that:

> We believe that in the course of learning something like a field map of the environment gets established in the rat's brain. […] This position […] contains two assumptions: First, that learning consists not in stimulus-response connections but in the building up in the nervous system of sets which function like cognitive maps, and second, that such cognitive maps may be usefully characterized as varying from a narrow strip variety to a broader comprehensive variety. (Tolman 1948 :192–193)

The general consensus for the past half century is that animals map the world they live in, not just in egocentric but also in allocentric terms, all of which are coded 3P in grammar. In a review of navigation in humans, Ekstrom *et al.* argue against the idea that allocentric representations are actually *maplike*, but acknowledge that "the idea that most species, including humans, posses multiple mechanisms for navigating, including one dependent on information about the position of the self relative to the environment (egocentric) and another regarding the position of other objects position relative to each other in the environment (allocentric), is generally well accepted" (Ekstrom *et al.* 2014: 1).

I follow Tolman, Gallistel, and most of the field in thinking that maps provide an excellent model for animal navigation, but it is true that the exact details of all this remain unclear. For the purposes of this paper, it does not matter if the allocentric 3P representations are literally map-like or not; all that matters is that they are 3P.

Damasio distinguishes three types of mapping, two of them internal to the organism, the third external:

> A normal mind includes images of all three varieties. […] (I) Images of an organism's internal state constitute primordial feelings. (II) Images of other aspects of the organism combined with those of the internal state constitute specific body feelings. Feelings of emotions are variations on complex body feelings caused by and referred to a specific object. (III) Images of the external world are normally accompanied by images of varieties I and II.
> (Damasio 2010: 80)

Most of the biological literature on mapping, though, is of the external kind. A classic discussion of cognitive maps in insects is found in Gallistel (1989):

> When a foraging ant leaves the nest, it winds this way and that in a tortuous search for fodder, but when it finds something, it turns and runs more or less directly back toward its nest a 1-mm hole in the ground as much as 200 m away. It does not retrace its outward path. If the ant is displaced at the start of its homeward run, it nonetheless runs straight in the predisplacement direction of the nest for a distance approximately equal to the predisplacement distance to the nest, then breaks into a search pattern. It is hard to resist the inference that the foraging ant possesses a continually updated representation of its spatial position relative to its starting point—a moment-to-moment representation of the direction in which the nest lies and how far away it is.
>
> When one displaces the landmarks that immediately surround either a bee's feeding source or the nest hole of a digger wasp, the position to which the animal flies is systematically displaced. It is hard to resist the inference that the animal represents something about the spatial relationship between the landmarks and its goal and uses this representation to direct its flight toward the goal. (Gallistel 1989: 155–156, references omitted)

More recent work on foraging ants suggests this even more clearly: they can find their way back to their nests walking *backward*, that is, even when egocentric navigation is thwarted, showing that they use allocentric directional frames, including the position of the sun (Schwartz *et al.* 2017). Bumblebees make similar use of map-like representations and can correct for things like wind drift, which does not seem possible if only egocentric representations are used:

> We have investigated wind compensation […] using radar to record the flight trajectories of individual bumble-bees (*Bombus terrestris L.*) foraging over arable farmland. Flights typically covered distances of 200 to 700 metres, but bees maintained direct routes between the forage areas and their nests, even in winds with a strong cross-track component. Some bees overcompensated slightly […] but most stayed on course by heading partly into the wind and moving obliquely over the ground. […] We propose that a simple strategy to keep on track in cross-winds would be for them to adjust their headings until the direction of ground image movement over their retinae (the optical flow) occurred at the angle relative to the sun's azimuth that corresponded to their intended tracks. (Riley et al 1999: 126)

Navigation in birds is generally understood in terms of a map and compass model (see Chernetsov 2015, which this section heavily draws upon). Like the rest of us, birds have to know where they are with respect to where they are going (the map) and they have to travel in a specific direction (the compass) to get there, both of which involve detailed 3P representations of the world and the things in it. Avian *compasses* are based on the sun, the stars, and the magnetic field of the earth. Avian *maps* are less well understood but include geomagnetic maps of the earth and possibly olfactory maps as well, based on the fact that birds cannot navigate if their sense of smell is destroyed experimentally.

Some of this navigation is learned and some is innate, as shown by displacement studies, in which birds are moved to a different location before they migrate (or return home in the case of homing pigeons) to see what effect this has on where they end up. The major finding is that (experienced) adults and (naïve) juveniles show up in different places:

> [A]dult birds can truly navigate in the sense that they can direct their movements specifically towards a goal, and when displaced during migration, they alter their headings accordingly. Juvenile birds on their first migration, in contrast, do not do this. The reason is not that they lack the ability to navigate—young migrants have been shown to be able to navigate at the respective age. […] What they lack is the navigational information about the goal area—first-time migrants travel to a yet unknown winter quarter. Birds can truly navigate only to a familiar goal where they know the 'local coordinates'. (Wiltschko 2017: 457)

This strongly suggests that adult birds manage to construct cognitive maps of their migration routes, which shows a careful monitoring of the 3P world as they mature. Displaced juveniles end up somewhere else because they have not yet built such maps:

> Young first-time migrants thus have to use a different strategy. Some avian species, such as, e.g., geese and cranes, migrate in family groups or flocks […] and young birds could, theoretically at least, be guided by their parents or experienced conspecifics. Yet, in most species, the young birds migrate independently from experienced birds, sometimes even leaving before the older birds leave. For their first migration, these birds have to rely on innate information to reach their wintering area. (Wiltschko 2017: 457)

Much is known about innate migration programs, but for our purposes it suffices that they indicate intricate 3P world knowledge, including the direction and length of the migration route.

Reptiles and teleosts (bony fish) also behave as if following maps; see Rodríguez *et al.* (2002) for a number of experiments which show "that turtles and goldfish, like mammals and birds, are able to use place strategies based on map-like or relational memory representations of the allocentric space" (p. 501ff.). The same is true of lizards, once thought to be insensitive to place memory (LaDage *et al.* 2012).

The point of the present section is not that grammar encodes the azimuth of the sun or the earth's magnetic field; these are 3P issues relevant to other animals, not to us. The point of this section is that all animals have rich 3P representations of their environment, based on their biological needs. Spatial relations among 3P objects are not the only 3P representations, of course, but they are well-studied and are common if not universal among animals.

For vertebrates it looks like such spatial mapping is inherited from our last common ancestor. Rodríguez *et al.* (2002) point out "that mammals, birds, reptiles, and teleost fish share a number of similar basic spatial cognition mechanisms, in particular, that all of these vertebrate groups have place memory capabilities, based on maplike or relational memory representations of the allocentric space" (p. 499); "the close functional similarity among the hippocampus of mammals and birds, the medial cortex of reptiles, and the lateral pallium of teleost fish suggest that early in the evolution of vertebrates, the medial pallium of an ancestral fish group that lived some 400 million years ago and gave rise to these extant vertebrate groups became specialized for encoding and processing complex spatial information, possibly as a navigational device that has been conserved through the evolution of each independent vertebrate lineage" (p. 502).

2.3.2. *What*

The maps our dorsal stream helps construct are populated by objects that are grammatically coded 3P. Psychologists and biologists tend to concentrate on actual *objects*, but of course language has many 3P referents that are not objects in any real sense: properties, emotions, relations, situations, events. And from a grammatical perspective, *3P is just 3P*, without any differentiation as to type (aside from gender, *q.v.* below). The most critical external 3P referents include predators, prey, and conspecifics, and there's reason to think that most or all animals process the world in terms of such categories.

