Language Composition

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Talk aims

1. The programming language status quo limits us.

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1. The programming language status quo limits us.
2. Language composition might offer a way forward.

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1. The programming language status quo limits us.
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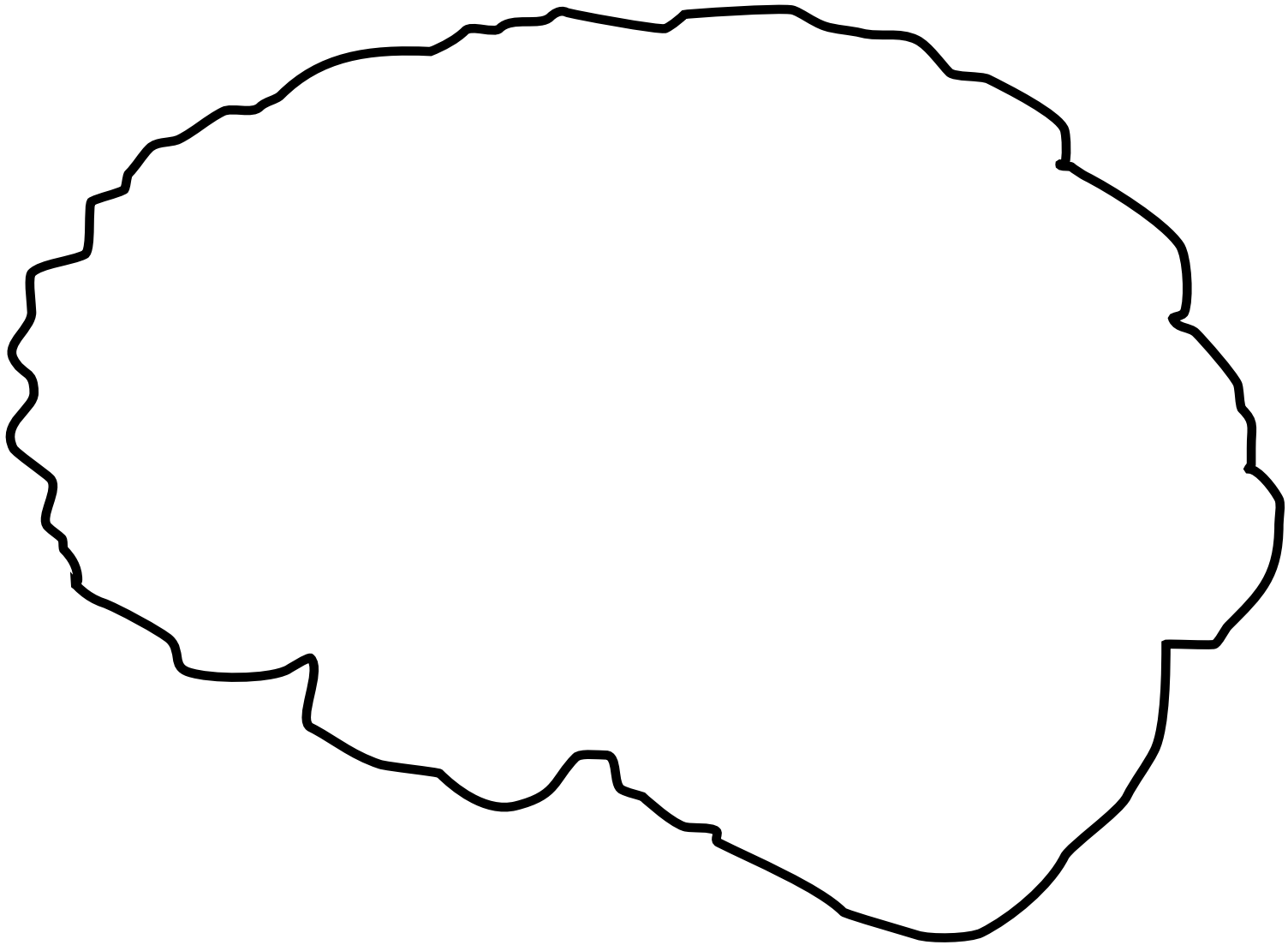
3. We're not very good at it yet.

Talk aims

1. The programming language status quo limits us.
2. Language composition might offer a way forward.
3. We're not very good at it yet.
4. Possible future routes.

The status quo

Languages conceptual size



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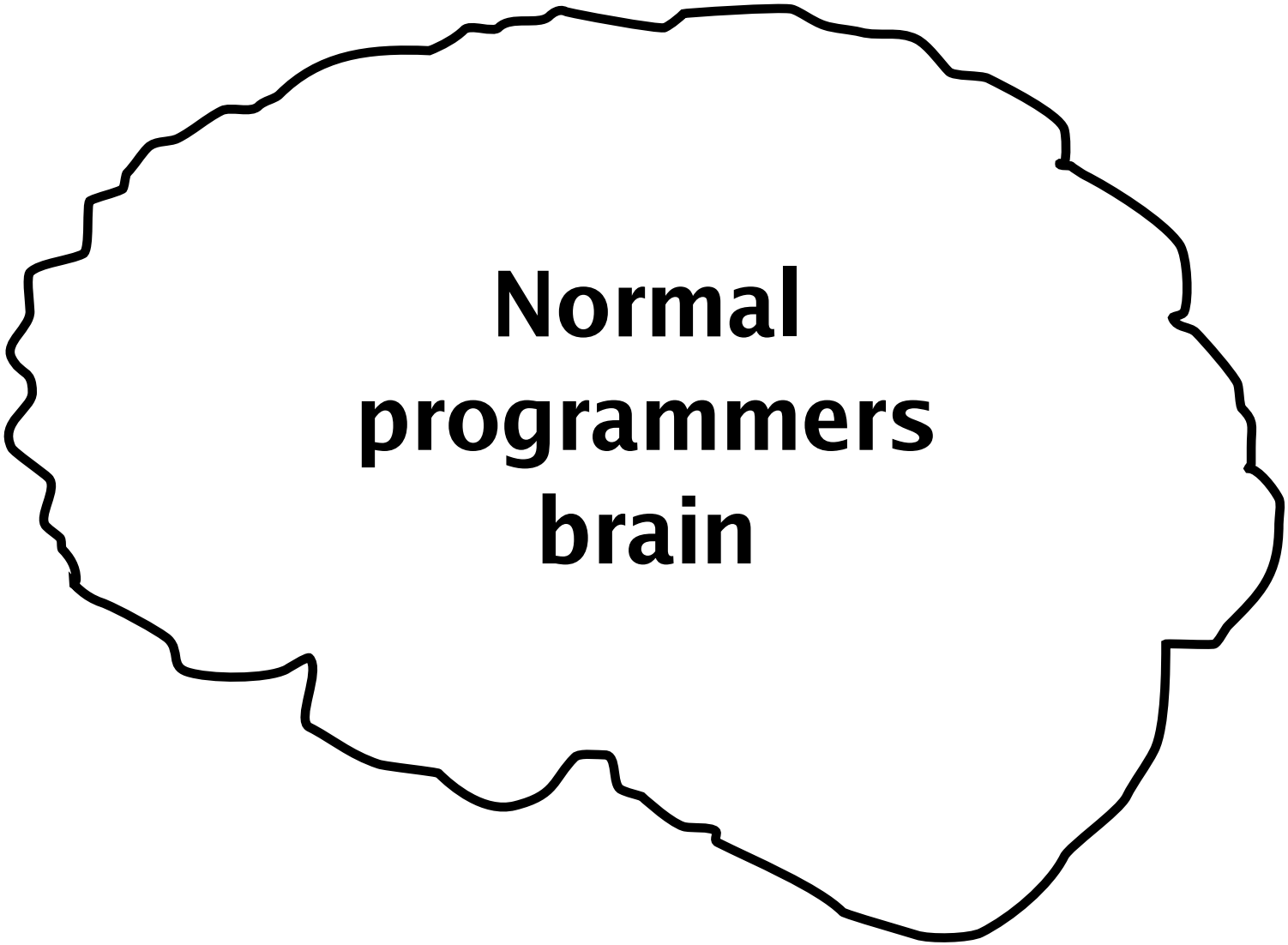

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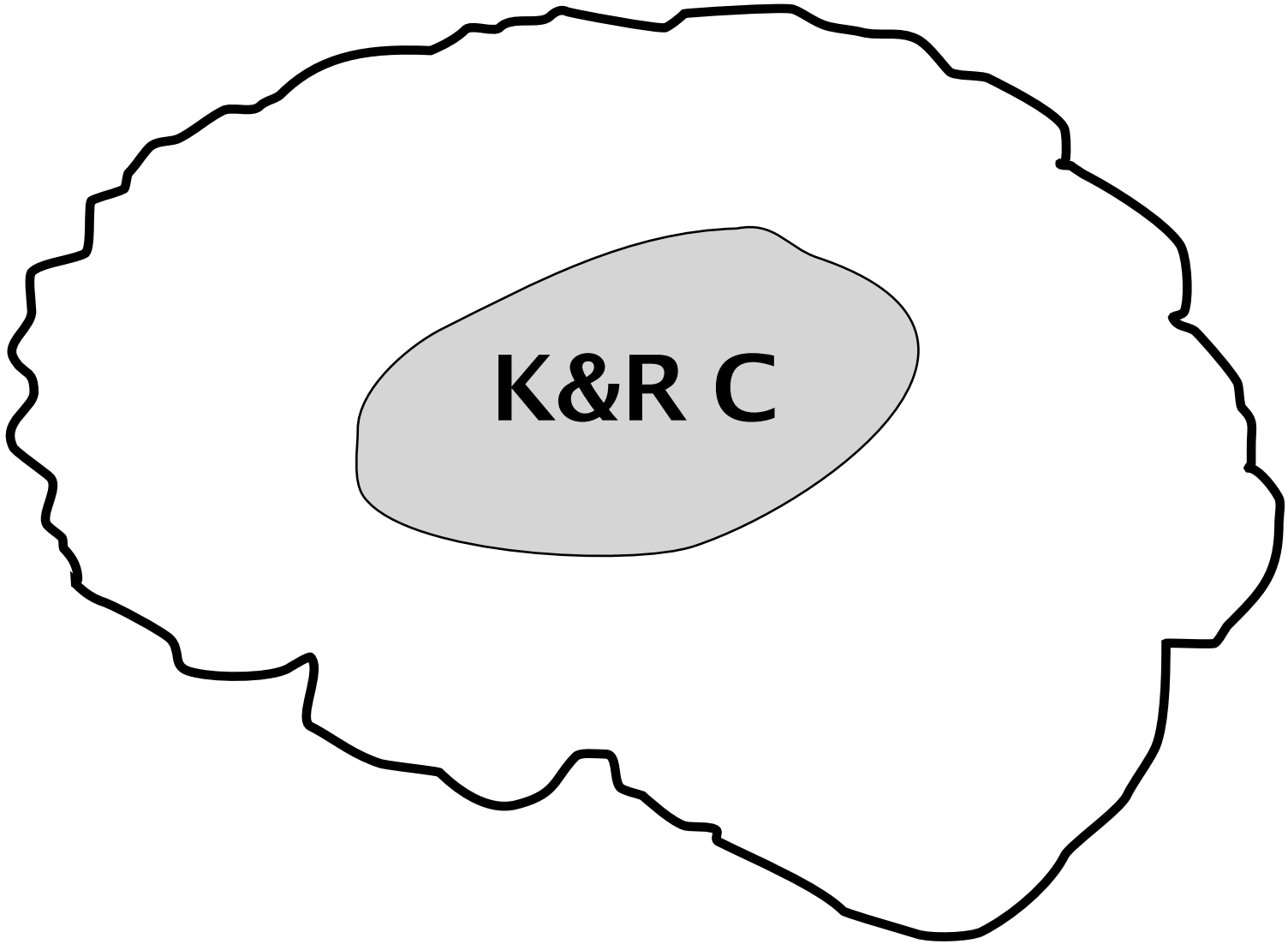

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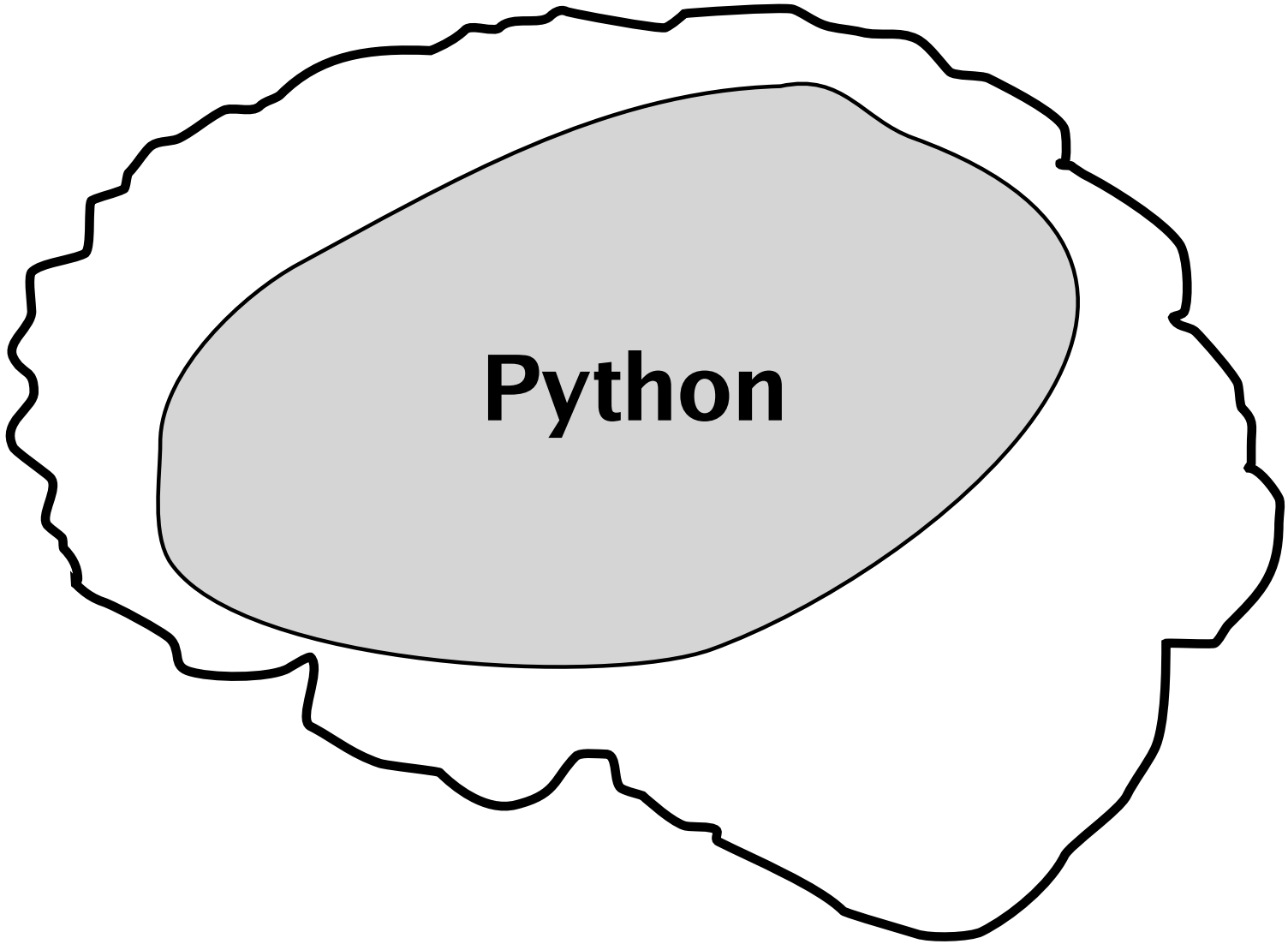

