

Implementing NBO's Ethology Use Case

Ditch Townsend, 7th August 2023

Introduction

“Maybe all that is needed for the NBO is some housekeeping: a consistent rewrite of the labels, definitions and annotations, a style guide, better cross referencing and axioms.”¹

Seemingly prescient, obtaining consensus on a new model structure has proven too challenging for me. Instead I'm proposing this 'one dimensional' reconfiguration.²

Background

I opened an issue to review the NBO on 13th January 2023.³ It suggested eight needs/opportunities:

1. The NBO is effectively a community-owned ontology; we move forward by consent, although without financial resources, it will tend to drift in the direction of of its main volunteer time resource (which has been me so far this year).
2. An updated style and convention guide sheet was uploaded recently, rooted in OBO principles and a detailed published reference. Without strong community assent, I am only confident to apply it as a guideline.⁴
3. On 18th January 2023, I proposed a three dimensional model to restructure the NBO.⁵ This was simplified soon after as a two dimensional model.¹ With no traction, the issue was closed on 9th February 2023.⁶
4. Refocusing:
 - a) The trait/phenotype focus of the original NBO has been relinquished, although the deprecation process is stalled. The same applies to disease, disorders, and disabilities.⁷ (Funding is probably required by other ontologies to allow them to fully integrate our deprecations.)
 - b) On 6th July 2023, a video call explored the potential for NBO and BCIO (among others) to align, with the potential to migrate some branches, not least the heavily human ones.⁸ (Funding is being explored to aid this process in due course.)
 - c) I circulated a paper for the meeting with my own thoughts on the NBO's scope, and suggested some necessary obsoletions and potential deprecations in sections 1 and 2.⁹

Very little has yet been done to advance the other four opportunities (5. consistency, 6. saturation, 7. cross-referencing, and 8. logic).

Meanwhile, the question of NBO use cases has been discussed. With the deprecation of phenotypes underway, and human behaviour more usefully the remit of the BCIO, we are currently left with Ethology including field, laboratory, and citizen science observations of natural behaviour.¹⁰

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Baseline

Classes¹¹

A summary statistics report noted that NBO has 929 classes, of which 606 are not in the **phenotype** branch.¹² (This has proven too low, mainly caused by counting duplicated phenotype classes before deletion: it should be 297 not 322.) My NBO scope paper found 635 non-phenotype NBO classes.⁹

Relations

These shared 682 internal subclass relations. The handful of object properties were treated as problematic and ignored. The few multi-parent classes tended to be simple composites, including **emotional conditioning**, **oral communication behavior**, and **paternal aggressive behavior**. A handful illustrated more complex synergies, such as **acute stress response**, **impulsive behavior**, and **predator behavior**.

Sub-branches

The **behavior process** branch grew 13 sub-branches. Of these, **emotional behavior**, **regulation of behavior**, **rhythmic behavior**, **impulsive behavior**, **stress related behavior**, and **consumption behavior** were proposed for migration to other ontologies in varyingly piecemeal degrees.

Pre-amputation

Redundant, anomalous, synonymous, duplicate, or misplaced classes amounted to 31. More significantly, I identified 132 classes which I argued would fit well as migrants to BCIO.

Post-amputation

By the end of the second knowledge graph section, I had retained 472 of the original classes.

Rebuilding

A refresh

The third knowledge graph section of my July 2023 paper proposed a number of new post-amputation classes and discussed re-amalgamating the NBO into four sub-branches. It did not offer a major expansion in terms: new classes were generally interpolations to aid understanding, with an occasional extrapolation to illustrate a point. However, it:

- introduced the concepts of embodiment, emergence, and habitat engineering;
- reintroduced ABO ideas such as maintenance, signalling, construction, and super-organisms;
- explored ways to integrate with BCIO needs for societal and cultural classes;
- compromised itself on the thorny issue of motivation;
- suggested that more pruning could lie in the cognitive realm.

Whilst the current proposal draws inspiration from the July 2023 paper, it essentially restarts post-amputation.

Assumptions

This section contributes to need/opportunity 5 (consistency).³

Thinking about what behaviour is has led me to the following assumptions (but far be it from me to assume the capacity to define behaviour!) Rather than using them as aggregation classes in an ontology, I think they can be used to test any NBO behaviour class:

Process

Every behaviour is a process: there is always some kind of reconfiguration.

Corporeal

Behaviours will always happen to a tangible, whole entity, whether a body, a colony, a self-aware mind, or a super-organism.

Purposeful

If not an individual intent, then a behaviour will have an outcome, and be traceable to a function itself affording evolutionary fitness, even if it is individually detrimental.

Responsive

Behaviours will either be reactions to stimuli, or emergences from complexity.

Patterned

Any behaviour will be to a significant degree recognisable and repeatable in its components and sequences.

Object properties

This section contributes to need/opportunity 8 (logic).³

is a

Most current relationships in the NBO are this form by implication in the subclass relation. I want to reserve its stand-alone use in the NBO to subclasses representing exclusive alternatives, sub-parts with a shared part label, simple transformations, and simple sub-processes.

realizes

No current relationships in the NBO take this form. Taking a lead from the BCIO, I would like to introduce this object property for any classes which put a parent class into effect, are caused by it, deliver it, achieve it, follow it, reify it, function as/to it, or respond to it. This allows for more or less functional relationships dependant on relative terms rather than predefining particular 'function' or 'action' classes.

part of

This is very rarely used directly in NBO – mostly pointing to GO classes, but discoverable (like hens teeth) in odd moments like **locomotor activation behavior NBO:0000447** which is *part of* some **locomotory behavior NBO:0000013**. It does appear frequently as an anonymous ancestor because GO uses it so much.