The notion *conspecific* seems to be innate for reptiles (Suboski 1992: 75) and fish (Hawkins *et al.* 2004: 1250), but is a mix of innate and learned for birds and mammals. A well-known case is imprinting in young birds, who *can* imprint on a red box (learned) but have an innate predisposition to imprint on something that looks like their mother (innate, Bolhuis & Honey 1998). Birds raised by other species of birds generally prefer to mate with their *adopted* species, showing that avian conspecificity is more learned than innate (Irwin & Price 1999). In a study of cuckoos (brood parasites that lay their eggs in nests of other species that end up raising them), Soler & Soler 1999 introduced some nestlings into nests in pairs and others alone:

> When two cuckoos were introduced into the same nest, they behaved like cuckoos on leaving the nest. […] That is, they learnt to recognize their own species. When only one cuckoo was introduced per nest, at fledging they did not join a group, even when they met other cuckoo fledglings. […] Thus, these fledgling cuckoos did not recognize conspecifics when they were reared without any other cuckoo nestling in a nest where we experimentally prevented contact with adult cuckoos. (Soler & Soler 1999: 100)

An animal that recognizes conspecifics, innately or not, has 3P representations that divide the world up in a very specific way; conspecifics are of course the ideal 2P referents as well.

Predators form a special class of 3P representations that are innate in many species, as we know from our fear of snakes. Fear like this is intentional in the sense of being *about something* in the environment like a predator or dangerous conspecific, and it can tell us a great deal about the 3P representations an animal has. Silva *et al.* see

> 'fear' as a central state, which is induced when the subject perceives danger and that mediates bodily and behavioral responses to such danger. These responses include defense mechanisms that are necessary for the survival of the individual and can be observed in virtually all animal species. Fear responses are triggered by a variety of stimuli, including predators, aggressive members of the same species, pain, and dangerous features of the

> environment such as heights. Importantly, these types of stimuli strongly and systematically induce defensive behaviors and do not depend on the experience of direct harm associated with the threat nor on a learning process assigning a valence of danger to the threat. This type of fear is what has been referred to as 'innate fear'. (Silva *et al.* 2016: 544, references omitted)

If we want to know what it is like to be a bat, we should probably think of *fear*. Like much of an animal's 3P world, fear is driven not only by sight and sound but by smell: "Prey species belonging to many taxa, including birds and mammals, amphibians, reptiles and crustaceans, show an innate ability to recognise predator odour cues" (Hawkins *et al.* 2004: 1251, references omitted).

Pheromones regulate massive amounts of an animal's world, "including modulation of puberty and estrous; control of reproduction, aggression, suckling, and parental behaviors; individual recognition; and distinguishing of own species from predators, competitors, and prey" (Liberles 2014: 151). All of this implicates 3P in grammar, just as much as objects in the visual field do. Similarly for "other odor-driven behaviors, including responses to sickness cues, alarm pheromones, social dominance cues, nest pheromones, and odors that underlie the social transmission of food preference" (p. 167).

A good deal of 3P perception seems to be innate: "A considerable amount of evidence has been accumulated in the last century which suggests that all vertebrates, from primitive fishes to primates, are able to recognize important classes of stimuli, including visual objects, sounds and pheromones, with no previous experience of those types of stimuli" (Sewards & Sewards 2002: 861). Innateness is less of an issue for us than for frogs and toads, but it is there:

> In primate species, visual object recognition in early infancy is innate and entirely mediated by subcortical structures, and cortical visual areas are essentially non-functional. During the transition period, both the subcortical and cortical systems function, and thereafter only the cortical (learned) visual system operates overtly. This ontogenetic sequence mirrors the phylogenetic progression from the all-innate visual system of anurans to the dual system of birds and rodents, and ending in the all-cortical system of primates. (Sewards & Sewards 2002: 884)

Leaving vertebrates, insects also have innate object recognition. Innate prey recognition, for instance, has been shown experimentally for praying mantises (Prete *et al.* 2011) and jumping spiders (Dolev & Nelson 2014). The schemata involved are probably more a function of the prey than the predator:

> [S]imilar prey-recognition schema are used by animals with very different brains, for instance, amphibians, the amphibious fish *Periophthalmus koehlreuteri*, cuttlefish, and mantises. For all of these animals, objects that elicit appetitive behaviors are defined by their inclusion within a perceptual envelop that includes a variety of images all of which share some subset of certain key stimulus characteristics. (Prete *et al.* 2011: 891, references omitted)

3P representations are rich, varied, and common in animals, from insects to primates. Some of these are innate, even for primates, and some are learned, but the world apart from the *self* is well-mapped and well-populated.

2.4. Multiple Persons

Do animals distinguish 2P vs. 3P interactions? Evidence that they do comes from *triadic* interactions involving two animals (usually of the same species) engaged with each other and a third object (usually inanimate). It is clear, for instance, that "gorillas engage with conspecifics in collaborative social activities involving objects; when they do, they perform many types of behavior that in humans are criteria for triadic interaction and experience-sharing" (Tanner & Byrne 2010: 592). Special cases of triadic interaction that have been studied in humans and other animals are gaze following (*I look at what I think you're looking at*) and joint visual attention (*we both look at the same thing, and know it*), which simultaneously demonstrate 1P and 2P interaction with a 3P object. These seem to be much less common in the animal world than are simplex 1P, 2P, 3P. In a review, Itakura (2004) notes that there is positive evidence for gaze following and joint attention in primates (macaques, capuchin monkeys, gibbons, chimpanzees, orangutans, and gorillas), domesticated animals (dogs, horses), and some birds (jays).

Interestingly, no language grammatically marks {1P, 2P, 3P} in a way that is distinct from {1P, 2P} or {1P, 3P}. A few languages have morphemes that mark, for example, '1P acting upon 2P' or the like, as we find in the Penutian language Nez Perce. In (6) both subject (*boy*) and object (*fish*) are 3P and the portmanteau prefix *pée–* marks this directly (3/3); Crook glosses it as "third person acting on third person":

(6) *Nez Perce*

háacwàl–nim	cùy'éem–ne	pée–k'ùsmì–se
boy–ERGATIVE	*fish–OBJECT*	*3/3–fry–INCOMPLETIVE*

'The boy is frying the fish.'

(Crook 1999: 51)

Nez Perce has a number of suffixes that do the same thing; note that all of them pair exactly two arguments, and thus exactly two persons:

(7) *Nez Perce*

–k	LS/3S, LS/3P, 3S/LS, 3P/LS
–m	2S/LS, 2S/LP, 2S/3P, 3S/2S, 3P/2S, 2S/3S
–nm	3S/LP, LP/3S, LP/3P, 3P/LP
–pem	3S/2P, 2P/LS, 2P/3S, 2P/LP, 2P/3P, 3P/2P
–mek	LS/2S, LP/2S
–pem mek	LS/2P, LP/2P

(Aoki 1970: 130, notation changed slightly)

The Aymaran language Jaqaru has a similar system (Hardman 2000: 57). What seems to be lacking in the grammars of the world are portmanteaux for three persons. A possible reason for this is that the triadic cognition is too phylogenetically recent to have been coded into grammar. (Another is that ditransitives and causatives are just too rare to get their own portmanteaux).