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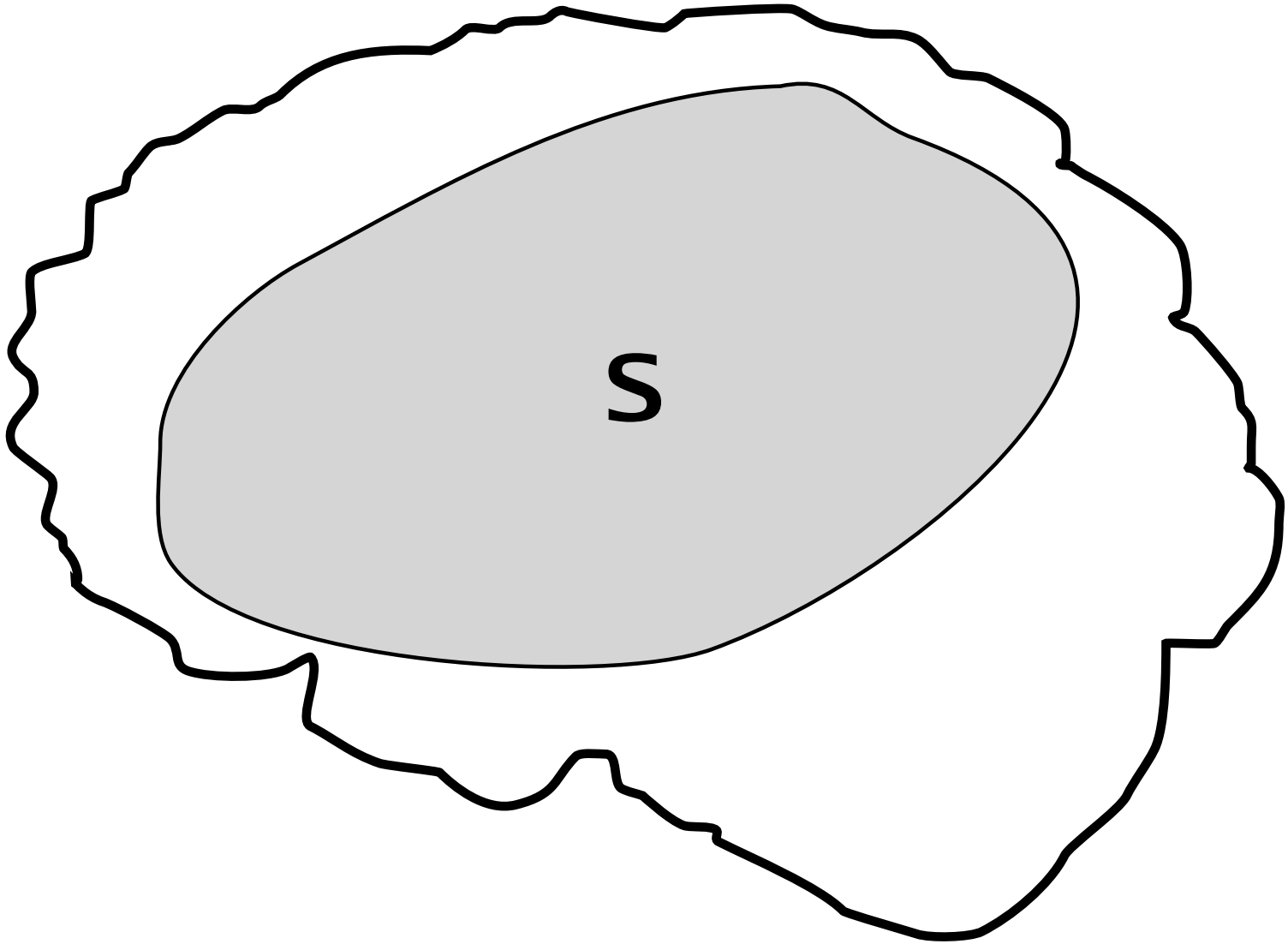
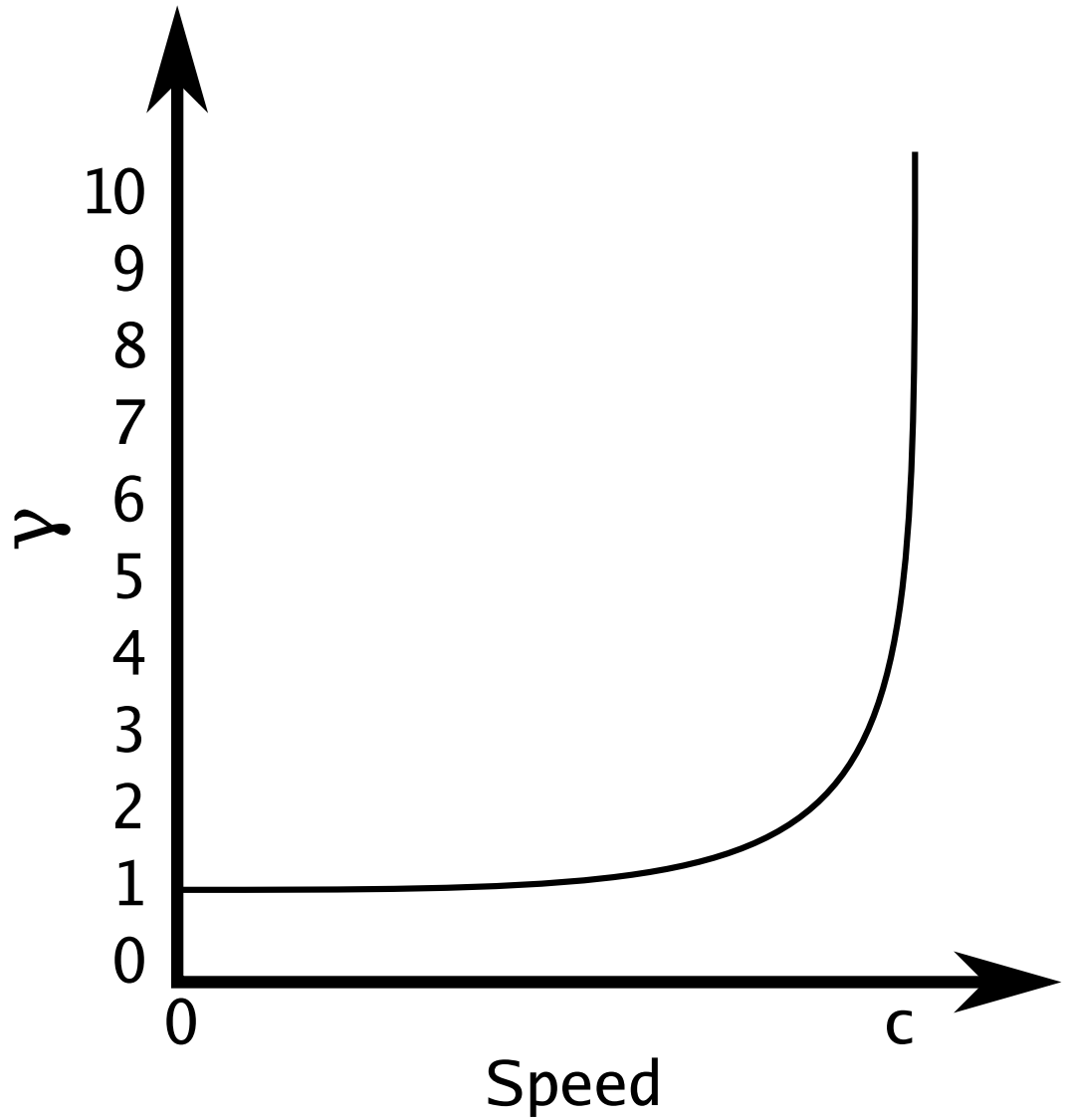


Programming languages' speed of light



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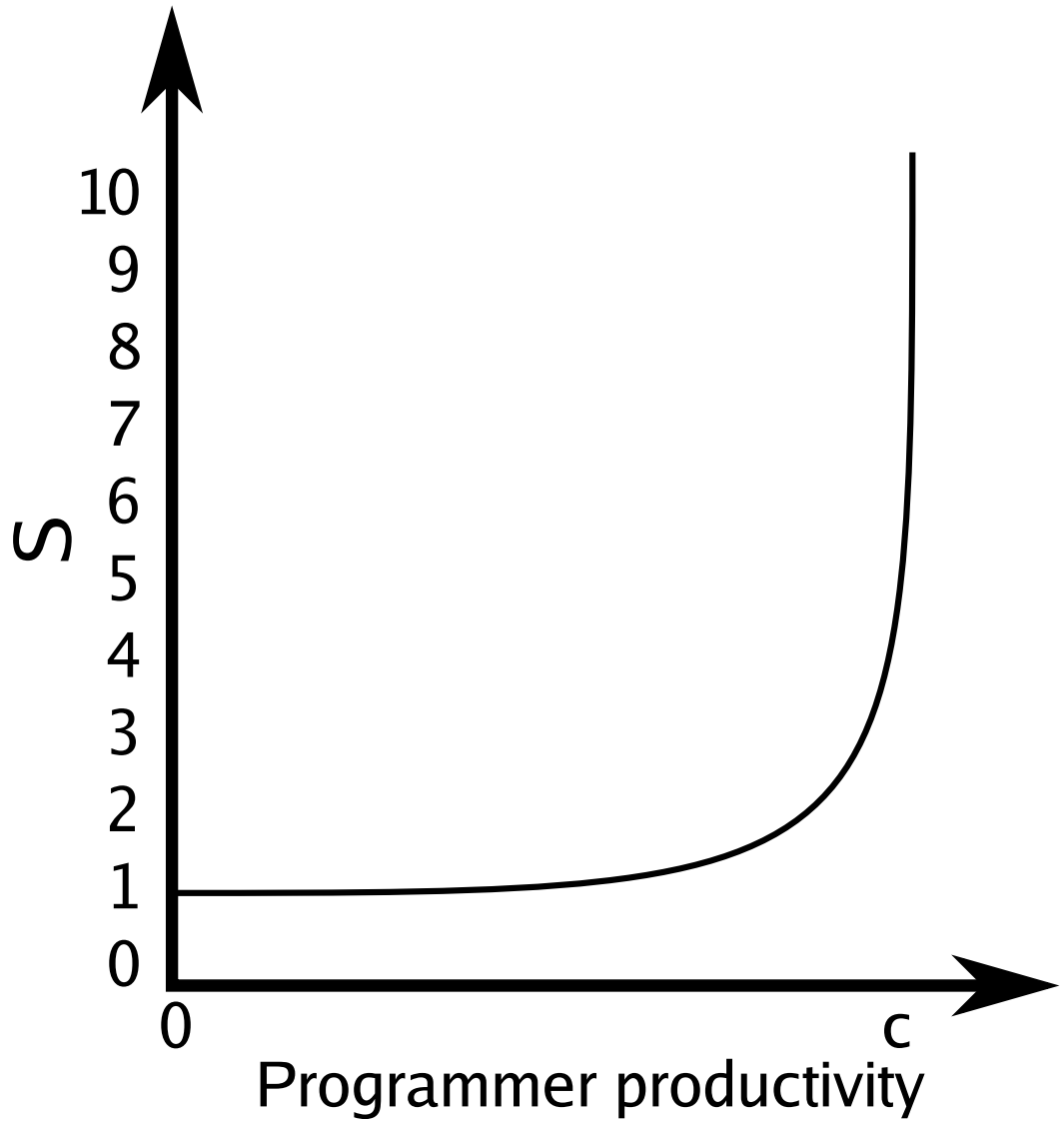

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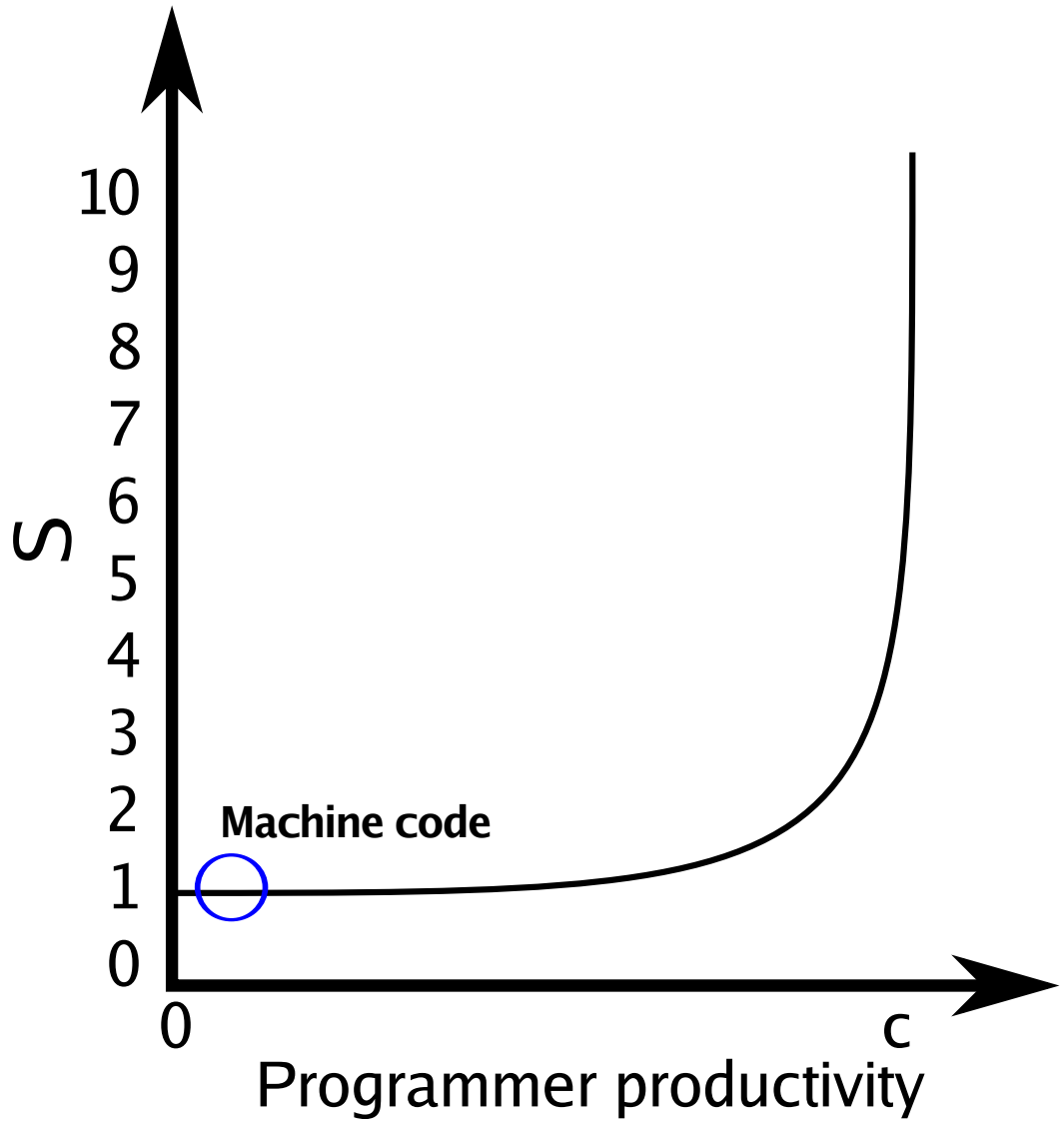