I want to begin using it in the context of multi-parenting:

- alongside *is a* in simple additive combinations (usually with a cumulative label), where elements or sequences are brought together, or in simple compounds;
- alongside *realizes* where combinations are multiplied, synergies, interactions, complex, or form a new system.

Disjointness

This section contributes to need/opportunity 8 (logic).³

Historically, the NBO is saddled with some child classes which create a difficulty if they can appear as joint parents further down the line. For example **courtship behavior** originally had two types of subclass, one based on activity (appeasement, begging, feeding) and the other on sex (female and male). In reality, but not represented in the NBO, a field worker might be glad of a class which represented male courtship feeding or another representing female courtship begging, etc.

I am not clear how this might be axiomatically achieved in the NBO, but I have not steered away from representing it visually in this paper on a handful of occasions, where one or another of multiple parents might be disjoint in particular instances.

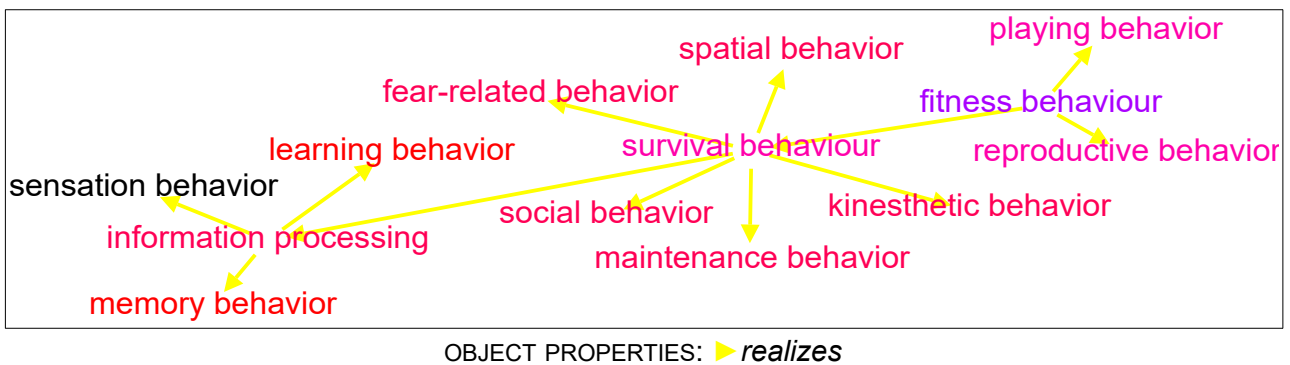
Scope & Scale

This paper does not elucidate a way forward for the whole of the NBO, although I made such a suggestion in my July 2023 paper. It proposes a core scope for which I am keen to give my attention, currently comprising 400 classes (90% of them original) incorporating 555 relations (many of which have been changed or added since the original). I'm calling it the Ethology module. Major components missing in addition to those 'amputated' in July 2023 are the subclasses of **memory behavior**, **learning behavior**, and **reflexive behavior**. Not every tier of subclass is discussed or shown in the following knowledge graphs, but a complete one is presented in the appendix (as an SVG it can be zoomed in detail on a computer).

Highest levels

The original GO **behavior process** class is retained at NBO's core but not visible in the following knowledge graphs. Subsidiary to this, I am proposing the recognition that we are essentially interested in **fitness behavior**. From here flow the original **playing behavior** and **reproductive behavior** sub-branches alongside a new **survival behavior** one. **Survival behavior** gives birth to **kinesthetic behavior**, **social behavior**, **fear-related behavior**, and the new classes **maintenance behavior**, **spatial behavior**, and **information processing** (incorporating **cognitive behavior**'s child **sensation behavior** alongside it's former **learning behavior** and **memory behavior** stubs).

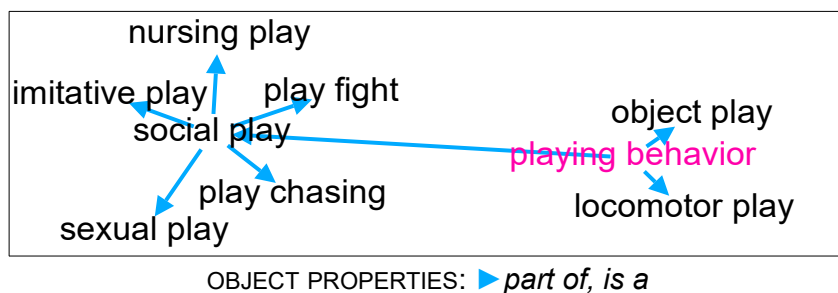
Knowledge graph 1: Upper ontology (Ethology module)



Playing behavior

This has seven all original terminal classes (leaves), five of which are subclasses of social play.

Knowledge graph 2: Descendants of playing behavior (Ethology module)