Evidence that animals actively differentiate 1P, 2P, and 3P in the same activity comes from the study of animal play. Burghardt (2010: 340) distinguishes three types of play: "Play in animals means solitary (or parallel) locomotor-rotational play (jumping, leaping, twisting, swinging, running), object play (carrying, dropping, manipulating, biting, mouthing), and social play (chasing, wrestling)". Grammatically speaking, solitary play is 1SG; object play combines 1P and 3P; social play is 1P and 2P—it involves conspecifics, and is often both dyadic and reciprocal. Play has been demonstrated in many monkeys, kangaroos, birds, lizards, and fish and is particularly well-studied in dogs, both feral and domesticated (see Hamon-Hill & Gadbois 2013 for a brief review with respect to 2P). Burghardt stresses that play itself is probably not derived from a common ancestor (p. 347), though this does not affect whether 1P, 2P, 3P are.[4]

Summarizing, it seems that 1P and 3P are evolutionarily quite old and shared not only with vertebrates but with animals generally. A precursor to 1P proper may be found generally in beings with immune systems, as these require the *self-referencing* of Bekoff & Sherman (2004). This may be the case for 2P as well, as seems likely when we consider its connection with conspecificity, which is a broadly shared concept among animals. If it is limited to *social* animals, 2P is much more recent in our lineage and has most likely evolved separately among social insects, birds, and mammals. Placed on a tree of life, the pre-cursor to 1P (*self-referencing*) might go back to the LCA of bacteria, archaea, and eukaryota, all of which have immune systems that differentiate *self* from *other*. 1P proper (*self-awareness*) is likely restricted to *animalia*:

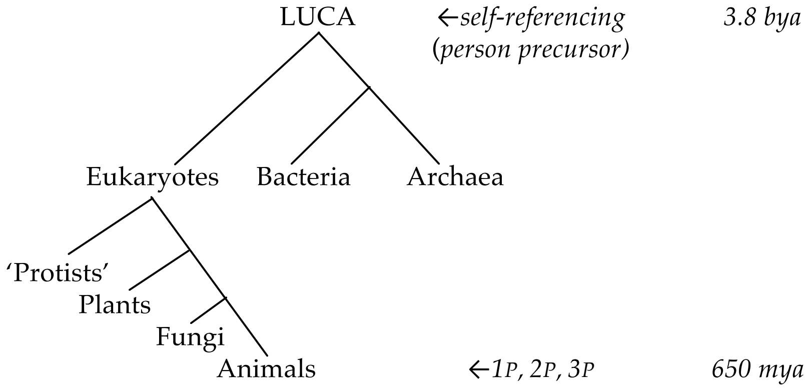

Figure 1: Possible age of person *('Protist' is shown as a group for simplicity).*

3. Number

Grammar has two ways of dealing with amounts, a delicate counting metric used only for small countable quantities, traditionally known as number, and a coarse *more/most* metric used for things that are not countable for some reason. Ancient Greek had simple ways of marking both:

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[4] It is not clear how common social play with an object is; a study of dog–dog and dog–human play found that dog–dog play with an object is much less common than dog–human play with an object (Rooney *et al.* 2000: 246).

(8) *Ancient Greek*

	‘citizen’	‘soldier’	‘son of Atreus’
singular	polí:t–e:s	stratió:t–e:s	atreíd–e:s
dual	polí:t–a:	stratió:t–a:	atreíd–a:
plural	polî:t–ai	stratiô:t–ai	atréid–ai
	‘wise’	‘small’	‘terrible’
positive	sopʰ–ós	mi:kr–ós	dein–ós
comparative	sopʰ–óteros	mi:kr–óteros	dein–óteros
superlative	sopʰ–ótatos	mi:kr–ótatos	dein–ótatos

I will try and show in this section that number and comparatives correspond closely to the two ways animals deal with quantity.

Human numeracy is thought to come in two types, both of them inborn:

> Two non-verbal cognitive systems allow for numerical abilities before educational instruction (see Feigenson, Dehaene, & Spelke, 2004 for review). One, the approximate number system (ANS), allows us to mentally represent, compare, and compute over sets of items on the basis of their approximate numerical magnitude (e.g., Dehaene, 1997). The other, the parallel individuation system (PI), draws on attention and working memory resources to differentiate, track, and remember a limited number of individual items simultaneously (~3 or 4). […] Both systems are present from infancy, are shared with a wide variety of non-human animals, arise from distinct cortical regions, and are characterized by distinct brain and behavioral signatures (Feigenson *et al.*, 2004; Hyde, 2011). (Hyde *et al.* 2017: 1)

The semantics behind these two core number systems are shared for human and non-human animals.[5]

What most animals seem to lack is the successor principle (*x is one more than y*), the notion that allows humans to count (Carey 2009; Spelke 2011; Brannon & Park 2015). It is likely significant that *grammar* has no way of marking this notion: I know of no morpheme in any language that means ‘is one more than’. Grammar seems to mark only those concepts that predate our species and the successor principle is not one of them.

3.1. *Comparatives and Superlatives*

All languages have some way of comparing, usually called *comparative* and *superlative*, e.g., English *–er* and *–est*, or the Greek forms cited above. These are not generally treated as *ϕ -features* in syntax and morphology, in part because they do not seem to be involved in agreement: I am unaware of any language in which verbs agree with adjectives in terms of comparative or superlative morphology, though this may just be my ignorance. Still, comparison is basic to the grammatical systems of most languages and its semantics is usually straightforwardly *more* x, *most* x whether countable (*worms, rocks*) or not (*milk, truth*). The exact gramma-

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[5] This is not to suggest that the human mathematical ability is derivative from language, as Chomsky (2007: 7) has suggested. See Amalric & Dehaene (2010) for the refutation.

tical mechanisms behind comparison are much more diverse than one might expect (Bobaljik 2012; Stassen 2013), though this need not concern us here.

There is broad agreement on the existence of relative quantity judgments in animals, roughly *more/most*, attributed to an Approximate Number System (ANS) they seem to share with us. The ANS may operate on small quantities but most of the evidence for it comes for quantities greater than 3 or 4, with no upper limit, and for comparisons of mass, intensity, loudness, etc. It works in accordance with Weber's Law, which is based on ratios; the larger the ratio, the easier it is to discriminate, so that the difference between 4 and 5 is easier to appreciate than the difference between 14 and 15.

Evidence for an ANS is widespread in animals and comes in various forms. Many studies make use of how animals advance or retreat before larger groups of predators or angry conspecifics, which allows for careful manipulation in experimental settings. McComb *et al.* (1994), for instance, looked at how relative group size affects female lions' decision to approach intruders from another pride. Roars of female lions from other prides were recorded singly or in choral groups of three and replayed via amplifiers hidden in bushes. Some lions heard the roar of a single intruder, others heard the roars of three; some lions were alone or in small groups when they heard the intruders, others were in larger groups. Defenders in small groups were less likely to approach larger groups of intruders and when they did approach them, they did so more slowly, with more pauses, and with more looking at one another than when they approached smaller groups. Mathematically, the

> [n]umber of defending adult females and number of intruders could also be replaced with the single variable 'odds', calculated as the ratio of number of defenders to number of intruders, to produce an equivalent model explaining 60.4% of the deviance in probability of approach. Adult female defenders without dependent offspring preferred odds of 2:1 before approaching, while those with cubs were considerably more likely to approach.
> (McComb *et al.* 1994: 383)

Similarly, "free-ranging dogs are able to assess relative group size in intergroup conflicts and to use this information adaptively: dogs of the packs studied were more likely to approach aggressively opposing packs when the ratio of the number of opposing pack members present to the number of focal pack members present was lower, and were more likely to withdraw from a conflict when the ratio of the number of opposing pack members present to that of the focal pack members present was higher" (Bonanni *et al.* 2011: 111).