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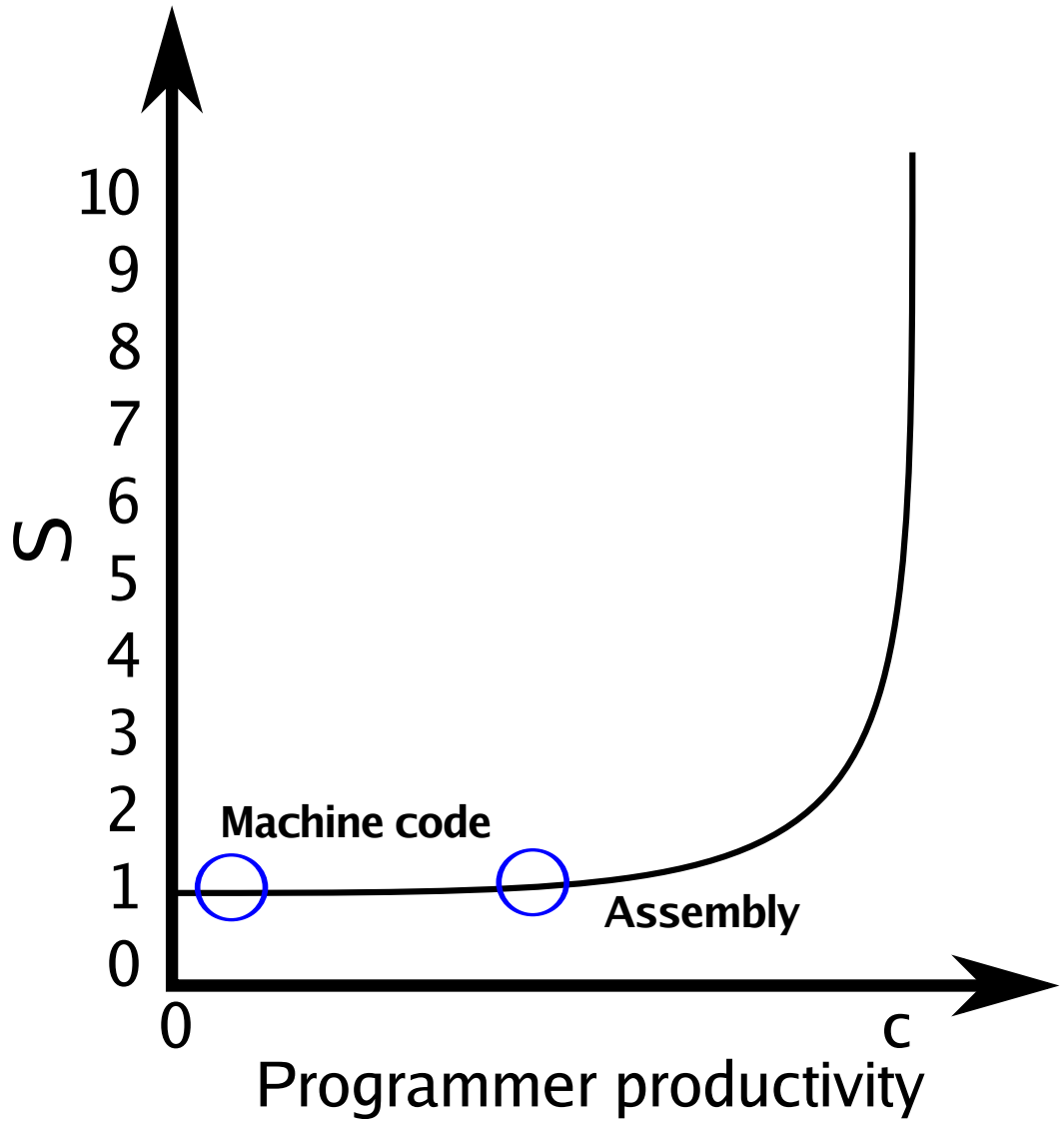

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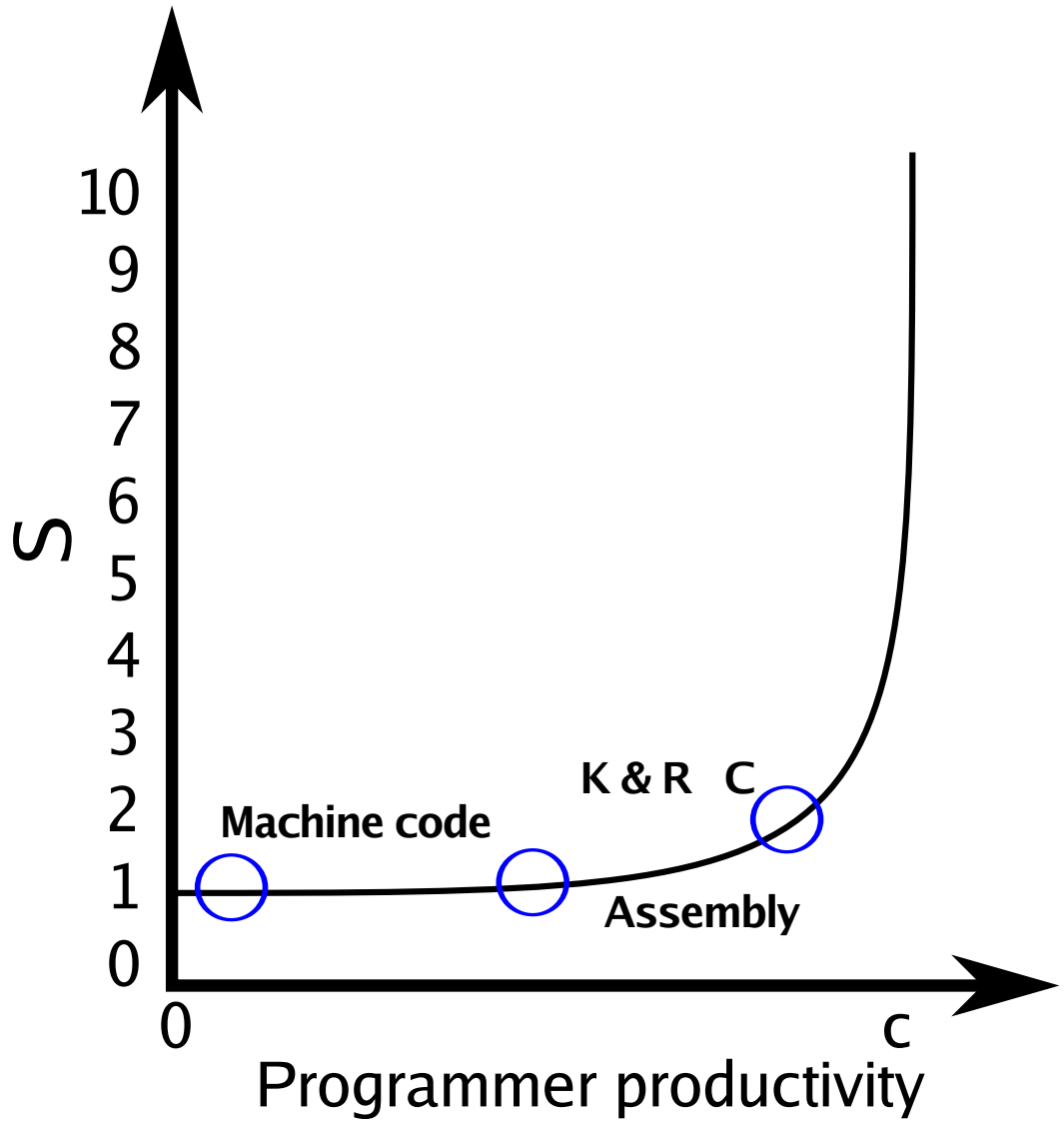

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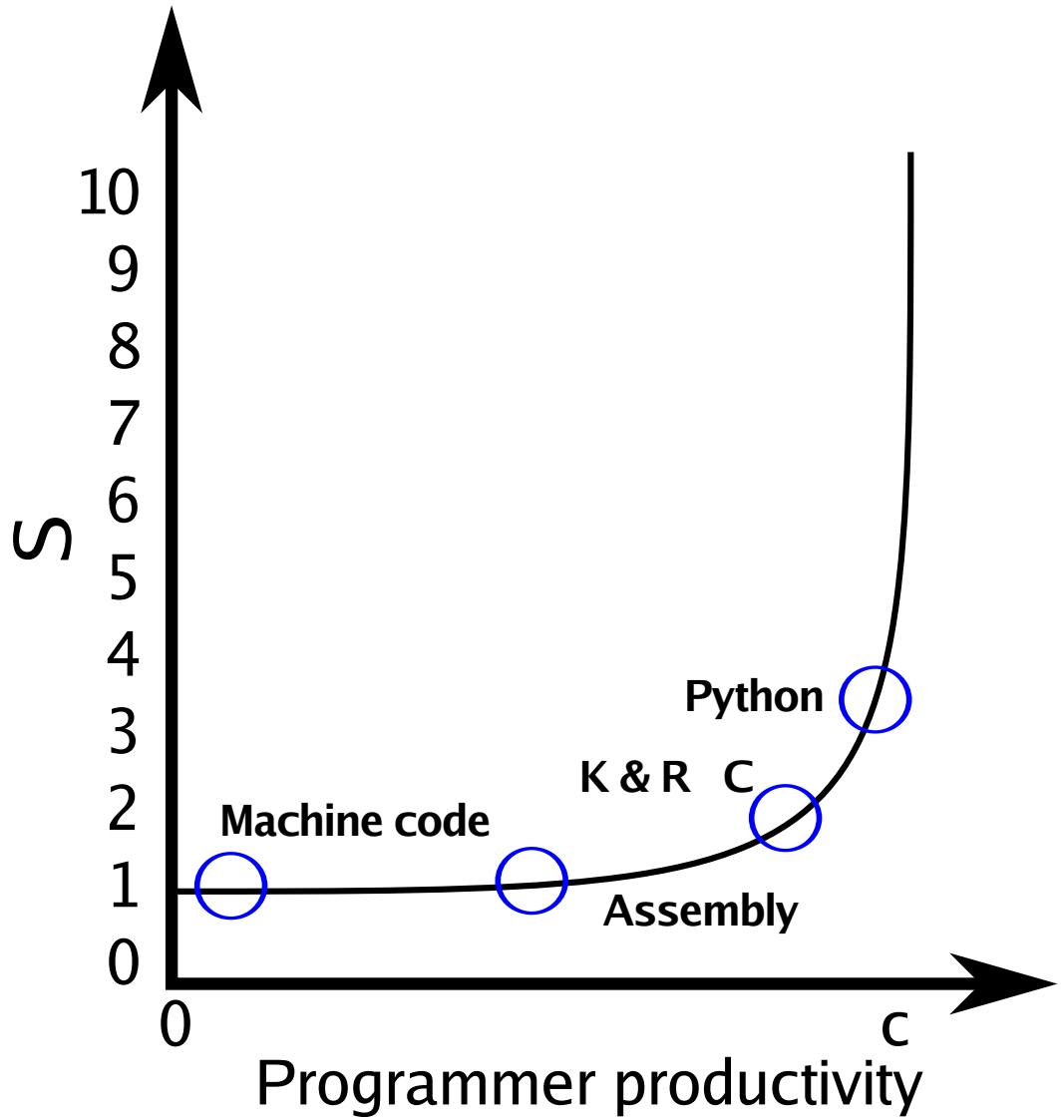