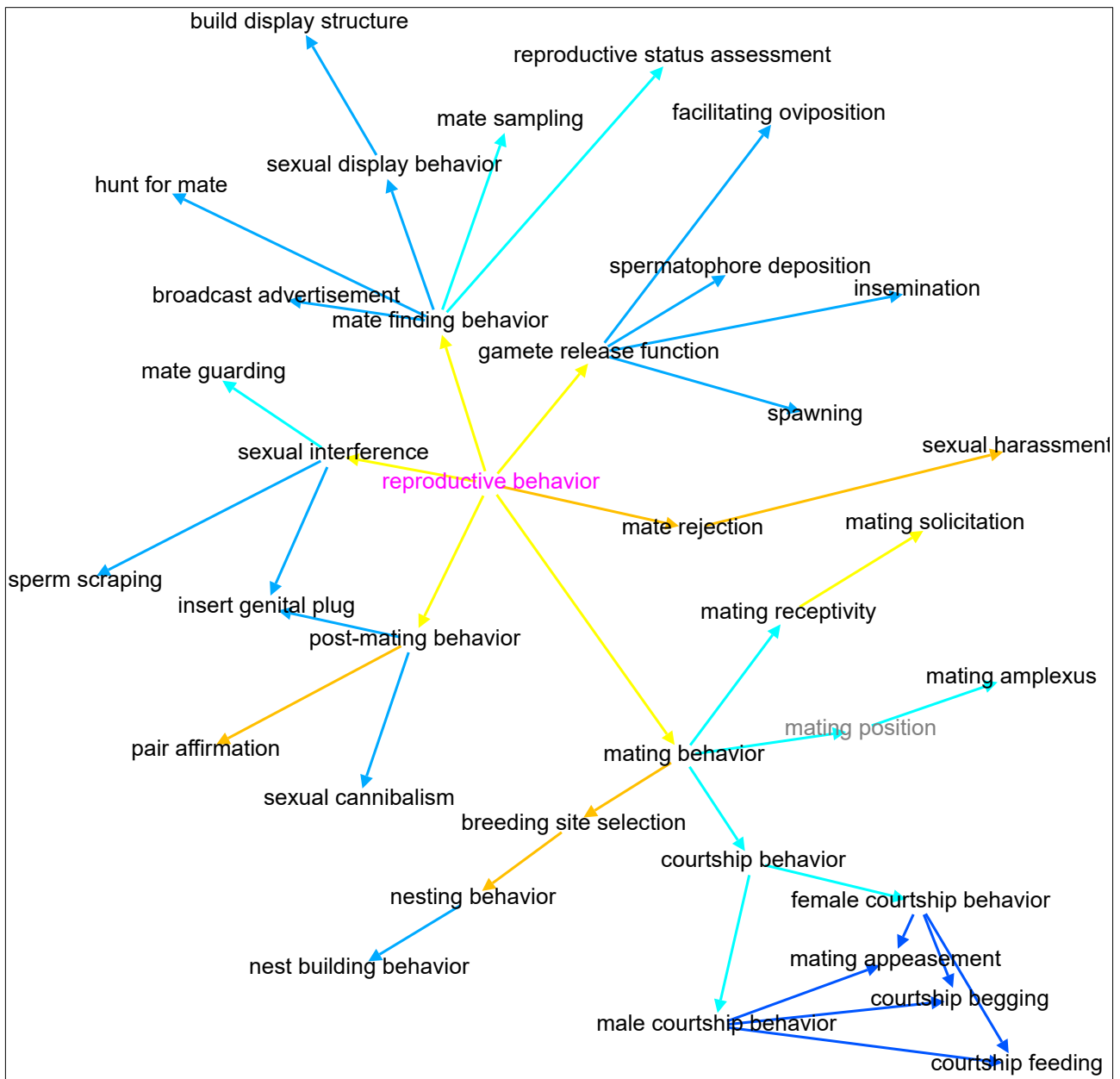


Reproductive behavior

This branch has six classes with eight subclasses and between them they serve 21 leaves. A total of 15 classes have multiple parents. Only *mating position* is a proposed new class.

Mate finding behavior has been recast as parent to a wider group of behaviors. Some nuances of **post-mating behavior** and **sexual interference** have been teased out. **Courtship behavior** is rejigged to acknowledge links to broader social behaviors and disjoint gender roles. **Gamete release function** is no longer subsidiary to **sexual activity**, which is more specifically defined (elsewhere) to relate to the kinesthetic actions of the sexual organs, and together they become parts of **insemination**, etc. Also, **sexual harassment** is explicitly related to **mate rejection**.

Knowledge graph 3: Descendants of reproductive behavior (Ethology module)



OBJECT PROPERTIES: ▶ is a ▶ part of, is a ▶ part of (disjoint), is a ▶ realizes ▶ part of, realizes