Animals choose larger amounts of food over smaller amounts, and this too can be used for determining how they quantify things. In a careful quantitative study, two elephants

> successfully selected the larger of two sets of food items, even when both sets were only presented one item at a time and could not be viewed as an entire set, and thus, the elephants needed to represent the summed total for each set. This confirms that elephants can perform relative quantity judgments. (Perdue *et al.* 2012: 959)

Utrata *et al.* (2012: 8) found "that wolves are able to make quantitative judgments even when alternative strategies such as paying attention to non-numerical properties such as the surface area or time and total amount are ruled out". Vonk & Beran (2012: 237) found that "it is easier for bears to choose the larger amount rather than the smaller amount, even with two dimensional abstract stimuli, and even when they are reinforced for choosing the smaller amount'". And as Ward & Smuts (2007: 71) point out, "[n]atural selection should favor optimal decision-making, but animals must first compare in order to optimize".

Fish seem to have an ANS as well: They prefer large groups to small and choose which group to swim with ('shoaling') based on approximate group size (Agrillo & Dadda 2007). In a typical shoaling experiment (e.g., Agrillo *et al.* 2008, using mosquitofish), a fish is put into the center of a sectioned tank; one end of the tank has two fish and the other end has three, separated from the decider fish by transparent walls. The question is which group the fish in the middle swims toward. Experiments differ in the number of stimuli fish the decider sees (1 *vs.* 2, 2 *vs.* 3, etc.), their size, length, amount of area they cover, how fast they swim, and so on. Agrillo *et al.* used shoaling to compare the mathematical abilities of guppies (*Poecilia reticulata*) with those of undergrads:

> When tested in the same numerical tasks, the students and guppies showed almost identical performance patterns. In both species, the ability to discriminate between large numbers (>4) was approximate and strongly dependent on the ratio between the numerosities. In contrast, in both fish and students, discrimination in the small number range was not dependent on ratio and discriminating 3 from 4 was as easy as discriminating 1 from 4.
> (Agrillo *et al.* 2012: 6)

Reptiles are somewhat understudied with respect to number, but Soldati *et al.* (2017) trained red-footed tortoises (*Chelonoidis carbonaria*) to associate visual cues with more/less food and better/worse food and found that they retained the associations for eighteen months: "This suggests that tortoises can remember the relative value of a reward, and not just its presence or absence, for a period spanning seasons and significantly longer than previously found in hoarder species" (p. 3).

Using various experimental designs (Agrillo *et al.* 2014), support for an ANS has been found in salamanders (Krusche *et al.* 2010) and in birds, including robbins (Hunt et al 2008), parrots (Al Aïn *et al.* 2009), and crows (Ditz & Nieder 2016); see Agrillo (2015) for an overview. The Weber effect in these animals is similar to that found in humans (Revkin *et al.* 2008) and other primates (Beran 2004; Cantlon & Brannon 2007), suggesting that the semantics are the same.

As with comparatives in grammar, the ANS is not restricted to number proper but is also used in comparing things like area (Brannon *et al.* 2006) and time (van Marle & Wynn 2006), which animals are unlikely to compute in strictly numerical terms; see Feigenson (2007) for discussion. Krusche *et al.*'s (2010) work with salamanders suggests that *amount of movement* can be responsible for determining quantity differences as well. So the ANS is a way of determining magnitude rather than number *sensu stricto*—again, it is the vertebrate equivalent of *more*/*most*. The evolutionary roots of the ANS are deep and clear:

> Even the most elementary of organisms [...] are confronted with a never-ending search for the best environment with the most food, the fewest predators, the most partners of the opposite sex, and so on. One must optimize in order to survive, and compare in order to optimize. (Dehaene 1997: 24)

Based in part on the ability of cotton-top tamarins to discriminate number in the absence of training, Hauser *et al.* (2003: 1445) conclude that "humans are not the only species that is spontaneously attentive to number, and that at least part of our non-symbolic system derives from an evolutionarily ancient computational mechanism". More specifically,

> the mental number line seems to be logarithmic rather than linear, and not just in primates, but across vertebrates. It suggests that this way of coding numerical information has evolved based on convergent evolution, because it exhibits a superior solution to a common computational problem.
> (Ditz & Nieder 2016: 8)

3.2. *Number Proper*

There are a lot of numbers out there but grammar marks only three: *singular, dual, trial.* Anything more is just *plural.* Aside from *plural,* the commonest number is *singular,* followed by *dual. Trial* is cross-linguistically rare, but found in Larike (Laidig & Laidig 1990), Wunambal (Dixon 2002:246), and Urama:

(9) *Urama*

	singular	*dual*	*trial*	*plural*
1P	mo	nimoiti	nimoibi	nimo
2P	ro	rioiti	rioibi	rio
3P	nu	niti	nibi	ni

(Brown *et al.* 2016: 20)

Verbs in Urama agree in number with their subjects, showing that the grammar proper makes use of it (from Brown *et al.* 2016: 27):

(10) a. Nu nahuai abodo ka.
3SG song sing PRESENT
'S/he is singing a song.'

b. Niti nahuai abodo ka=ido.
*3**DU** song sing PRESENT=**DU***
'They both are singing a song.'

c. Nibi nahuai abodo bi=ka=umo.
*3**TR** song sing **TR**=PRESENT=PL*
'Those three are singing a song.'

d. Ni nahuai abodo ka=umo.
*3**PL** song sing PRESENT=**PL***
'They are singing a song.'

No affix in any language marks 4 things, or 5, or 6.[6] These lie beyond grammar, presumably because they lie beyond vertebrate mathematics.

Corbett (2012: 120ff.) argues that apparent quadrals are actually *paucals* of which he distinguishes two kinds, one ≅ 3 (*paucal* proper), the other ≅ 4 (*greater paucal).* Such a distinction (singular/dual/paucal/greater paucal/plural) is found in Sursurunga (Hutchisson 1986); Corbett (2000) claims that a five-way number distinction like this is as much as any language allows. He also distinguishes a rare *greater plural,* which "may imply an excessive number or else all possible instances of the referent" (Corbett 2012: 120, citing Ojeda 1992 on Arabic). So it seems that 1/2/3 are the only precise *number* categories human languages mark grammatically, with one or two additional categories of *paucal* and *greater plural*, but nothing specific past 1/2/3, where numbering gives way to *more/most*, the domain of the ANS.

Hurford (1987: 111) notes that the "domain of grammatical number systems […] corresponds very closely to the very low numerosities which are recognizable by subitizing". Subitizing is the immediate apprehension of the exact number of items in small sets and tops out at 3~4 in vision (Kaufman *et al.* 1949), audition (Camos & Tillmann 2008), and touch (Riggs *et al.* 2006) for humans. Hurford notes that the 3~4 number in subitizing is also found in the number of arguments taken by a verb (2007: 88ff), linking it directly to grammar. Subitizing 3~4 objects is thought to be driven by short-term memory, also limited to 3~4 things (Cowan 2001); Cutini & Bonato (2012) link it specifically to visual short term memory in humans and other animals.

What does subitizing correspond to in animal cognition? A great deal of work has been done since Koehler (1951) reported that crows can count and "there is evidence that a (non-verbal) distinction between singular and plural is available to animals" (Stancher *et al.* 2013: 308). More generally, grammatical number corresponds very closely to the 'object-file system' (OFS) or 'parallel individuation' system (PI) found in infants and reported for a number of vertebrate species. The ability to subitize 3~4 items has been reported in chimps (Tomonaga & Matsuzawa 2002) and monkeys (Hauser *et al.* 2000; Beran *et al.* 2011; Elmore *et al.* 2011). The Hauser *et al.* study involves rhesus monkeys watching apple slices get put into a number of opaque containers. Importantly, they never see all of the slices at once and therefore cannot get the result simply by subitizing; they must *count* the apple pieces.