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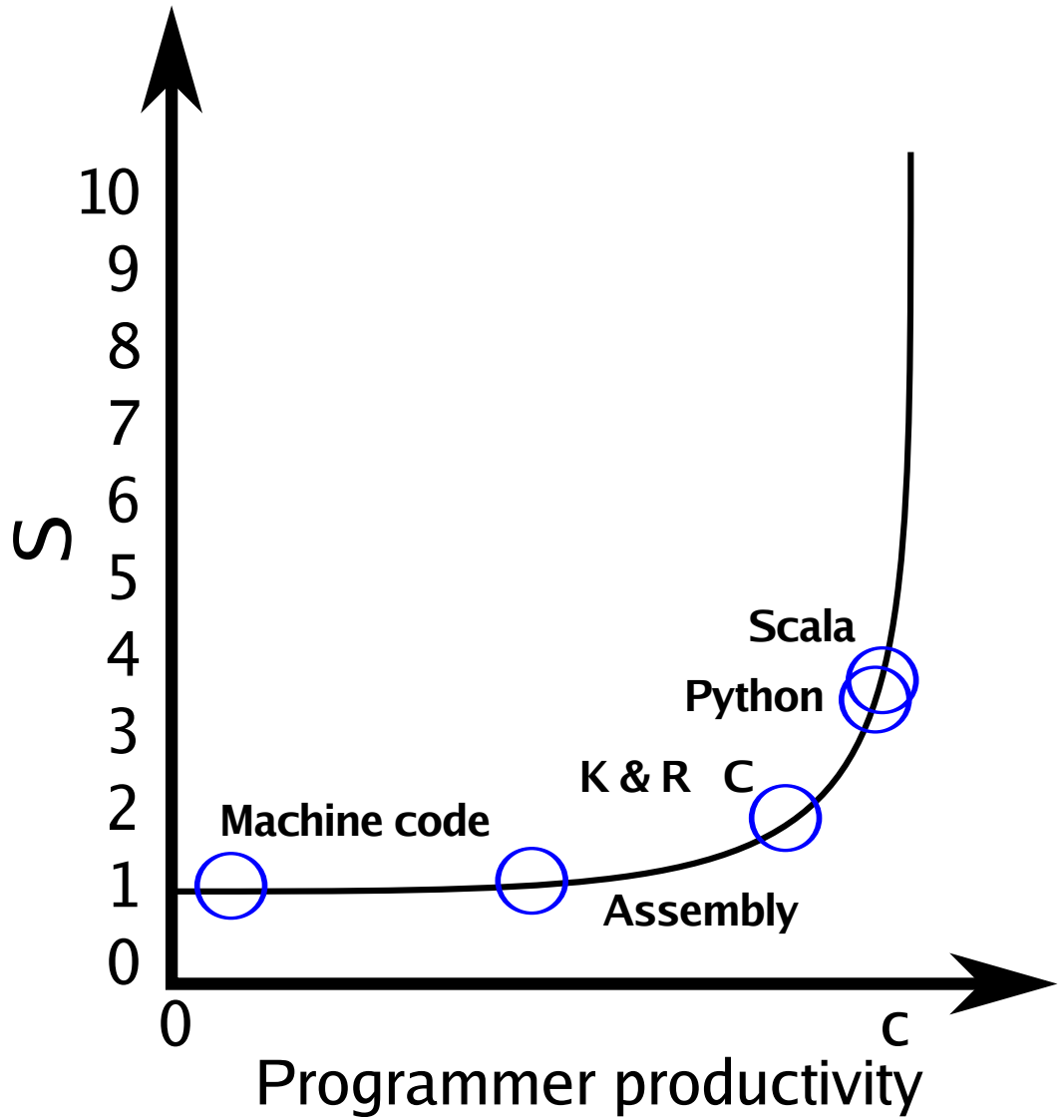

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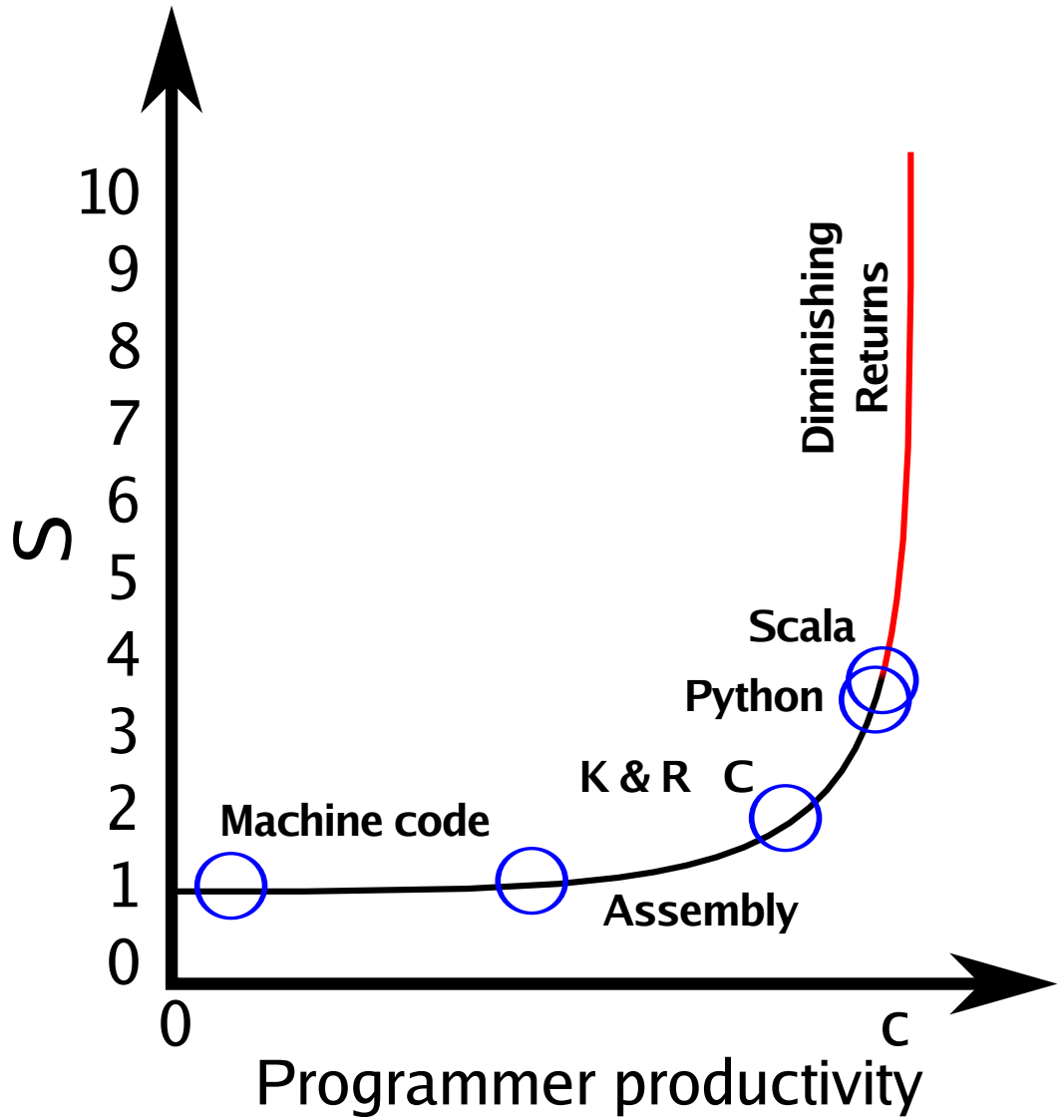
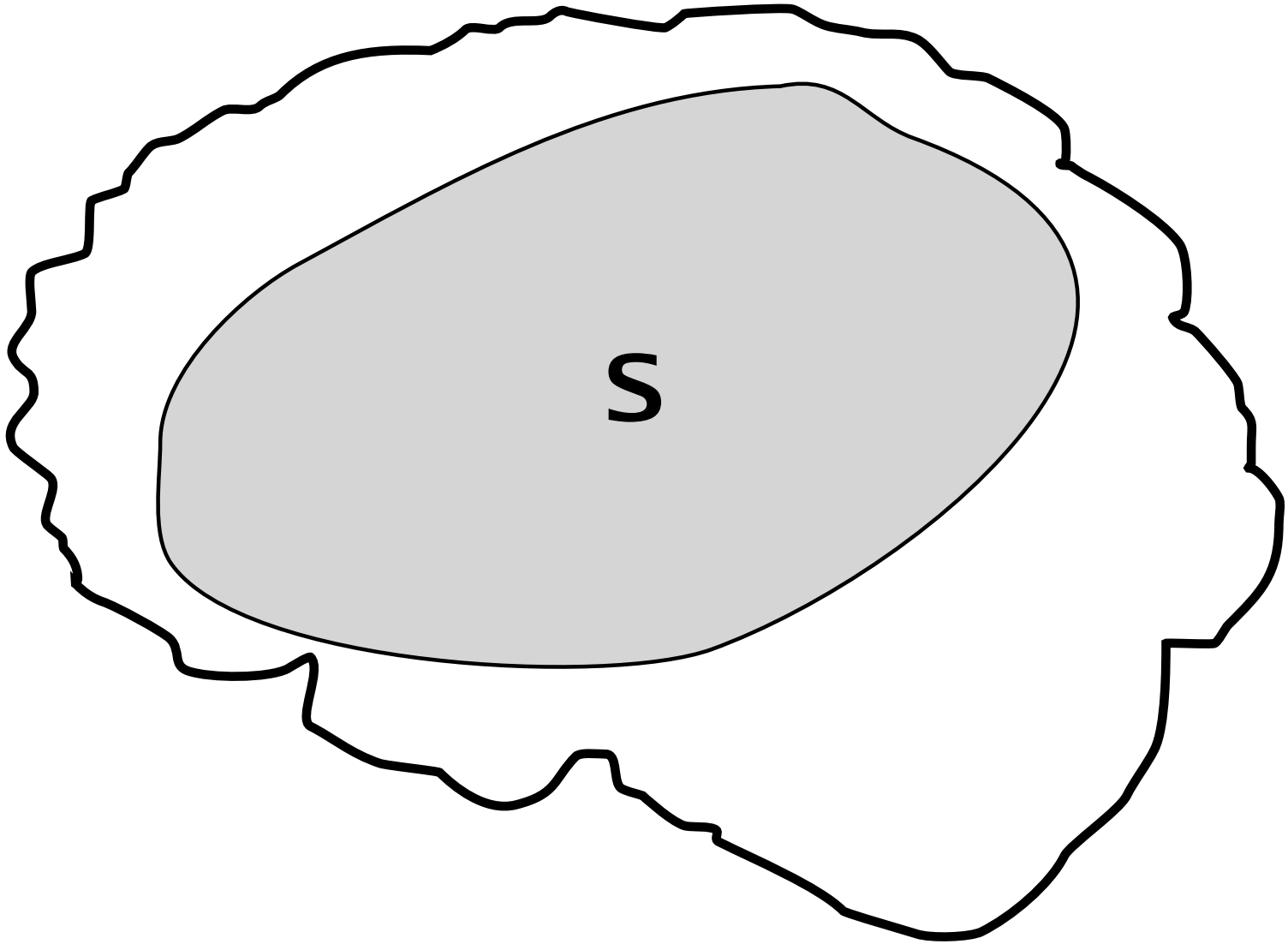


Can S become too big?



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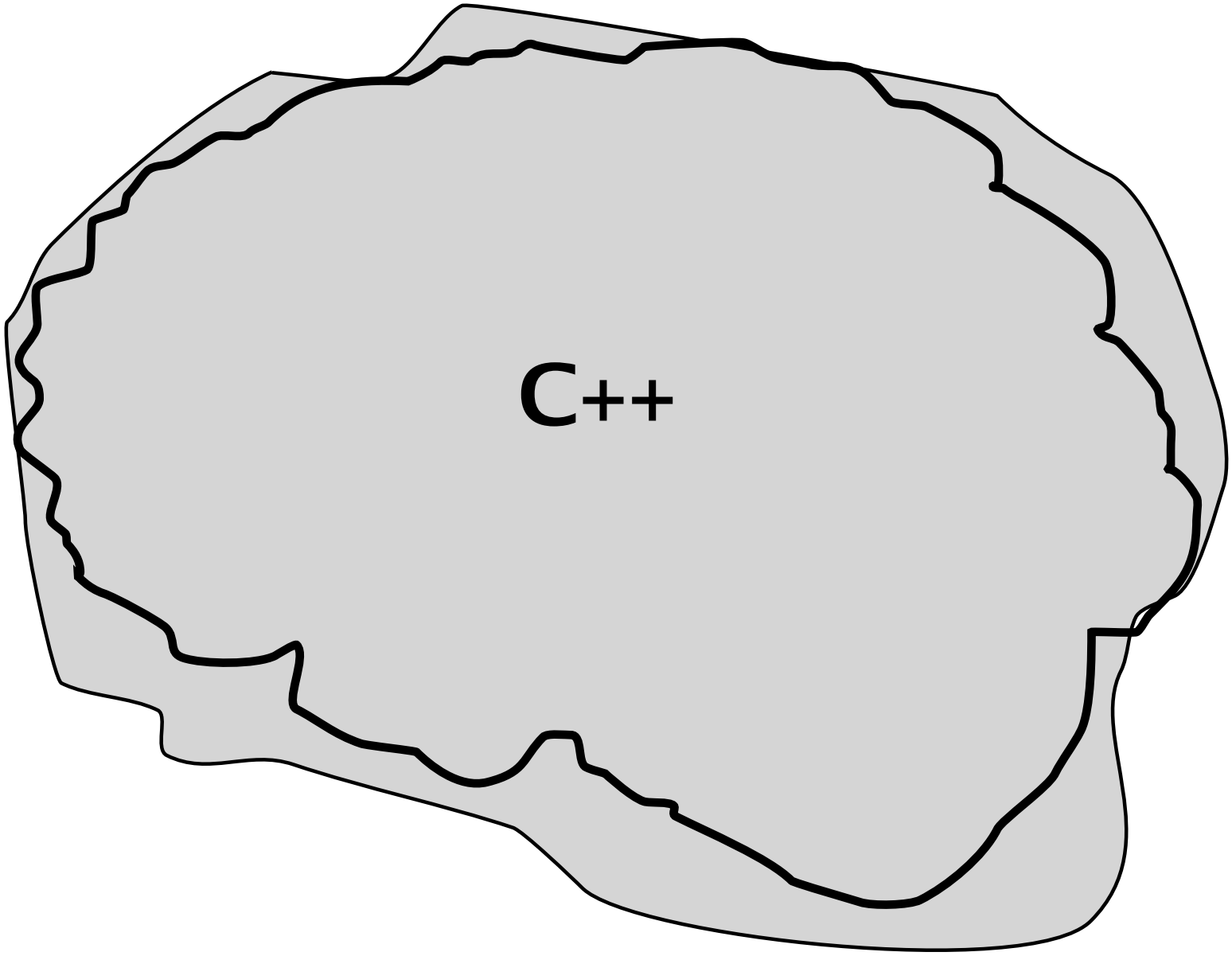
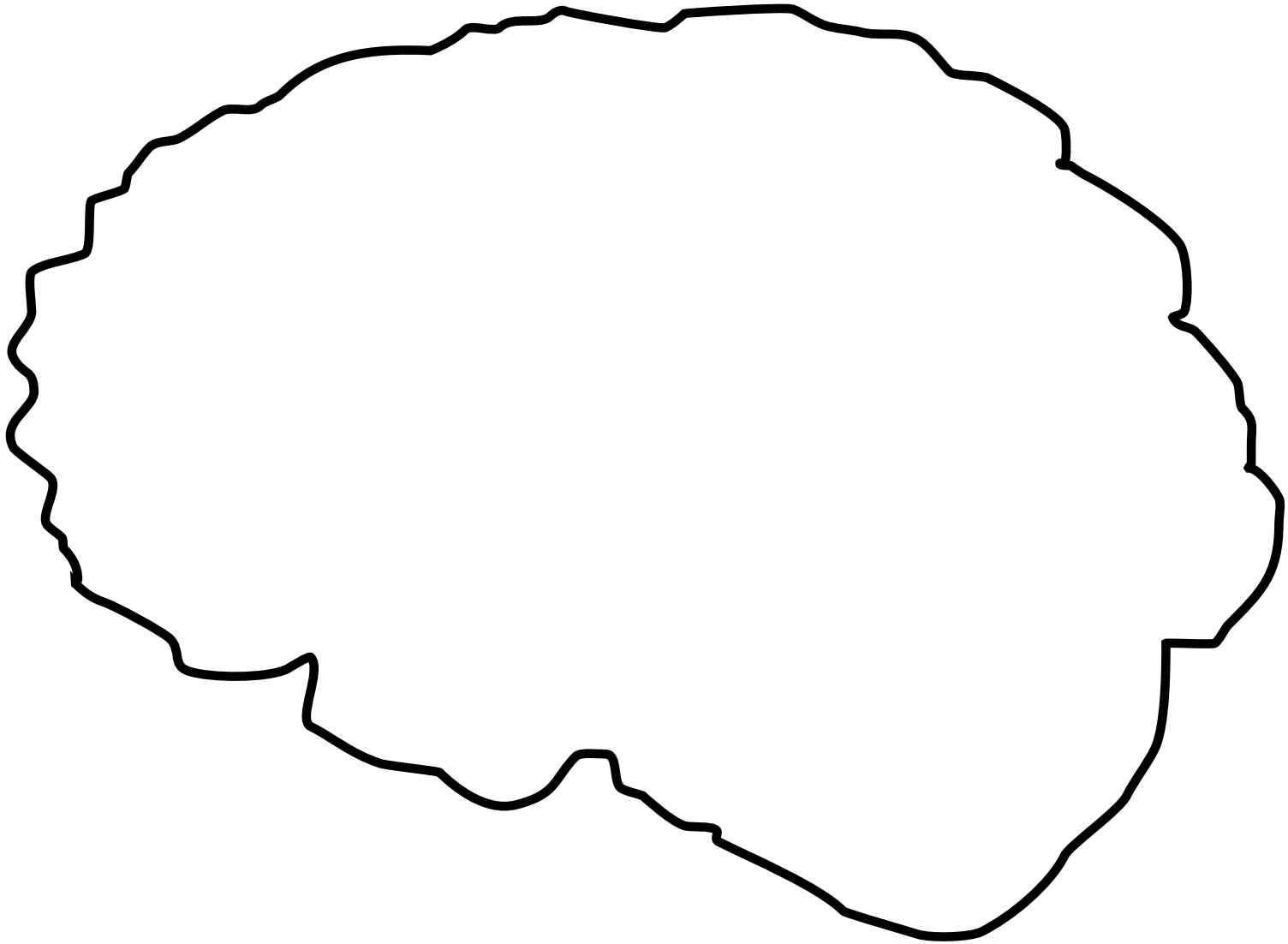