Survival behavior

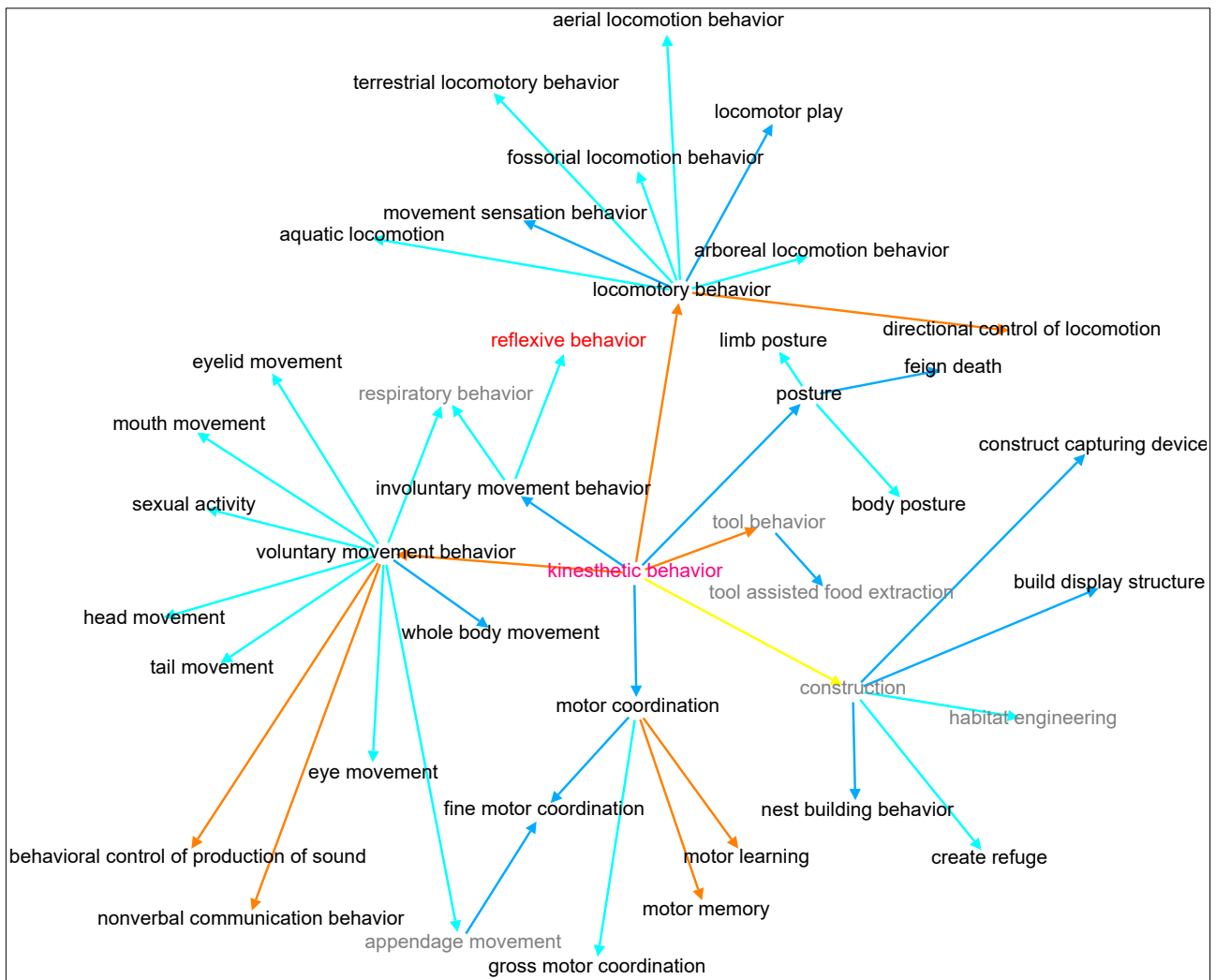
The majority (345) of classes are on sub-branches of this one.

Kinesthetic behavior

This well conserved branch retains original classes in 94% of its 145 member extent, and is nearly 90% subdivided by uncomplicated (*is a*) relationships. Notably, the very extensive **reflexive behavior** branch is represented here as a stub.

Perhaps the most interesting addition not already mentioned elsewhere, is the **construction** sub-branch, suggested by the original ABO as 'build', with its own new child: **habitat engineering**.

Knowledge graph 7: Two tier descendants of kinesthetic behavior (Ethology module)

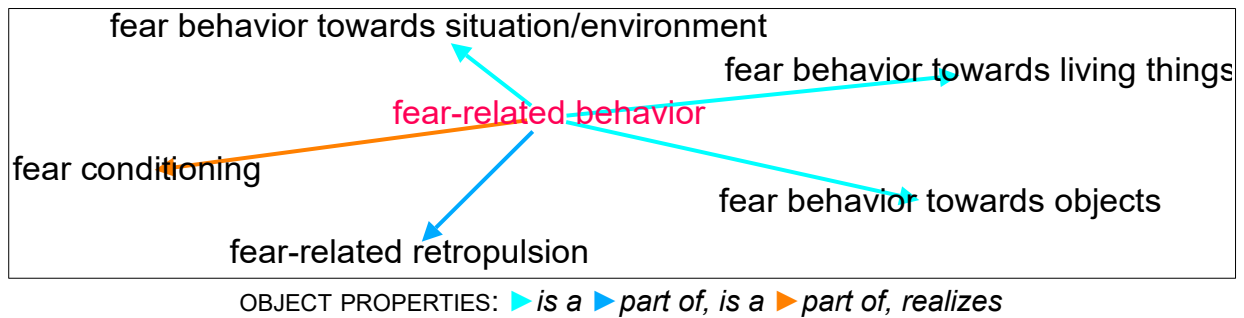


OBJECT PROPERTIES: ▶ *is a* ▶ *part of, is a* ▶ *realizes* ▶ *part of, realizes*

Fear-related behavior

This branch has five historical subclasses. **Fear-related retropulsion** has multiple parents. **Fear conditioning** would too, were the learning behavior branch not treated as a stub. No attempts have been made to connect to the many related classes of **agonistic behavior** and **protective behavior**.

Knowledge graph 4: Descendants of fear-related behavior (Ethology module)