> The monkeys chose the container with the greater number of apple slices when the comparisons were one versus two, two versus three, three versus four and three versus five slices. They failed at four versus five, four versus six, four versus eight and three versus eight slices. (Hauser *et al.* 2000: 829)

These monkeys seem to code *singular, dual, trial, plural,* just like the grammars of Larike, Wunambal, and Urama. Similar results have been reported for a number of species of birds (Rugani *et al.* 2008; Hunt *et al.* 2009; Garland *et al.* 2012) and fish.

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[6] Baker-Shenk and Cokely (1996) claim that ASL has grammatical marking for 1–5, but 4 and 5 seem to be morphological compounds: 'You-four come over here!'.

In a shoaling experiment, Gómez-Laplaza & Gerlai (2011: 572) report that "the capacity shown by angelfish closely matches that attained by other fish species, in which the upper limit of spontaneous discrimination for small quantities seems to lie at three elements". The experiments in Dadda *et al.* (2009) involve sequential presentation of stimuli to mosquitofish, holding area constant so they have to rely on pure quantity. The results mirror those of the monkeys in Hauser *et al.* 2000: "[U]sing a method of 'item by item' presentation, we have provided the first evidence that fish are capable of selecting the larger group of social companions relying exclusively on numerical information" (Dadda *et al.* 2009: 346). Moreover, their findings suggest

> that mosquitofish can rely on multiple cues to estimate numerosity and that the preferential access to the numerical information over the non-numerical may be task- and context-dependent. To discriminate which of two mosquitofish shoals is more numerous is likely to be a complex endeavour. The fish within the shoals may be spaced out and often not simultaneously visible, fish frequently move within the shoal, can change orientation and occlude each other. In this condition it may be advantageous to encode multiple attributes of the stimulus (number, area, movement, etc.) and base number estimation on different combinations of cues depending on contextual variables such as structure of the environment, time available for choice, numerosity and numerical ratio of items. Indeed, recent studies on humans and non-human primates suggest that this may be a common situation. (Dadda *et al.* 2009: 347)

Utrata *et al.* (2012: 1) show that "wolves are able to make quantitative judgments […] even when alternative strategies such as paying attention to non-numerical properties such as the surface area or time and total amount are ruled out", though the authors were unable to determine whether this was due to a (*more/most*) approximate number system or to a (*singular/dual/trial*) object file system.

Agrillo *et al.* report on the ability of fish to discriminate smaller numerical differences (2 items from 3) in fish:

> Our experiments show that the ability of mosquitofish to discriminate among sets containing a different number of elements is not limited to the socio-sexual context […] but also applies to sets of abstract elements. They also indicate that mosquitofish can accomplish this task when all non-numerical perceptual variables are matched between the stimuli, thus strongly suggesting that teleosts [bony fish that can protrude their jaws, a class most fish fall into—CG], like mammals, possess true counting abilities, at least in the domain of small numbers. (Agrillo *et al.* 2009: 3-4)

In the article showing both ANS and OFS counting in undergrads and guppies, they suggest that "the evolutionary emergence of numerical abilities may be very ancient, possibly dating back to before the teleost-tetrapod divergence" about 400 mya (Agrillo *et al.* 2012: 7; cf. Piffer *et al.* 2012).

Reptiles have only recently been studied in terms of numerical abilities and the results are currently too mixed to draw any firm conclusions from. Petrazzini *et al.* (2017) found that ruin lizards (*Podarcis sicula*) were better at discriminating size than number, while a follow up study found essentially the reverse: Some lizards were able to discriminate number, but none was able to discriminate the area of two items (Petrazzini *et al.* 2018). They conclude that the "poor performance observed here using a methodological approach commonly used in other vertebrates, might suggest a limit in ruin lizards' quantitative skills, although we cannot exclude other factors that affected their accuracy' (Petrazzini *et al.* 2018: 5).

Invertebrates also show mixed results. A recent review concludes that bees and possibly other insects have basic numerical cognition to 3~4, but notes that there is as of yet no evidence for an ANS in insects (Skorupski *et al.* 2017: 7).

3.3. Number Bound with Person

Person and number have a close affinity in language: most of the world's pronouns are simple portmanteau combinations of the two, as the following show, from White Hmong:

(11) *White Hmong*

	singular	*dual*	*plural*
1P	kǔ	ɨ̂	pé
2P	kô	né	ně
3P	nɨ̀s	nkàɨ̂	làɨ̂

Surprisingly, perhaps, there is evidence that person and number bind together in animal cognition as well. Group decision making among social animals suggests that 1P can bind to dual and to plural. In the philosophical literature on humans the problem of such 'plural selves' is shown by the many terms for it including *shared cooperative activity* (Bratman 1992) and *plural subjects:* "One is willing to be the member of a plural subject if one is willing, at least in relation to certain conditions, to put one's own will into a 'pool of wills' dedicated, as one, to a single goal (or whatever it is that the pool is dedicated to)" (Gilbert 1989: 8).

Despite the ontological difficulties they create, 1PL decisions are made by many types of mammal including bats, canids, cetaceans, primates, and ungulates. For a herd to leave a feeding or drinking area, for instance, or for predators to coordinate their actions in hunting, requires group decisions: No animal constitutes a herd or a pack on its own. African wild dogs are a case in point: They require a *quorum* to leave for a hunt and signal their vote by sneezing. These

> sneezes, a previously undocumented unvoiced sound in the species, are positively correlated with the likelihood of rally success preceding group movements and may function as a voting mechanism to establish group consensus in an otherwise despotically driven social system. […] Our results contribute to a growing trend in the literature that finds voting mechanisms and quorum thresholds used in decision making processes across taxa.
>
> (Walker *et al.* 2017)

Group decisions are also made by flocks of birds, for example, when thousands of starlings shift midflight in response to a falcon and the response-wave propogates across the flock at a rate quicker than individual starlings can fly (Procaccini *et al.* 2011). In modeling how the members of a flock distribute themselves with respect to patches of food, Farine *et al.* (2014: 177) found that their "great tits relied more heavily on the decisions of conspecifics than heterospecifics", obeying the rules 'avoid sites below one-third' for conspecifics and 'avoid sites below one-half' for heterospecifics; this shows that the internal composition of 1P is important as well. Pettit *et al.* (2013) show how pairs of homing pigeons follow flight paths that are a compromise of those each has separately learned earlier, and at speeds that are a complex compromise of the normal speeds of each bird.[7]

1PL decisions are made by fish as well in shoaling behavior, when they group together with other fish, usually conspecifics. Sumpter *et al.* (2008) show, for instance, how small groups of sticklebacks collectively decide which leader to follow and show that larger groups make better decisions than smaller groups (in picking better looking leaders), explaining in part how group decision making evolves via natural selection:

> The quorum-response rule provides a simple and effective way of integrating information. Individuals watch the decisions of others before committing themselves to a decision. (Sumpter *et al.* 2008: 1776)

School size in shoaling behavior during spawning and migration can range to 250 million herring and span as far as 40 kilometers, through which a quorum decision wave can propogate in only tens of minutes (Makris *et al.* 2009); as in grammar, the exact number of 'plural' is irrelevant.