Wiggle room



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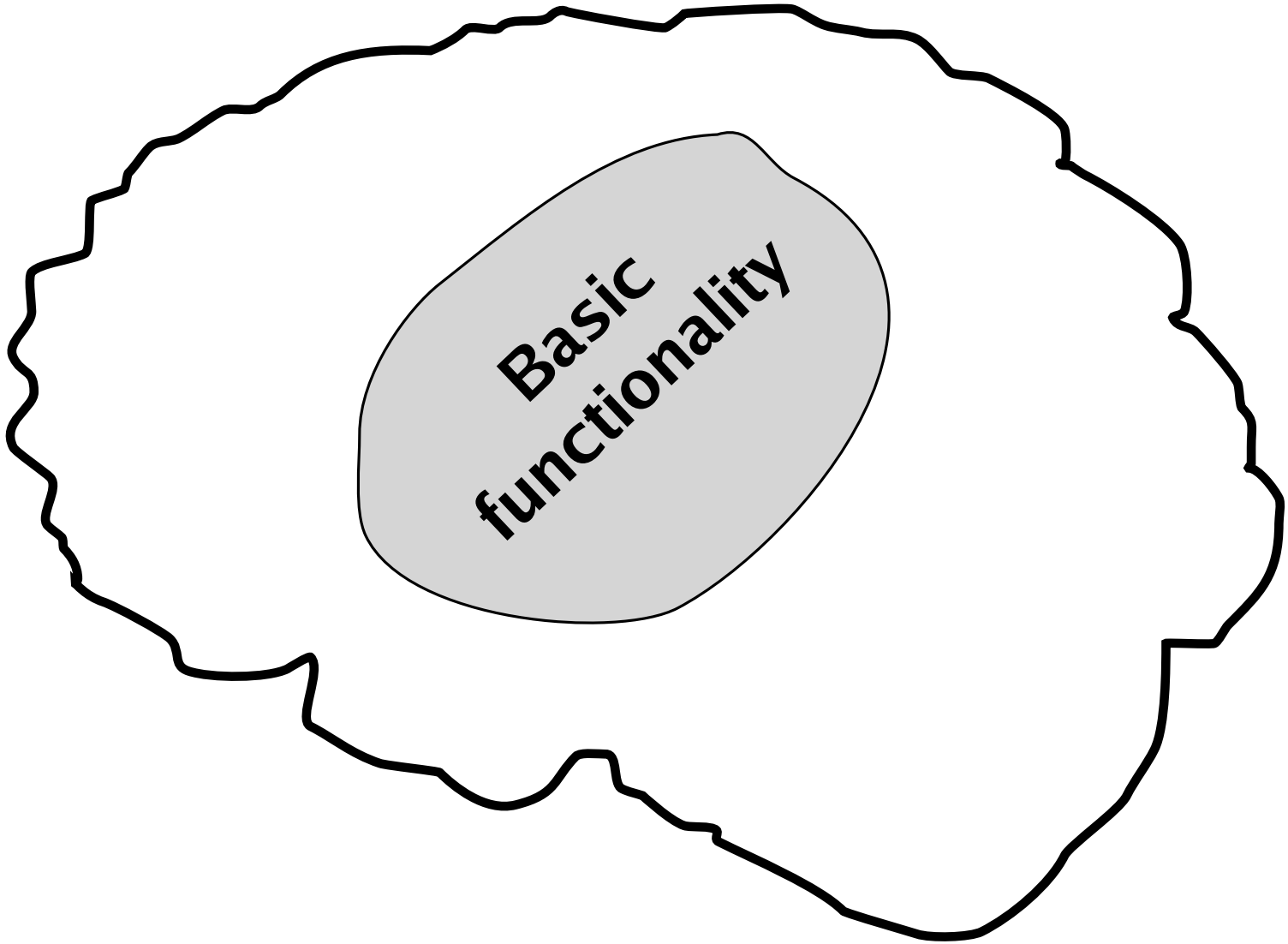

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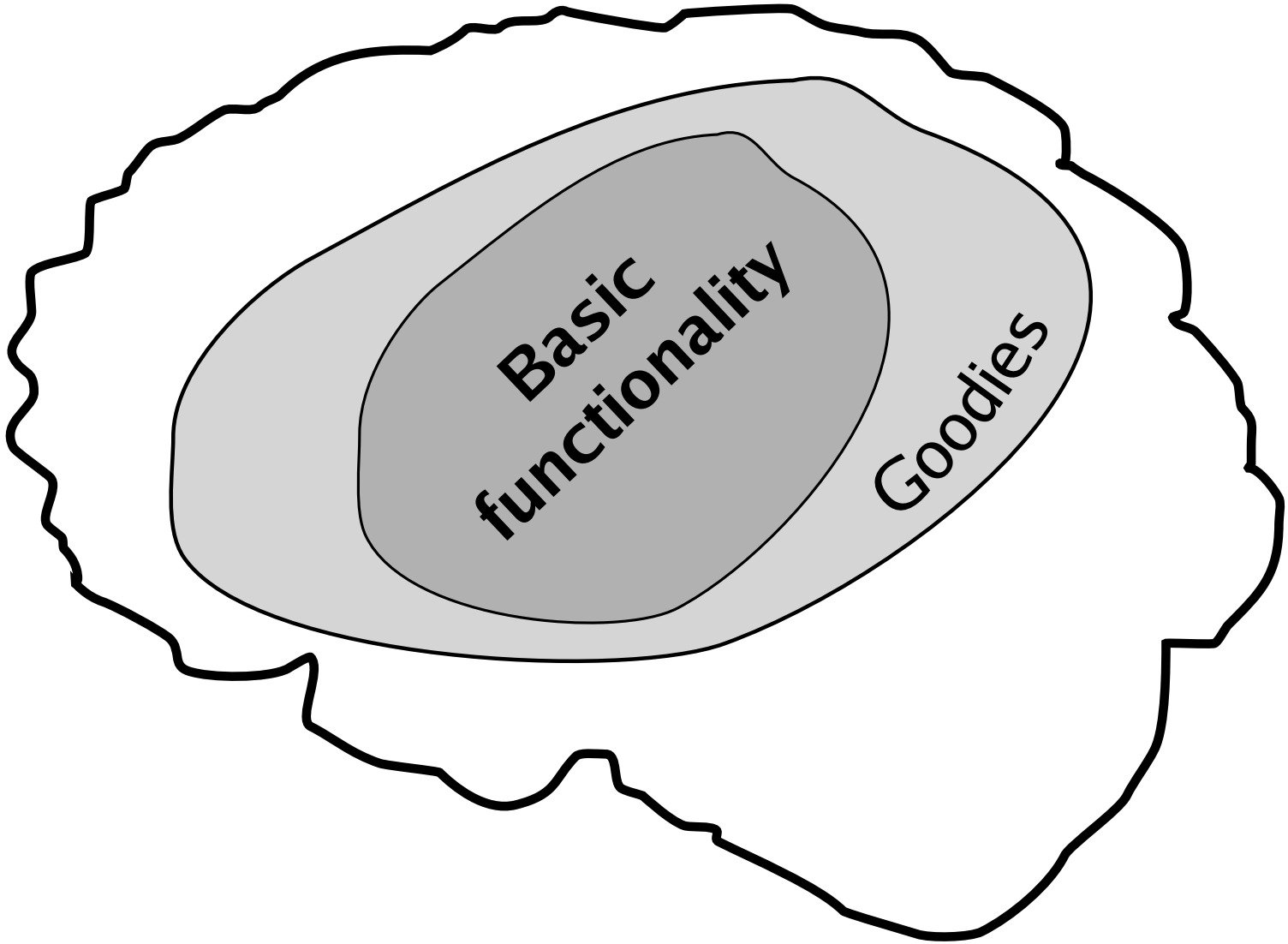
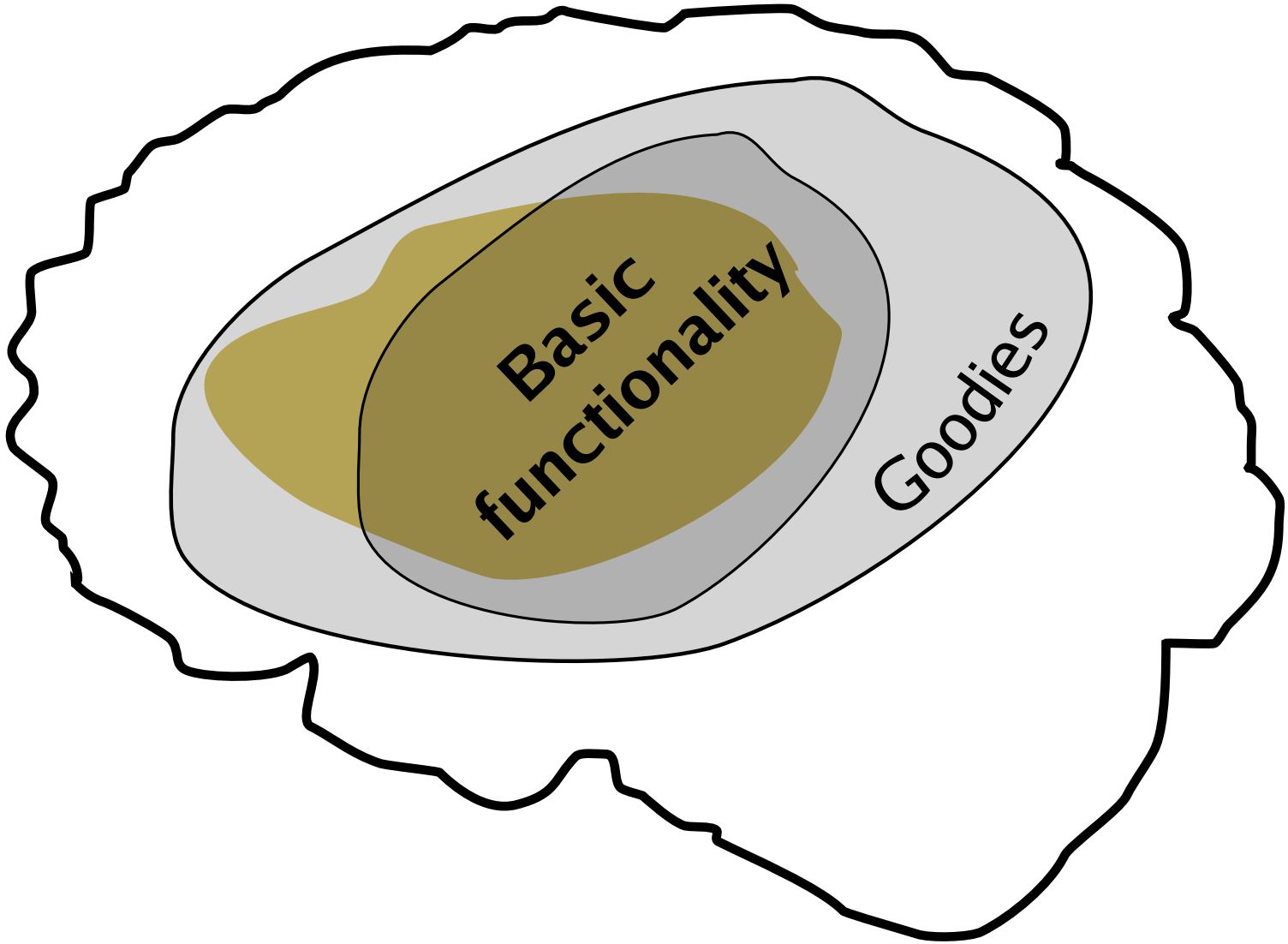