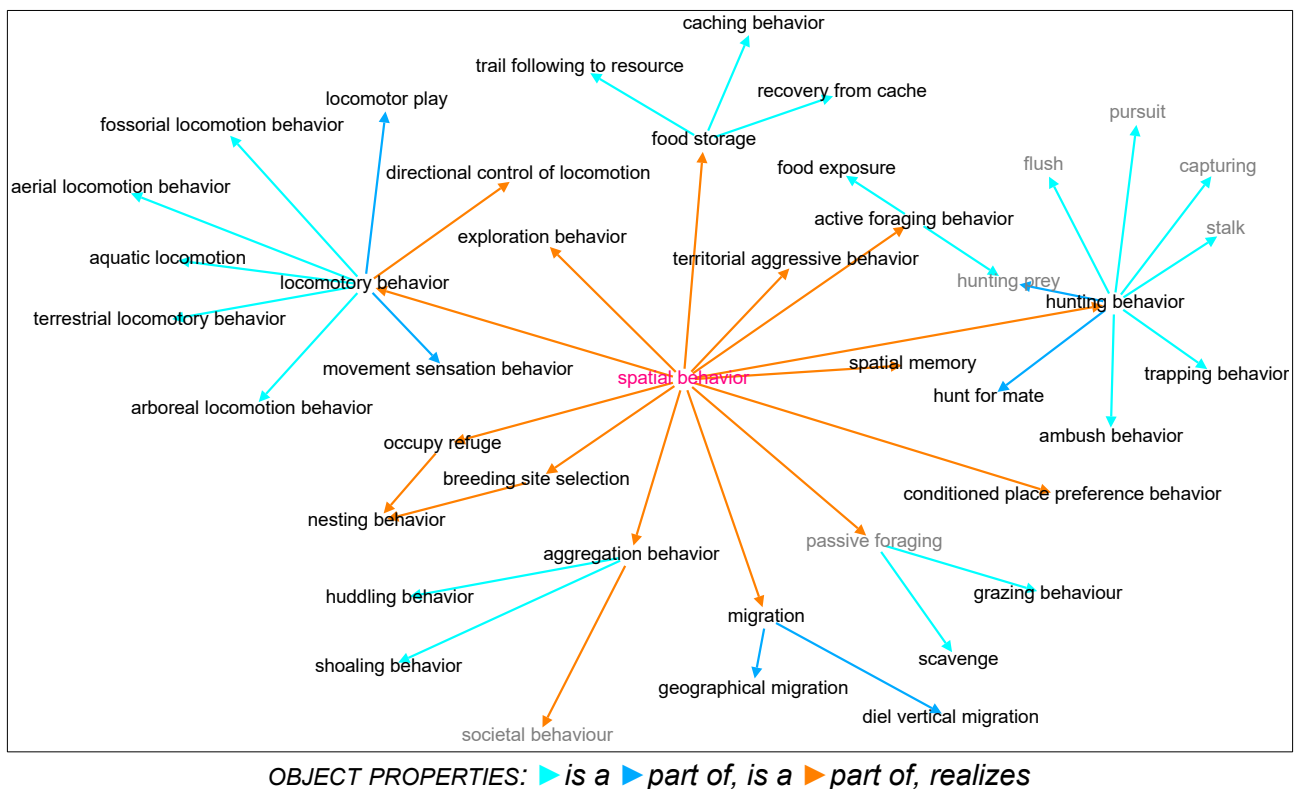


Spatial behavior

Much has been reorganised to create this 95-member, 107-relation, six-tier branch, which more explicitly acknowledges the place of space in animal behavior.

Hunting behavior has been significantly reworked, alongside extended ideas about foraging. **Locomotorory behavior** too has been recast, not least via its grandchild **steering behavior** to be ready for future ethogram-friendly expansions. Lastly, **aggregation behavior** is now a key driver for **societal behavior**, alongside simpler emergent behaviours.

Knowledge graph 6: Two tier descendants of spatial behavior (Ethology module)