Social insects also make 1PL group decisions, including ants (Cronin & Stump 2014) and cockroaches (Amé *et al.* 2006). In bees, "a swarm's choice of a future home is broadly distributed among the scout bees, and […] this leaderless process of group decision-making consists of a friendly competition among the different groups of dancers representing the different potential nest sites" (Seeley & Visscher 2004: 104). Such behavior seems to involve the same 1PL representation as that found in grammar: *self plus some number of others*, usually conspecifics.

A possible precursor to group decision making in animals is found in bacteria (Waters *et al.* 2005), archaea (Charlesworth 2017), and fungi (Sprague & Winan 2006). It goes under the name *quorum sensing* and can come about where members of a colony need to do something in unison that no single cell organism can do on its own, like form a biofilm. Our mouths have millions of bacteria, for instance, which our immune system usually copes with; but the bacteria can join together and form a hard biofilm (plaque) that makes them nearly impossible to kill. Some bacteria can bioluminesce when they occur in great density and famously use this in a symbiotic relation with Hawaiian squid they live inside.

> [Their] environmental sensing system […] allows bacteria to monitor their own population density. The bacteria produce a diffusible compound termed autoinducer which accumulates in the surrounding environment during growth. At low cell densities this substance is in low concentration, while at high cell densities this substance accumulates to the critical concentration required for activation of luminescence genes. (Fuqua *et al.* 1994: 269)

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[7] Though the study involves only pairs of birds, it was designed to show flock behavior for any number of birds; this is not special dual behavior.

Quorum sensing like this allows single-cell organisms to function together somewhat like a multi-cell organism and may facilitate their actions as social beings: '[W]hereas bacteria have traditionally been thought of as simple, single-celled organisms, we now know that bacterial populations and communities commonly exhibit complex behaviors such as intra- and interspecific communication, kin discrimination, and cooperation" (Platt & Fuqua 2010: 386). Quorum sensing is a crucial part of this communication and cooperation.

When multiple bacterial species exist in the same environment "each species can distinguish, measure, and respond only to the buildup of its own signal" (Waters & Bassler 2005), so that quorum sensing can serve as a cell-to-cell communication system within bacterial species as well as across them (Xavier & Bassler 2003). Though we should not take the term too literally (Platt & Fuqua 2010), quorum sensing might well be a precursor to the approximate number system found in animals.

1DUAL decisions are also reported in animal cognition, though there is no evidence I know of that these are necessarily treated as separate from 1PL decisions. They go under the name *conspecific cooperation tasks* and require two animals to work together to solve a task that neither can solve alone. A rope pulling task that requires two animals to cooperate to get a reward (Drea & Carter 2009, hyenas) "has been used with a wide range of species, from ravens to elephants [chimpanzees, macaques, elephants, gray parrots, rooks, ravens, kea, and dogs], with many succeeding in solving the task after being initially trained individually to pull the tray out by pulling both ends of the rope together" (Marshall-Pescini *et al.* 2017: 11793, references omitted). Such tasks bind 1P and 2P into a 1DU inclusive, *you and I*, just as the group decision tasks above bind 1P and 2P into a 1PL inclusive. I know of no evidence in animal cognition for 1P combining with 3P to form a dual or plural *exclusive* of 2P, though I think the question has not been raised.

Summarizing, it seems that the exact numerical system of grammar (*singular, dual, trial*) is matched by the 'object-file system' or 'parallel individuation' system found in pre-linguistic infants and many vertebrates (modulo reptiles, where the results are not yet in). This vertebrate system may have developed from an earlier and less sophisticated system like the ones we see in invertebrates or the quorum sensing found archaea, bacteria, and fungi.

3.4. Zero

No language to my knowledge has an affix indicating zero number. It is easy to imagine a language where zero is marked distinctly from singular, dual, and plural. Consider such a made-up language—'Pseudo-Greek', by adding a zero row to the Greek pattern from (8) above:

(12) *Pseudo-Greek*

	'citizen'	'soldier'	'son of Atreus'
zero	*polí:t–e:*	*stratió:t–e:*	*atreíd–e:*
singular	polí:t–e:s	stratió:t–e:s	atreíd–e:s
dual	polí:t–a:	stratió:t–a:	atreíd–a:
plural	polî:t–ai	stratiô:t–ai	atréid–ai

In Pseudo-Greek, *políːt–eː* would mean ‘no citizen’ and a verb that agrees with it might show agreement distinct from singular, dual, and plural agreement. Again, no such language exists as far as I can determine. In actual Greek, zero counts as grammatically *singular*, as we can see with the agreement on the verb:

(13) oud–éìs ekoiméːtʰ–e
*not–one slept–3*SG
‘noone slept’

The same obtains in English, where the verb in *noone sleeps* is 3SG. Grammar treats *noone, nobody,* and *nothing* as *less than two*: We find *noone is here, nobody is coming, nothing is worthwhile*. That is, grammar treats homespun words for zero as part of the ANS, where they are less than two, three, four, etc. Grammar does not treat these words as a special category alongside *singular, dual, trial,* that is, as part of the object-file system.

Historically, the notion *zero* is a recent mathematical discovery from 7th century India and languages that have borrowed this word treat it like 2, 3, or 4: *Zero children are here, *Zero child is here*. Languages may have a (borrowed) *word* for zero, but there is no grammatical category for it; it is just one of the things less than two. (For a formal analysis of the difficult semantics of *zero*, see Bylinina & Nouwen, to appear.)

Animals also seem to treat zero as nothing rather than as zero in the mathematical sense. The facts are not decisive (or many), but they are suggestive. Brannon *et al.* (2009) provide experimental evidence that monkeys have a *precursor to zero* based on the approximate number system discussed earlier. In one experiment, monkeys were able to match empty sets to empty sets, just as they were able to match sets of 2 to sets of 2, or sets of 6 to sets of 6; and when they did so they showed distance effects, such that an empty set was less likely matched to a set of 6 than to a set of 2. This is a more/most effect. In a second experiment, monkeys were taught to order smaller and larger sets; when they were tested on empty sets they tended to treat them as smaller than sets of 1, 2, 3…9. They summarize their results: “Overall, these findings demonstrate that the ANS can support representations of empty sets and these representations may serve as a precursor for the ability to represent symbolic zero” (Brannon & Merritt 2011: 215).

The same has been found for honey bees, using a task in which honey bees were taught the notions ‘greater than’ and ‘less than’ and then had to apply them to novel situations that included the empty set, e.g., to rank an empty visual set as less than one that contained one or more dots.

> Our findings show that honey bees can learn and apply the concepts of greater than and less than to interpret a blank stimulus as representing the conceptual number of zero and place zero in relation to other numerical values. Bees thus perform at a level consistent with that of nonhuman primates by understanding that zero is lower than one.
>
> (Howard *et al.* 2018: 1126)

This supports an ANS in monkeys that can compare empty sets with larger sets, a ‘precursor’ to the full idea of zero. If animals lack the full ability to represent symbolic zero they may be in line with human grammar, which lacks means for expressing zero as well.