Even worse



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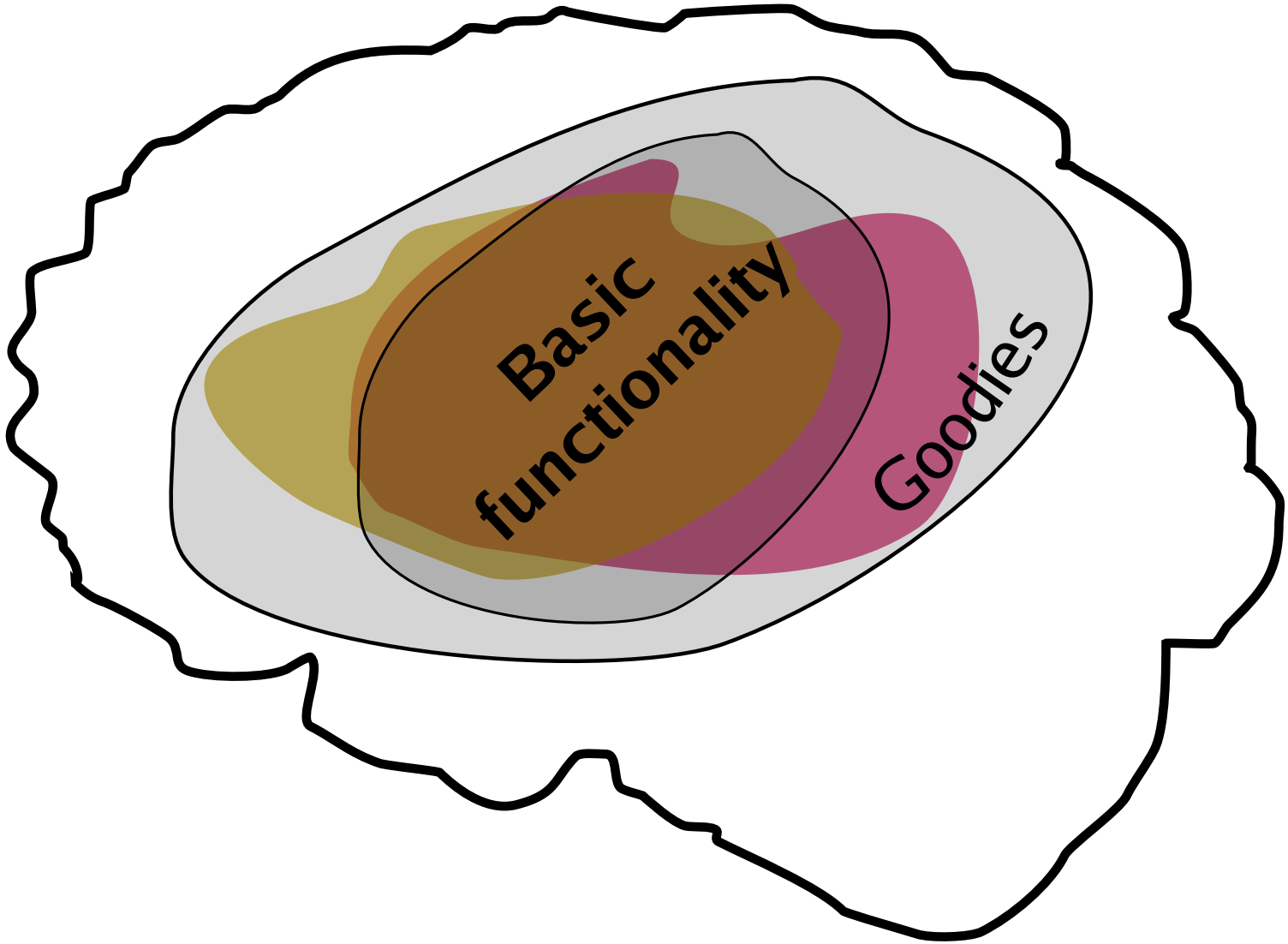

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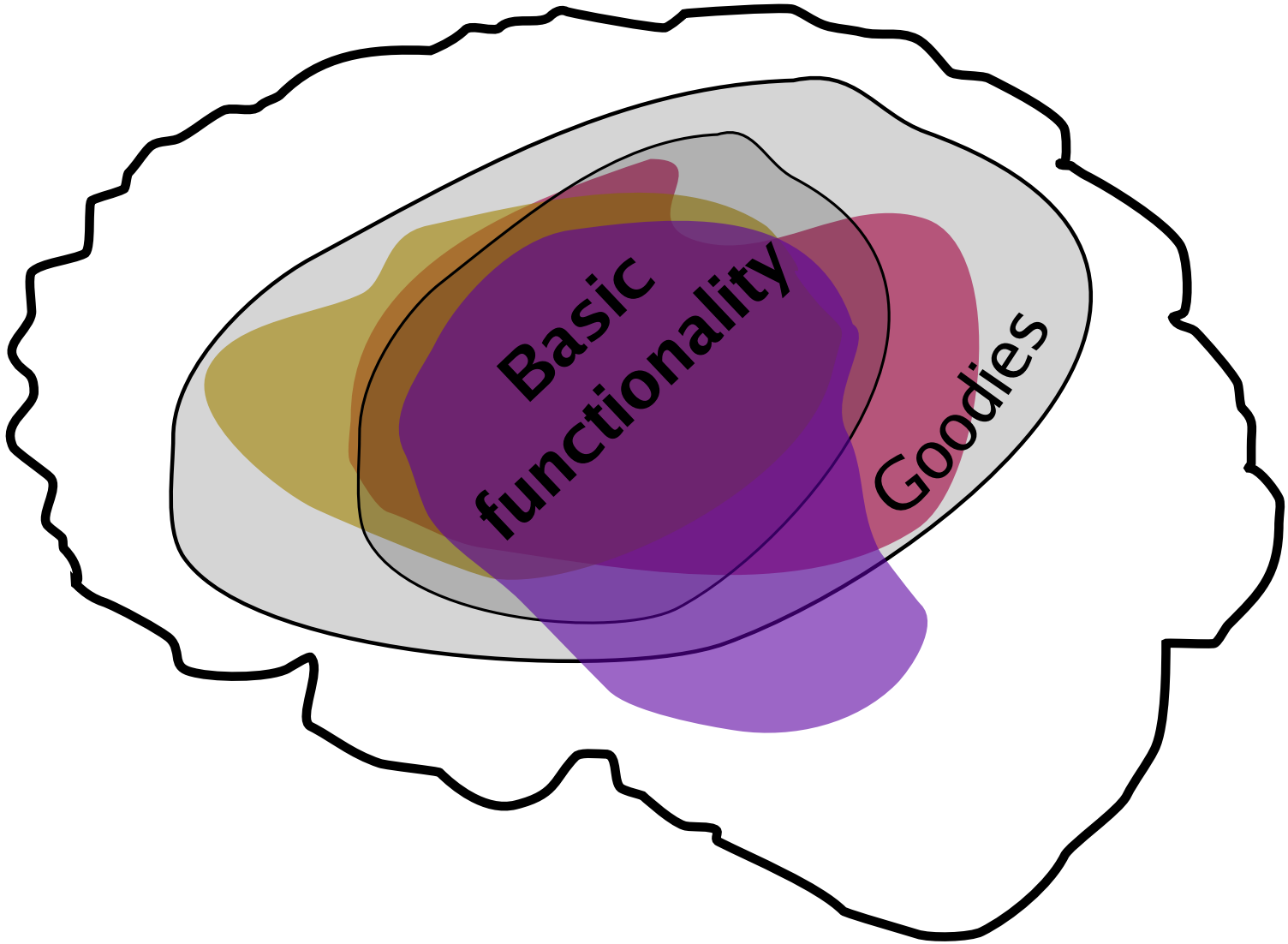

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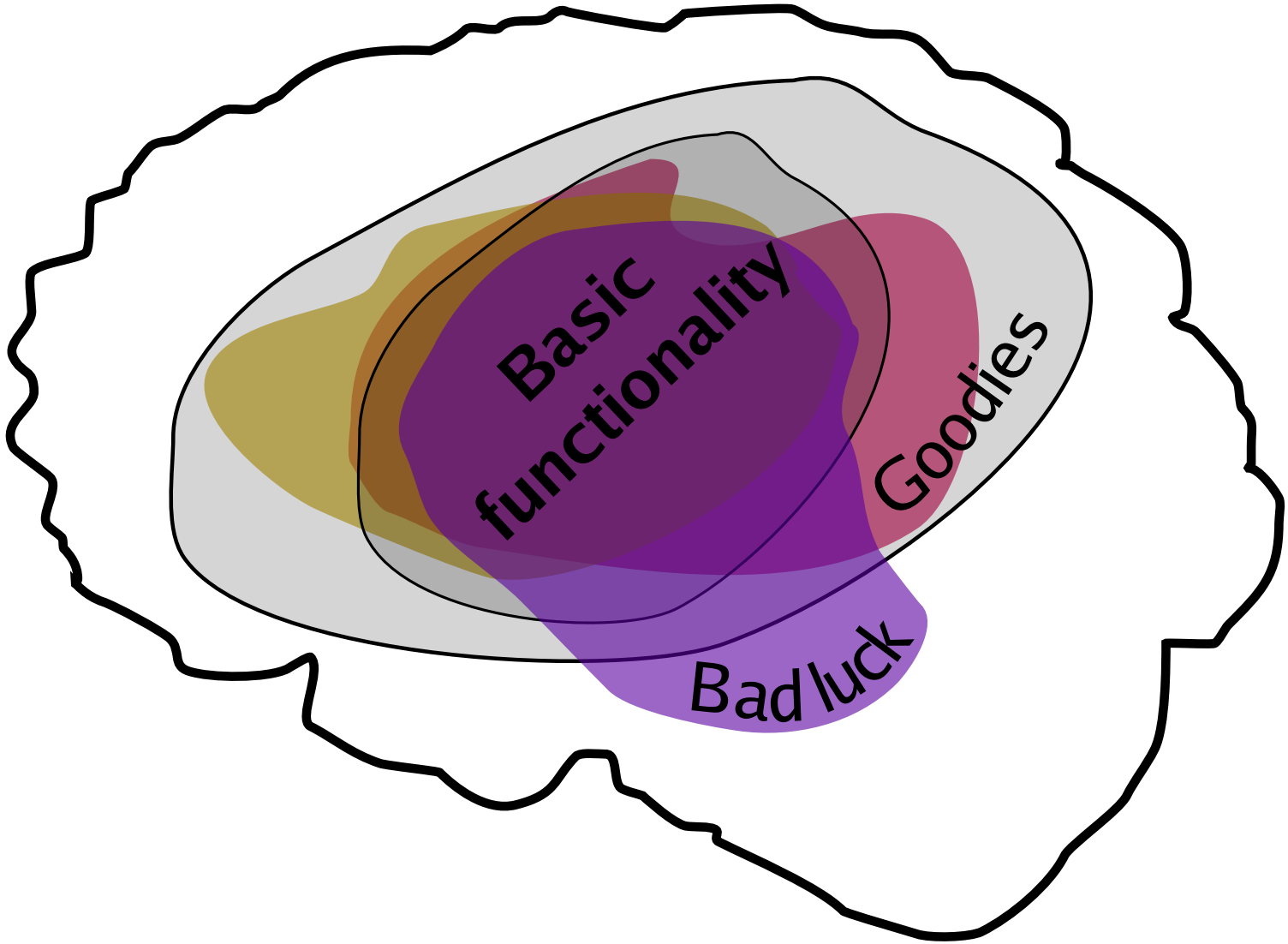
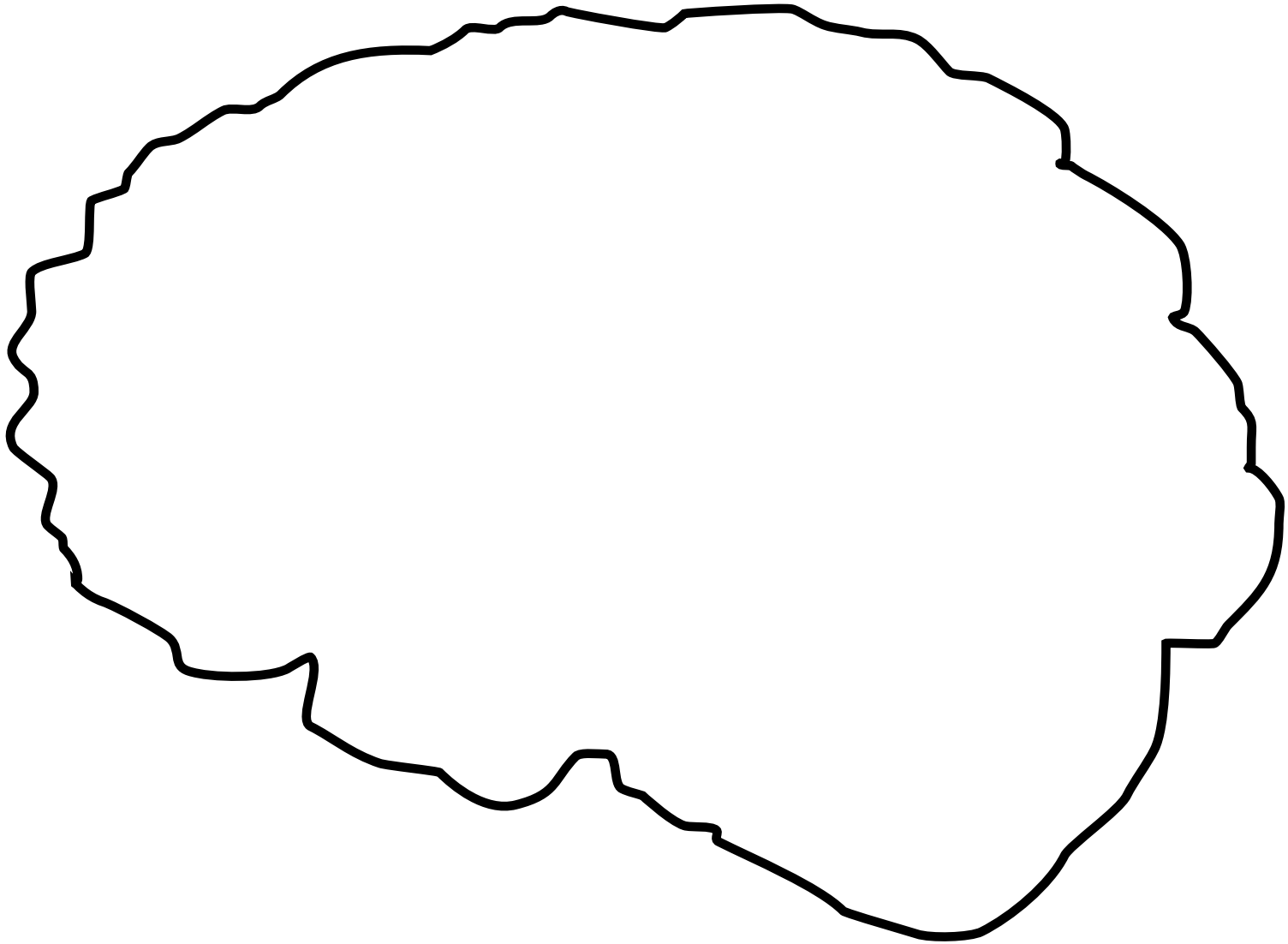


Is this about DSLs?