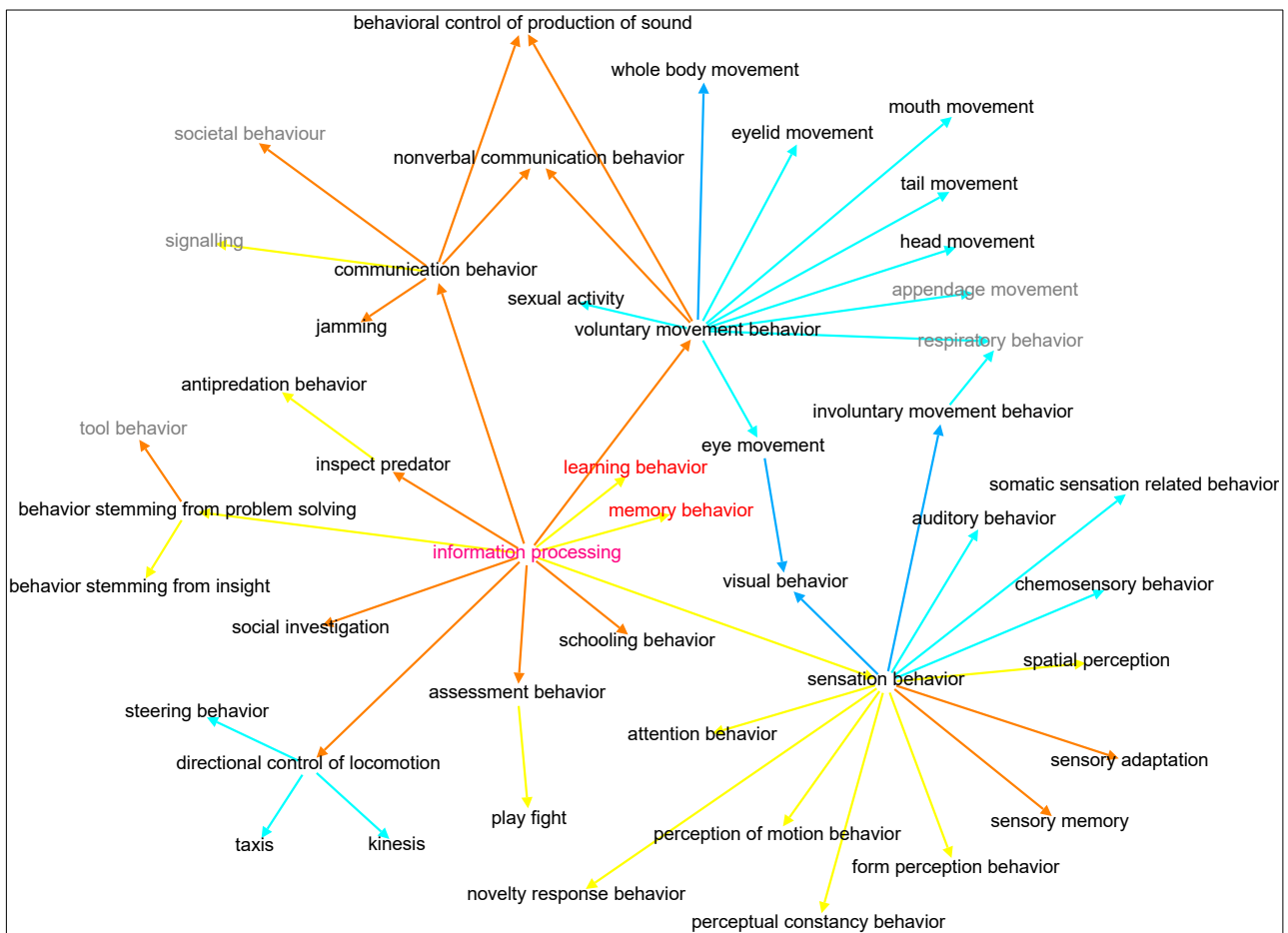


Information processing

Whilst none of this branch's first tier sub-branches are new classes, the whole branch is a new amalgamation. Focused on **sensation behavior**, it also acknowledges **memory behavior** and **learning behavior** as fundamental components, even if they are stubs in this module, and picks out fragments of **behavior stemming from intelligence**, adding the seemingly necessary **tool behavior**.

The memory and learning stubs haven't been treated here, but **sensory adaptation** and **sensory memory** (on the second tier) would likely make reference to a **learning behavior** and **memory behavior** derivative respectively. **Novelty response behavior** is transferred to the **sensation behavior** branch, having lost most of its **emotional behavior** siblings. While **voluntary movement behavior** is now defined with reference to all **information processing** components (alongside **kinesthetic behavior**), **involuntary movement behavior** is considered to rely solely on **sensation behavior**. **Voluntary movement behavior** is also promoted, with two new classes for **appendage movement** and **respiratory behavior**, and **sexual (organ) activity**, **nonverbal communication behavior**, and **behavioral control of production of sound** given a new home there. **Information processing** now also plays a part in **schooling** (beyond the simply emergent **shoaling**), **directional control of locomotion**, and several modes of evaluative behaviour. **Communication behavior** is also re-homed, with a key new child: **signalling** (with **honesty** and **deception** waiting in the wings).

Knowledge graph 5: Two-tier descendants of information processing (Ethology module)

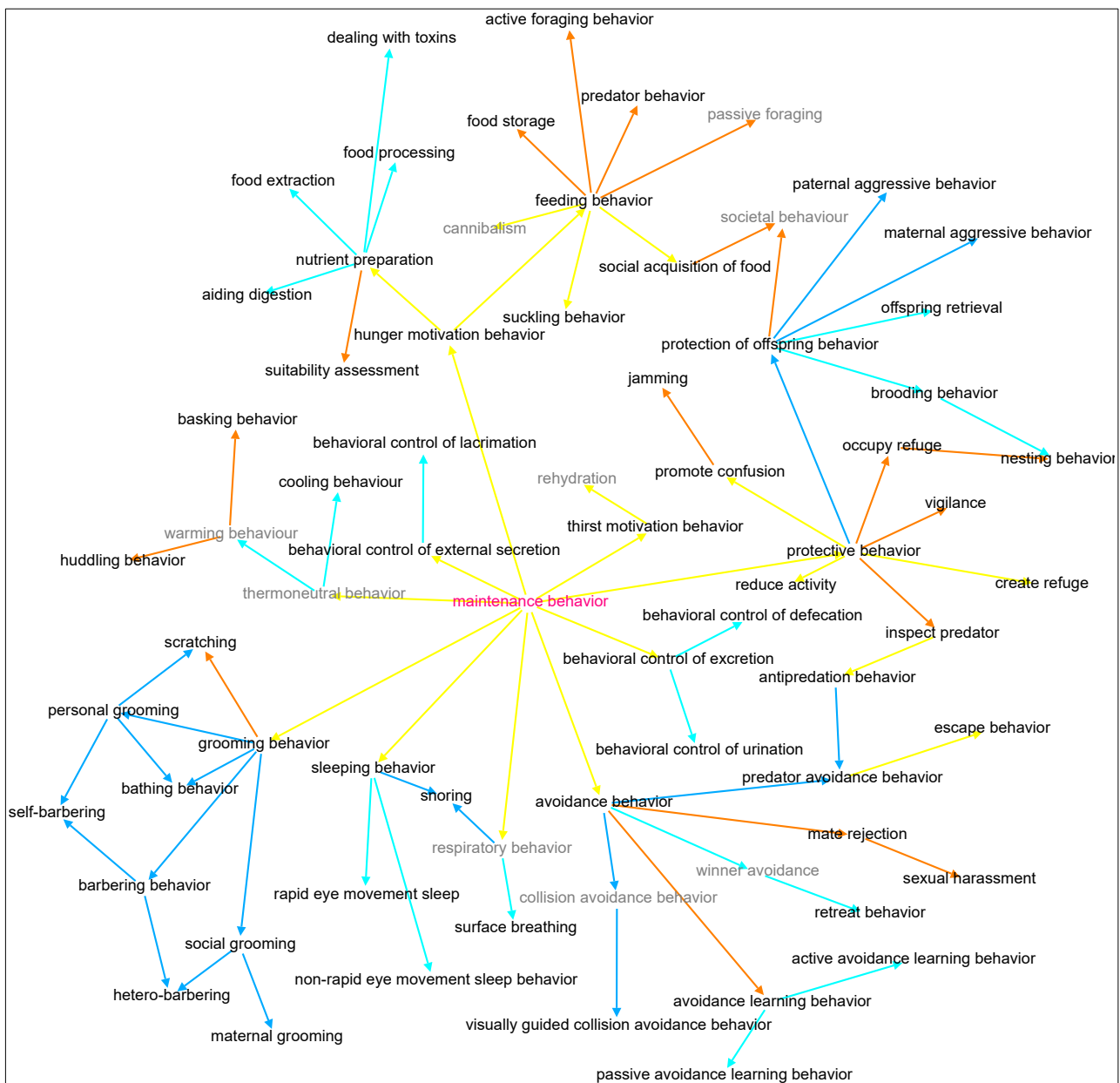


Maintenance behavior

This branch has been introduced in deference to the original ABO. With 120 classes and 131 relations, it mostly recycles former branches.