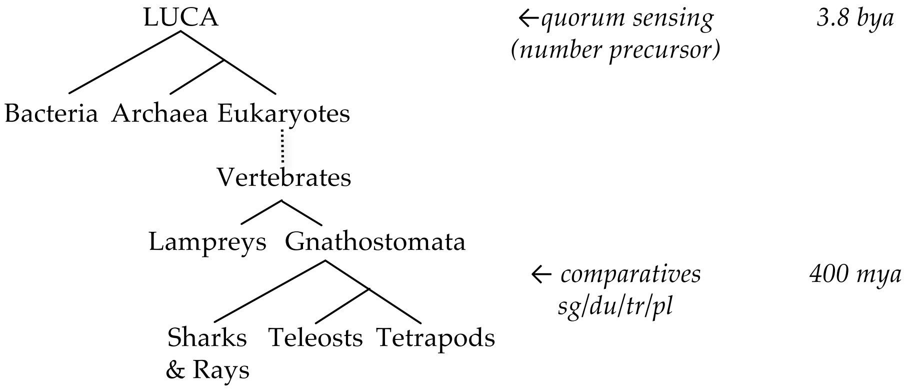

Figure 2: Possible age of number.

4. Gender

Morphologists generally use the term gender to mean 'kind', as befits its Latin root, and it is usually abstract, so that all nouns are shoe-horned into categories based on a few semantic categories. Most languages do not distinguish different kinds of noun, but those that do use one of two criteria:

> From our sample, of the languages with a gender system, the majority—84—have sex-base gender systems, compared with 28 with systems with the other possible basis, namely animacy. This is a remarkably clear result, with a surprising disjunctive pattern: gender systems are based on sex or on animacy. (Corbett 2012: 113)

4.1. Sex-Based Gender

Up to a third of languages grammatically encode gender systems based on the sex of the referent, with inanimates assigned randomly to the male or female class. As Dahl points out:

> The pervasiveness of sex as gender criterion is striking. There are many possible ways of classifying animates, in particular human beings, that might be used as a basis for gender, such as social status, ethnic origin, profession, age, hair color, etc. but none of them except perhaps age seems to play any important role in gender assignment. (Dahl 2000: 102)

If grammatical categories marked what was important to people, we might expect genders based on profession, age, and hair color. But such categories are lacking in grammars of all languages, probably because they are not deeply enough embedded in the representational systems we share with most vertebrates: Only pieces of this system seem to be coded grammatically.

Ancient Greek can again serve as an example of how a language assigns words to genders. Words with male referents (*man, boy*) in Greek are almost always grammatically masculine, words with female referents (*woman, girl*) are almost always feminine: This makes it a sex-based gender system and words like *anḗr* 'man' and *gúnē* 'woman' are said to have 'natural gender'. Words with sexless referents (*speech, island, wall,* etc.) can be of any grammatical gender and some diminutives (*manikin, child*) are grammatically neuter even though they have male or female referents.

(14) *Ancient Greek*

masculine	anḗr 'man'	kóuros 'boy'
	pátrōn 'uncle	huiós 'son'
	lógos 'speech'	háls 'salt'
	ánemos 'wind'	dáktylos 'finger'
feminine	gúnē 'woman'	kórē 'girl'
	tʰeía 'aunt'	tʰugátēr 'daughter'
	nêsos 'island'	náus 'ship'
	pétra 'rock'	sîgma 'letter S'
neuter	téikʰos 'wall'	álgēma 'pain'
	hydōr 'water'	álpʰa 'letter A'
	antʰrṓpion 'manikin'	gúnaion 'little woman'
	teknon 'child'	andrápodon 'captive'

(Smyth 1920: §197)

Other elements in the noun phrase agree with the noun in gender, a grammatical phenomenon known as *concord*:

(15) a. ekéin-**os** kóur–**os** esti kʰarí–**eis**
DEM–MASC boy–MASC is elegant–MASC
'That boy is elegant.'

b. ekeín-**ē** kór–**ē** esti kʰarí–**essa**
DEM–FEM girl–FEM is elegant–FEM
'That girl is elegant.'

c. ekéin-**o** eídōl–**on** esti kʰarí–**en**
DEM– NEU phantom–NEU is elegant–NEU
'That phantom is elegant.'

Animals presumably have no *grammatical gender* because they presumably have no nouns or adjectives. The question here though is whether they process sex and animacy in their lives. The sex part is simple: Plants and animals that reproduce sexually obviously process information about male and female; sex goes back to the last common eukaryote (Goodenough & Heitman 2014). Most animals and all vertebrates reproduce sexually, a point I will not belabor, so male and female are very old categories; neuter is as well, if only by default.

More surprising is that partner preference is not marked grammatically in any language. Grammar never marks who you prefer to have sex with, or even whether you have sex, just whether you are biologically male or female. This despite the clear importance of sexual preference to most people. It is not clear how sexual preference works in animals: “Spontaneous homosexual behaviour, defined as exclusive same-sex sexual preference, appears to be rare in animal species despite the fact homosexual behaviours (mounting or being mounted by a subject of the same sex) are frequently seen in hundreds of species when congeners of the opposite sex are not (easily) available” (Balthazart 2016: 4). For homosexual practice in the animal kingdom generally, see Bagemihl (1999). In any case, the rich notions of sex that humans deal with are ignored by grammar, which treats sex as a simple binary opposition, more along the lines of how other animals seem to treat it.

4.2. *Animacy-Based Gender*

Animacy is the other common grammatical gender, though animacy proper is often conflated with whether something is human or not (Ortmann 1998). Clear cases of grammatical animacy are well-studied in Algonquin languages, where all nouns are either animate or inanimate grammatically. Blackfoot noun roots serve as illustration. While some grammatically animate nouns (*knee, wagon, aspen*) are inanimate in the real world, all things that are animate in the real world are grammatically animate:

(16) *Blackfoot*

animate	ninaa ‘man’	aakii ‘woman’	omitaa ‘dog’
	mottoksis ‘knee’	áinaka’si ‘wagon’	siikokiína ‘aspen tree’
inanimate	awó’taan ‘shield’	naapioyis ‘house’	miistak ‘mountain’

(Wiltschko & Ritter 2015: 873)

The grammatical relevance of animacy shows up in how plurals are marked, *–iksi* for animates, but *–istsi* for inaminates. Note that the demonstrative agrees with the noun it modifies:

(17) a. om–**iksi** saahkomaapi–**iksi** iik–sspitaa–yi–aawa
DEM–PL boy–PL INTNS–be.tall.AI–PL–3PL.PRN
‘Those boys are tall.’

b. om–**istsi** naapioyis–**istsi** iik–sspii–yi–aawa
DEM–PL house–PL INTNS–be.tall.II–PL–3-PL.PRN
‘Those houses are tall.’

(Bliss 2013: 31)

Humans can tell biological motion from non-biological motion even with just limited points of light to represent it (Johansson 1973), so the animacy in grammar draws on part of our biology. The ability to detect animacy is innate in humans and is not limited to detecting humans:

> [N]ewborn babies are able to discriminate between two different point-light displays depicting either biological motion or nonbiological (random)

> motion and they manifest a spontaneous preference for the biological motion display even if it depicts an unfamiliar shape such as a walking hen. Even more interestingly, the results demonstrated that the preference for biological motion was orientation specific. Newborns were shown to prefer upright compared with inverted biological motion displays.
> (Simion *et al.* 2008: 811)

The ability to pick out animates is also innate in newborn chicks, who prefer film clips of lights strapped to walking hens over film clips of lights strapped to hens that twirl around rigidly or of lights moving about randomly:

> Intriguingly, the preference was not specific for the motion of a hen, but extended to the pattern of motion of other vertebrates, even to that of a potential predator, such as a cat. The predisposition found in the present research for certain kinds of movements shares characteristics in common with the predisposition for aspects of form. […] Visually inexperienced chicks prefer the head and neck region of a hen to artificial objects. Similar to this preference for form, the preference for movement is not species specific. Evolution seems to have equipped the visually inexperienced bird with a sophisticated set of detection systems. (Vallortega 2005: 1312)

Similar experiments have found this detection system in a number of vertebrate species including cats (Blake 1993), bottlenose dolphins (perhaps, Herman *et al.* 1990), female marmosets (Brown *et al.* 2010), and fish (Nakayasu & Watanabe 2014, Schluessel *et al.* 2015). Troje & Westhoff found that for some animals this is related to the perception of moving *feet.* They tentatively

> argue for an innate and possibly evolutionary old mechanism that the human visual system shares with other animals. The observation that it is relatively easy to get close to wild animals in a car, a canoe, or a similar vehicle might be due to the absence of the typical movement of feet. Similarly, the creeping movement of a hunting cat can be interpreted in terms of disguising the ballistic component in its locomotion. Our findings about the role of the feet as a cue to the direction of motion of scrambled point-light displays support the notion of such a general 'life detector'.
> (Troje & Westhoff 2015: 823)

Such abilities in various species support "the hypothesis that detection of biological motion is an intrinsic capacity of the visual system, which is presumably part of an evolutionarily ancient and non-species-specific system predisposing animals to preferentially attend to other animals" (Simion *et al.* 2008: 809).