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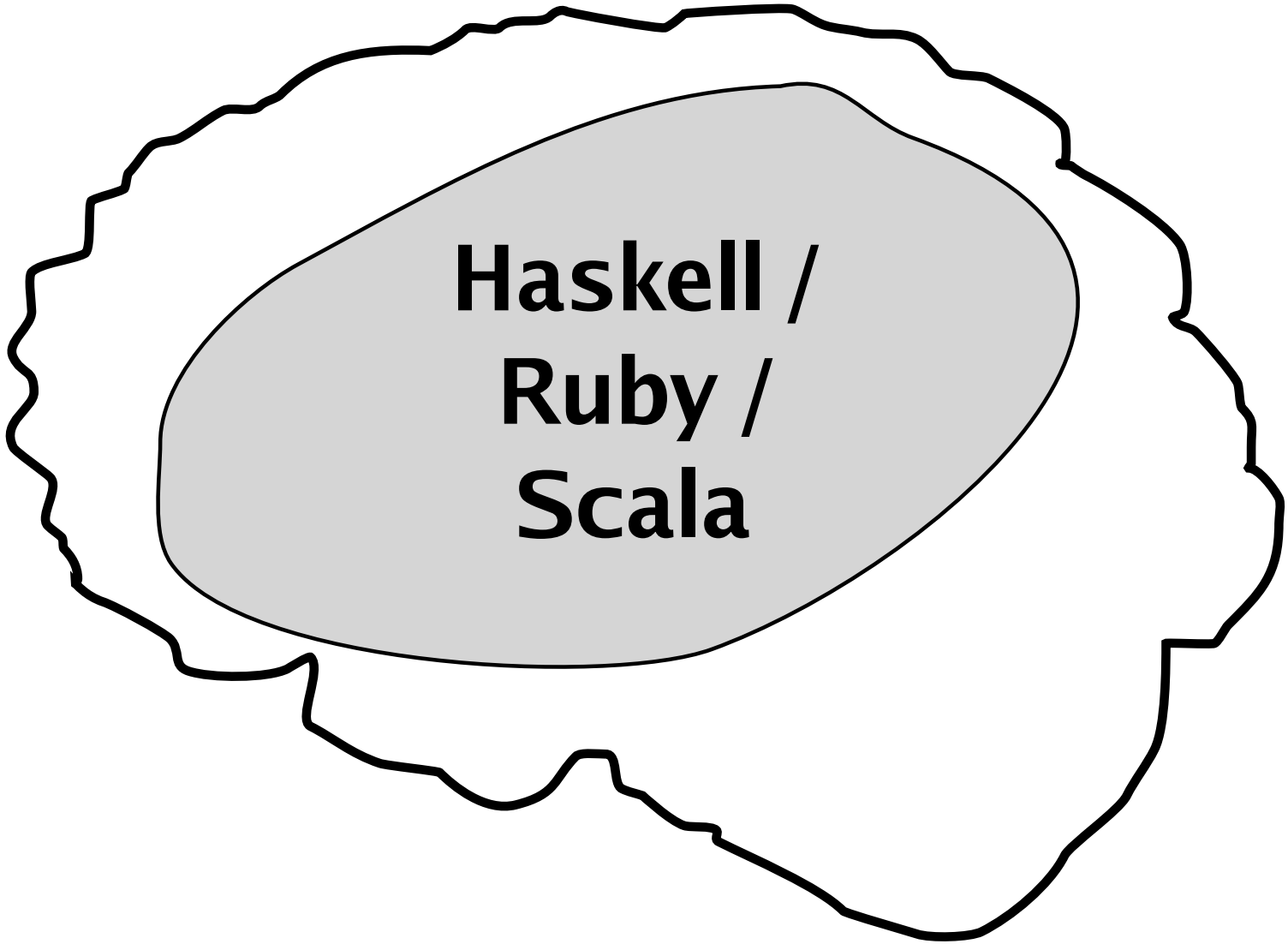

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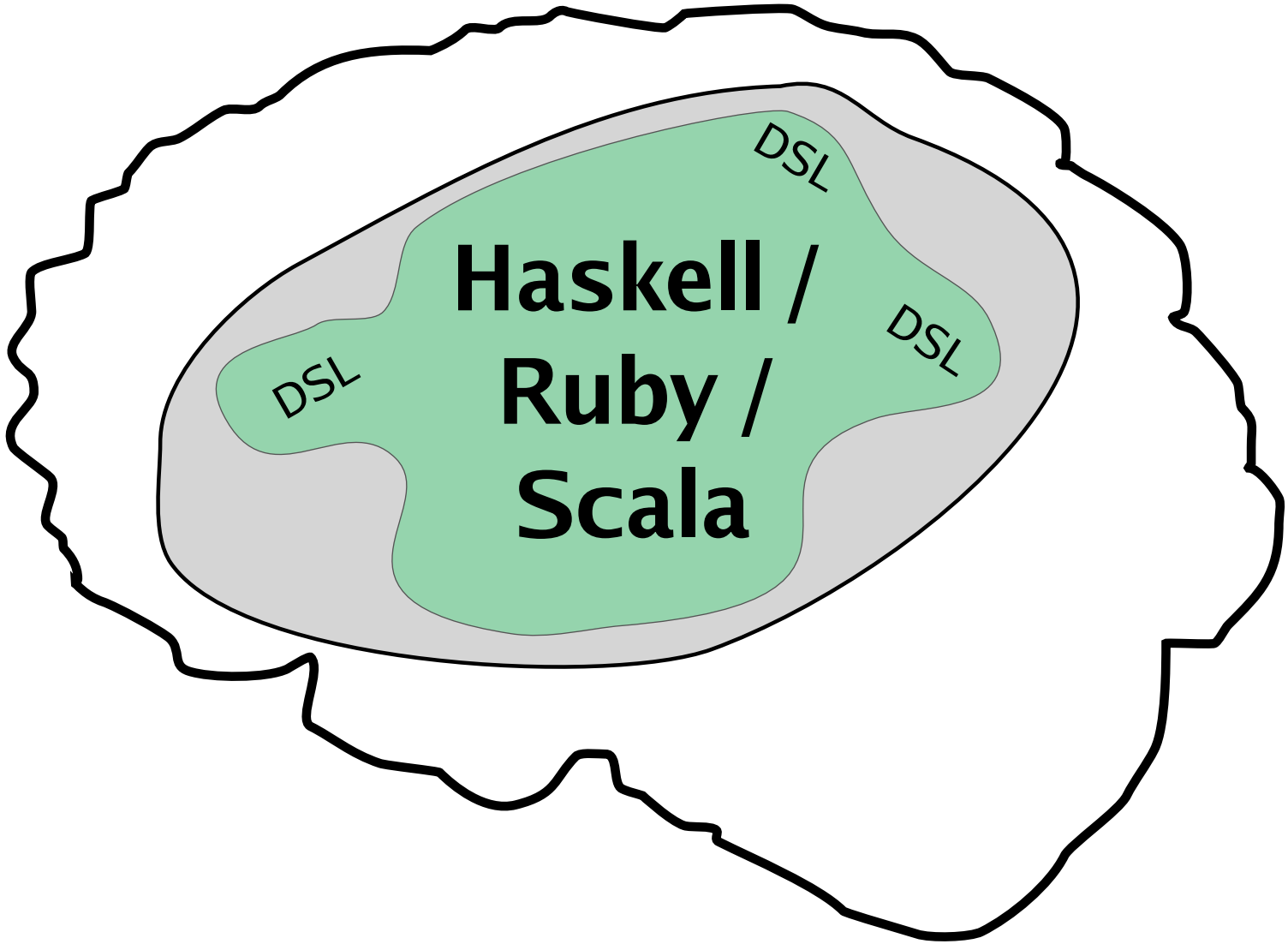

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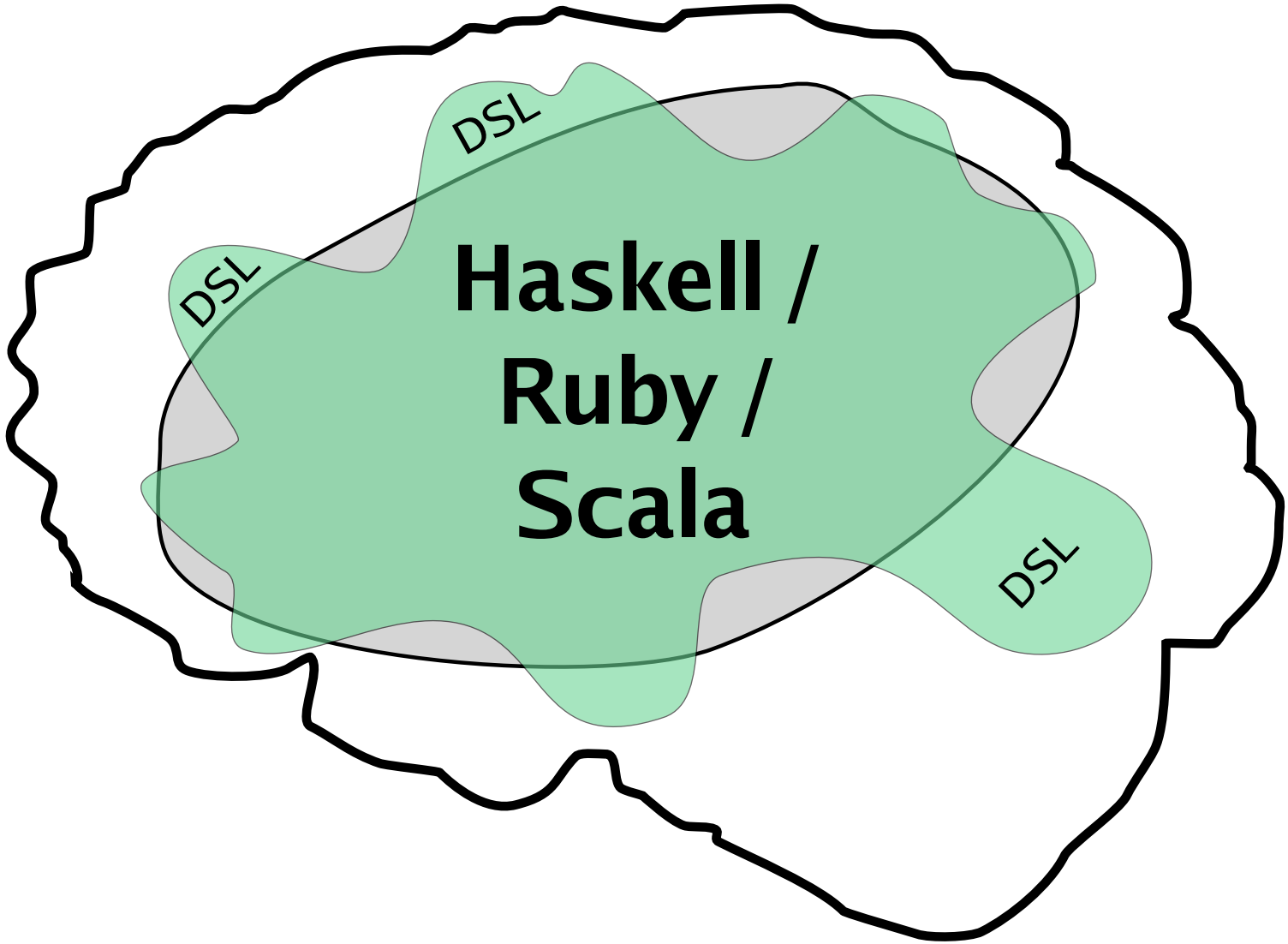

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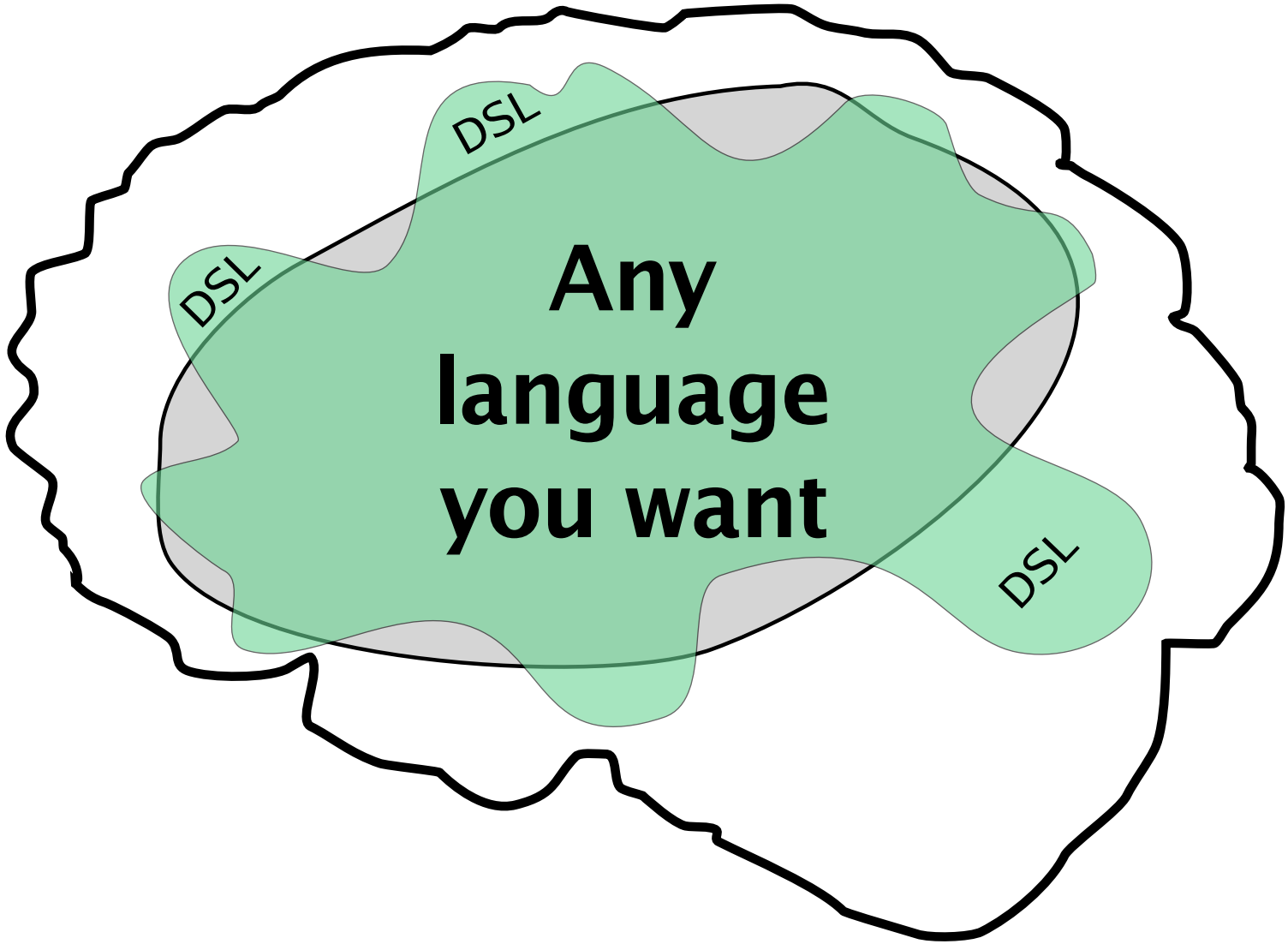

A way forward?