With **thermoregulation behavior** proposed for deprecation alongside **circadian temperature homeostasis** as a para-physiological process, **thermoneutral behavior** is introduced to link to the sub-branch of warming and cooling activities. **Feeding behavior** is reorganised including a general **cannibalism** class for eventual expansion. **Grooming behavior** and **antipredation behavior** too, the latter with an expanded **mimicry enhancement** branch (not shown) ready for future supplementation. Finally, **avoidance behavior** is more precisely delineated, with **protective behavior** promoted but trimmed in consequence.

Knowledge graph 8: Three tier descendants of maintenance behavior (Ethology module)



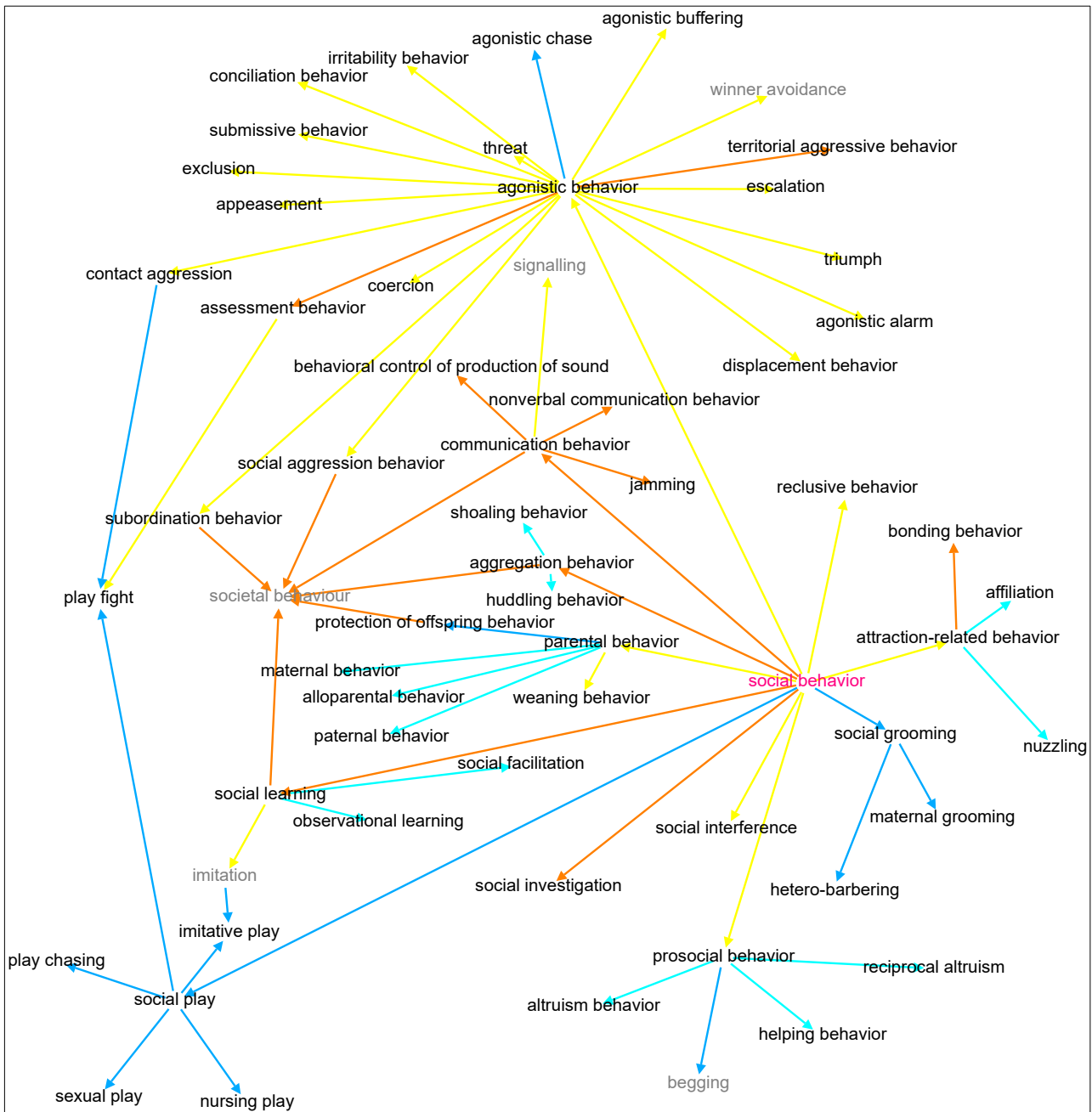
OBJECT PROPERTIES: ▶ is a ▶ part of, is a ▶ realizes ▶ part of, realizes

Social behavior

Much about this branch's 127 classes and 143 relations remains from before.