Some animals clearly detect *conspecific* motion. Japanese rice fish (medaka, *Oryzias latipes*), for instance, only shoal and school with conspecifics and thus must be able to detect them. It has been shown that they can recognize conspecifics from biological motion alone. In a recent study, Shibai *et al.*

> decomposed the biological motion of medaka into either posture or motion-trajectory elements, where the 'posture' element contains information regarding body-shape-level motion (also known as 'body motion') and the 'motion-trajectory' element contains information regarding entire-field-level motion (also known as 'locomotion'). We prepared visual stimuli that contain both, either, or none of those elements, using point-light stimuli; then,

> we presented the stimuli in separate experiments to determine the contribution of each element to the attractiveness of biological motion. We found that each of the two elements alone exhibited a significant degree of attractiveness […]. (Shibai *et al.* 2018: 2)

Animals generally recognize conspecifics as an important subset of the world, of course, usually using pheromones and the like rather than biological motion. A grammatical version of this occurs in languages that treat the category *human* as a special class of *animate* in agreement systems (see Ortmann 1998). Conspecific identification is probably universal among vertebrates and occurs from bumblebees (Dawson & Chittka 2012) to trees (Dong *et al.* 2017). Bacteria (Wall 2016) recognize kin as well, though the species/self distinction is blurred or lost for things that reproduce by fission:

> Bacterial kin recognition involves three steps. First, individuals recognize one another by receptor-ligand or receptor-receptor binding. Second, recognition leads to a signal or biochemical perception. Third, there is a behavioral response […]. [B]acterial kin recognition involves a molecular event(s) that can be directly observed—e.g., kin cells that adhere together. The end result of these interactions is a cooperative behavior that increases the fitness for the participating individuals. (Wall 2016: 2)

Kin recognition is essential to things like biofilm formation and quorum sensing, both of which are found in archaea as well as bacteria and eukaryotes. If archaea also recognize their kin, as seems likely, it could go back to LUCA (Fig. 3).

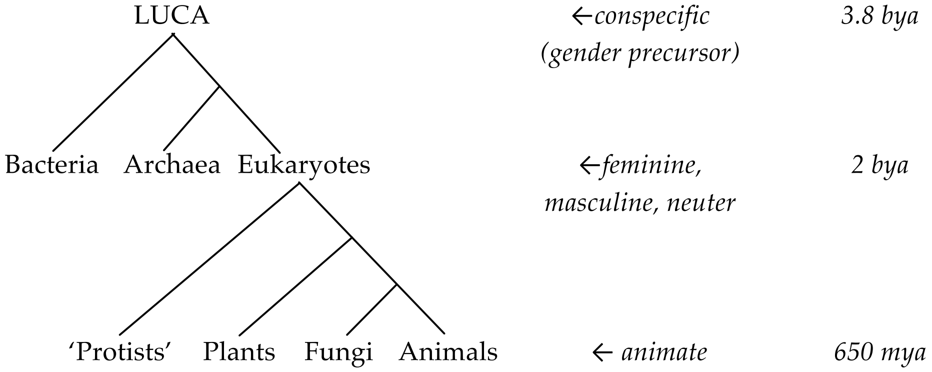

Figure 3: Possible age of gender *('Protists' shown as a group for simplicity).*

5. Conclusion

A recent book on the evolution of language states that the semantics of morphemes in natural language are not well understood:

> The atomic elements pose deep mysteries. The minimal meaning-bearing elements of human language—wordlike, but not words—are radically different from anything known in animal communication systems. Their origin is entirely obscure, posing a very serious problem for the evolution of human cognitive capacities, human language in particular.
> (Berwick & Chomsky 2016: 90)

I hope to have shown that the origin of a small subset of these atomic elements poses no such mystery: The origin of the ϕ-features that make up person, number, and gender seem quite clear. They have no analogues in animal communication systems but they do have clear analogues, often exact homologues, in the biological systems common to vertebrates, animals, even plants and single cell organisms. They predate humans by millions of years, as Bickerton (1990) and others suggested decades ago, and their semantic content remains unchanged.

Fig. 4 summarizes the evidence for animal use of the ϕ-features behind person, number, and gender, with an approximate age for each, mapped onto the recent chronology of life forms in Knoll & Nowak (2017). A precursor to person seems to have arisen very early among bacteria and archaea in *self-referencing*, required for immune systems. If we can associate person proper with *self-awareness*, it may trace back to animals generally. The likely precursor to *gender* is the detection of conspecifics, found already in bacteria and possibly archaea. *Sex*-based gender originates with eukaryotes 2 bya and *animacy*-based gender with animals 650 mya. *Quorum-sensing* is the likely precursor to number and traces back deep into bacteria; *number* proper (*more/most*, SG/DU/TR/PL) probably does not occur before vertebrates, about 400 mya.

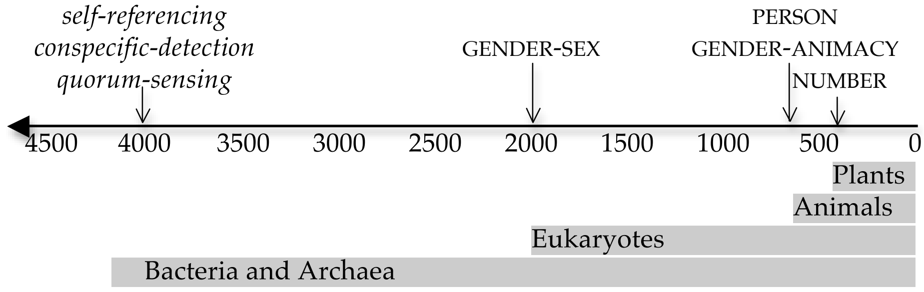

Figure 4: Approximate ages of ϕ-features (in mya).

In other work I argue that the verbal notions tense, mood, and aspect are also shared with animals, as are the thematic roles that link nouns to verbs (Golston 2018). I hypothesize more broadly that the semantics of all grammatical categories are used in animal cognition and that nothing of the semantics of grammar is unique to humans; grammatical categories like these have been called "the flesh and blood of grammar" (Ouhalla 1991/2005: 4–5).

It is increasingly clear that our representational systems are shared to a great extent with those of other animals, especially vertebrates. I hope to have shown that a number of core grammatical categories, the ϕ-features, are built directly on representational systems we share with others. We are probably unique among animals in *communicating* with ϕ-features, but we are probably not unique in *thinking* with them.

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