A fundamental new sub-branch has been developed enabling annotations for **societal behavior**, with (one tier below view) its associated **specialisation**, **microhabitat engineering**, and even **cultural behavior**, just for a start. On a minor note, **begging** has been introduced as a **deception** based **prosocial behavior**, as well as **winner avoidance** in an **agonistic behavior** sub-branch also shorn of general **aggressive behavior**.

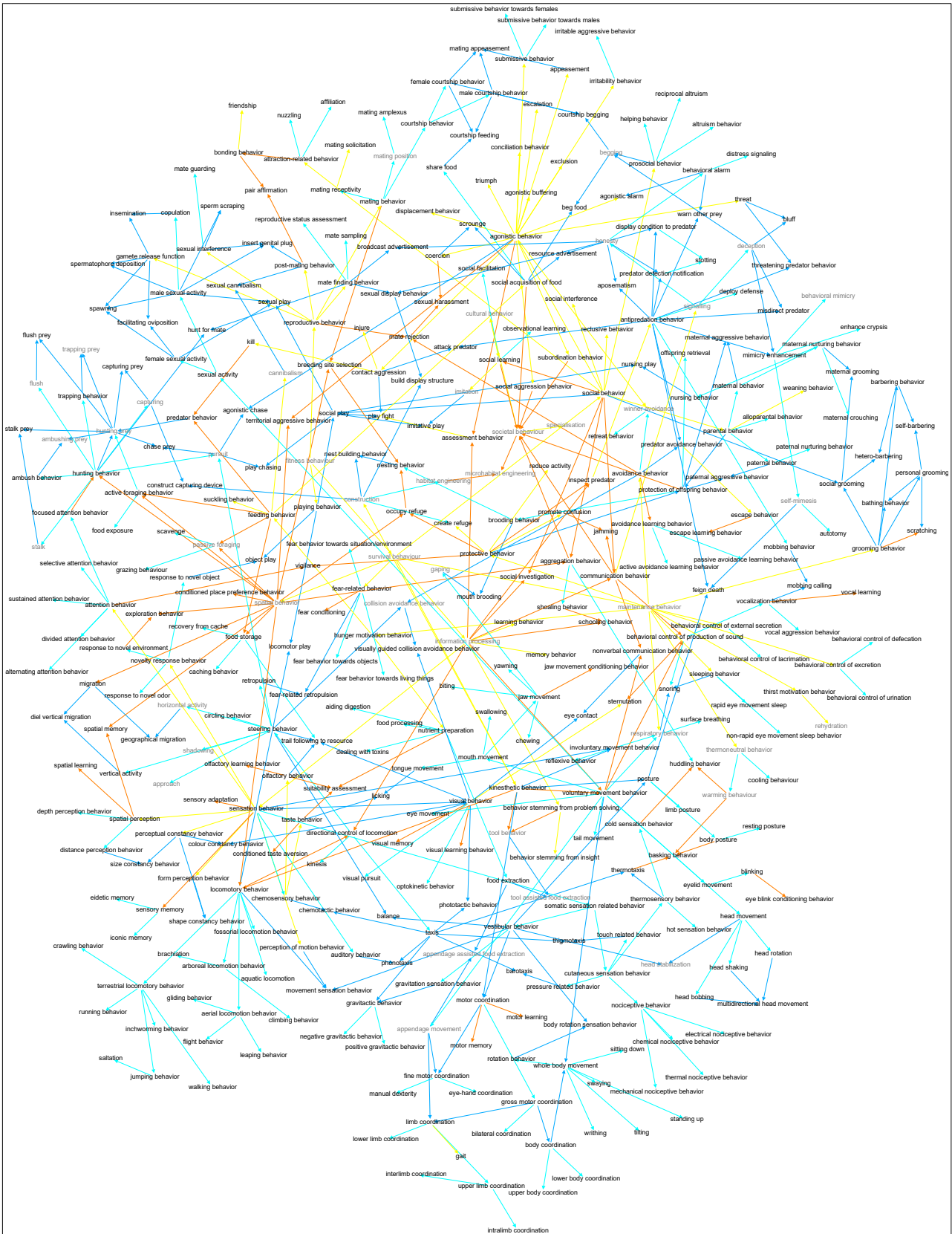
Knowledge graph 9: Two tier descendants of social behavior (Ethology module)



OBJECT PROPERTIES: ▶ is a ▶ part of, is a ▶ realizes ▶ part of, realizes

Appendix

Here is a full SVG version of my Ethology Module:



OBJECT PROPERTIES: ▶ is a ▶ part of, is a ▶ part of (disjoint), is a ▶ realizes ▶ part of, realizes

Endnotes

- 1 <https://github.com/obo-behavior/behavior-ontology/files/10474226/NBO.proposal.v2.230122.pdf>
- 2 <https://github.com/obo-behavior/behavior-ontology/issues/126#issuecomment-1424572907>
- 3 <https://github.com/obo-behavior/behavior-ontology/issues/124>
- 4 <https://github.com/obo-behavior/behavior-ontology/issues/122>
- 5 <https://github.com/obo-behavior/behavior-ontology/files/10451397/NBO.proposal.230118.pdf>
- 6 <https://github.com/obo-behavior/behavior-ontology/issues/126>
- 7 <https://github.com/orgs/obo-behavior/projects/1/views/5>
- 8 <https://github.com/obo-behavior/behavior-ontology/issues/157>
- 9 <https://github.com/obo-behavior/behavior-ontology/files/11937982/NBO.230706.pdf>
- 10 <https://github.com/obo-behavior/behavior-ontology/issues/127>
- 11 Original classes are **lower case bold** and proposed classes are *lower case bold italic* in the text, but lower case black and lower case grey respectively in the knowledge graphs.
- 12 <https://github.com/obo-behavior/behavior-ontology/issues/127#issuecomment-1426074371>