Idea: allow users to *compose* languages.

What does composition mean?

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$$\text{Language} \triangleq$$
$$\text{syntax} + \text{semantics}$$

What does composition mean?

$$\text{Language implementation} \triangleq \text{compiler} + \text{runtime}$$

What does composition mean?

$$\text{Language implementation} \triangleq \text{compiler} + \text{virtual machine}$$

What does composition mean?

$$\text{Compiler} \triangleq$$
$$\text{parser} + \text{code generator}$$

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$$\text{Compiler} \triangleq$$
$$\text{parser} + \cancel{\text{code generator}}$$

What does composition mean?

Minimally compose:

- parsers
- virtual machines

Example (1)

Example (1)

SQL and Java

```
for (pid : SELECT pid FROM personnel WHERE salary > 100000) {
   if (!is_worth_it(pid))
     UPDATE personnel SET salary=0 WHERE pid=pid;
}
```

Example (2)

Tax code

```
income tax {
  2010-2011 {
    allowance {
      age < 65: £6,475
      age >= 65 and age <= 74: £9,490
      age > 74: £9,640

      reduction: if income > £100,000 then
        max(0, allowance - ((income - £100,000) / 2))
    }
  }
}
```

Why aren’t we (me?) very good at it yet?

Converge

Converge

$$\text{Converge} \triangleq$$
$$\text{Python} + \text{macros}$$

$$\text{Converge} \triangleq$$
$$\text{Python} + \text{compile-time}$$
$$\text{meta-programming}$$

Compile-time meta-programming

Code (as trees, not text) is programmatically generated.

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Expression	`2 + 3`	evaluates to `5`.
Splice	`$<x>`	evaluates `x` at compile-time; AST returned overwrites splice.
Quasi-quote	`[| 2 + 3 |]`	evaluates to a *hygienic* AST representing `2 + 3`.
Insertion	`[| 2 + ${x} |]`	'inserts' AST `x` into the AST being created by the quasi-quotes.

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DSL Block	`$«x»: ...`	passes the text '...' to the function `x` at compile-time.

An example

Where it falls apart

- Parser composition: a mess.

Where it falls apart

- Parser composition: a mess.
- Extension languages second-class citizens.

Parsing composition

Should be easy

Parsing composition

- **LR**
- **Earley**
- **PEG**

Parsing composition

- **LR** composition undefined (in general).
- **Earley**
- **PEG**

Parsing composition

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- **PEG**

Parsing composition

- **LR** composition undefined (in general).
- **Earley** composition ambiguous (in general).
- **PEG** composition can shadow (in general).

Where it falls apart (2)

- Parser composition: a mess.
- Extension languages second-class citizens.

Where it falls apart (2)

- Parser composition: a mess.
- Extension languages second-class citizens.
- Text only.

Example (3)

Example (3)

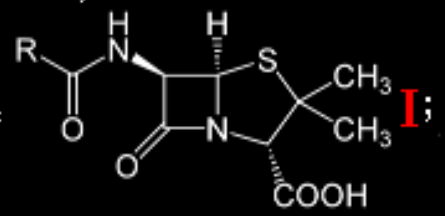
example.fnd - /home/ltratt/

File Edit Search Preferences Shell Macro Windows Help

/home/ltratt/example.fnd L: 24

```
func custom_prescription(Patient p) : Medicine
{
    if (p.penicillin_allergy())
        return NULL;

    Medicine m =
```




```
;

    candidate = generate(P, m);
    if (!check_with_doctor(candidate))
        return NULL;
    m.set_variable(R, candidate);

    return m;
}
```

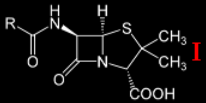
Example (4)

example.fnd - /home/ltratt/

File Edit Search Preferences Shell Macro Windows Help

/home/ltratt/example.fnd L:224

```
func check_all_suitabile(trial_id):
  for patient_id in SELECT pid FROM trial WHERE id=${trial_id}:
    if | SELECT * FROM prescribed                                | > 0:
       | WHERE contains(drug,                                  ) |
      warn("Patient ${patient_id} currently prescribed a "
        "penicillin derived anti-biotic and must be "
        "seen by a specialist before trial begins.")
```



What are our options?

Abandon parsing...

Abandon parsing...

...for SDE?

Language composition editor

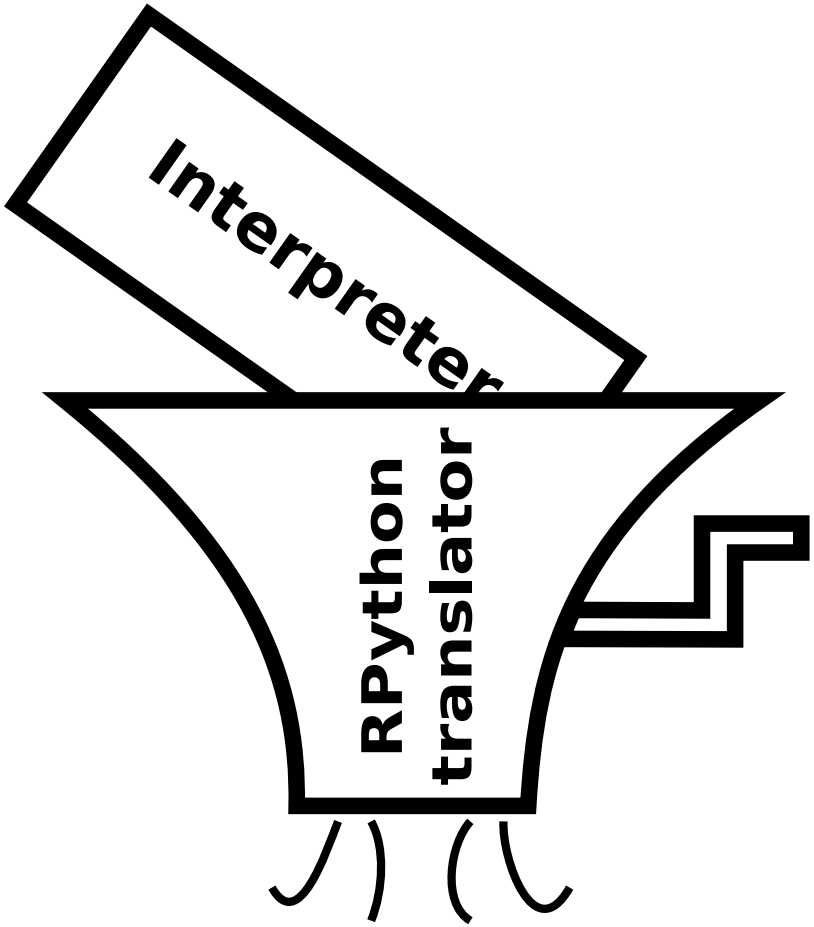
This research graciously funded by Oracle.

Boil down to the JVM

~~Boil down to the JVM~~

Meta-tracing / Truffle

RPython translation



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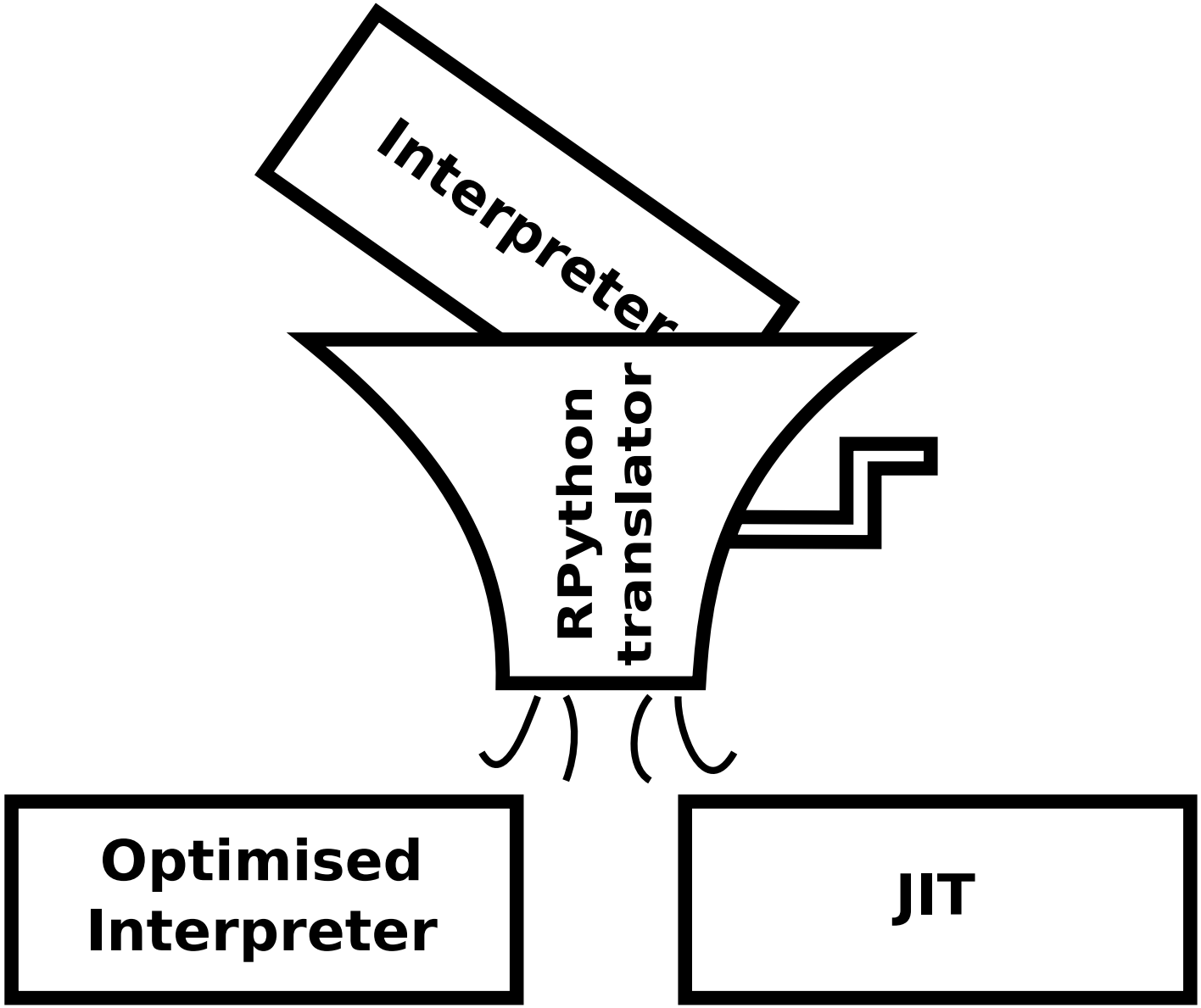

Adding a JIT to an RPython interpreter

```
...
pc := 0
while 1:

    instr := load_next_instruction(pc)
    if instr == POP:
        stack.pop()
        pc += 1
    elif instr == BRANCH:
        off = load_branch_jump(pc)

        pc += off
    elif ...:
        ...
```

Observation: interpreters are big loops.

Adding a JIT to an RPython interpreter

```
...
pc := 0
while 1:
    jit_merge_point(pc)
    instr := load_next_instruction(pc)
    if instr == POP:
        stack.pop()
        pc += 1
    elif instr == BRANCH:
        off = load_branch_jump(pc)
        if off < 0: can_enter_jit(pc)
        pc += off
    elif ...:
        ...
```

Observation: interpreters are big loops.

User program (lang *FL*)

```
if x < 0:
  x = x + 1
else:
  x = x + 2
x = x + 3
```

Tracing JITs

User program (lang *FL*)	Trace when x is set to 6
`if x < 0:`	`guard_type(x, int)`
`  x = x + 1`	`guard_not_less_than(x, 0)`
`else:`	`guard_type(x, int)`
`  x = x + 2`	`x = int_add(x, 2)`
`x = x + 3`	`guard_type(x, int)`
	`x = int_add(x, 3)`

Tracing JITs

User program (lang *FL*)	Optimised trace

`if x < 0:`
`  x = x + 1`
`else:`
`  x = x + 2`
`x = x + 3`
	`guard_type(x, int)`
	`guard_not_less_than(x, 0)`
	`x = int_add(x, 5)`

Converge 1 vs. Converge 2 VMs

	Converge 1	Converge 2
Size (KLoc)		
Effort (man months)		
Performance		

Converge 1 vs. Converge 2 VMs

	Converge 1	Converge 2
Size (KLoc)	13	
Effort (man months)		
Performance		

Converge 1 vs. Converge 2 VMs

	Converge 1	Converge 2
Size (KLoc)	13	5.5
Effort (man months)		
Performance		

Converge 1 vs. Converge 2 VMs

	Converge 1	Converge 2
Size (KLoc)	13	5.5
Effort (man months)	18	
Performance		

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Size (KLoc)	13	5.5
Effort (man months)	18	3
Performance	x	2-150x

Dhrystone benchmark

	50000	5000000
C (GCC 4.6.3)	0.004 ± 0.002	0.179 ± 0.010
HotSpot (1.7.0_09)	0.107 ± 0.006	0.240 ± 0.010
Converge1 (git #68c795d2be)	2.053 ± 0.029	207.274 ± 3.048
Converge2 (2.0)	0.118 ± 0.004	1.914 ± 0.022
Lua (5.2.1)	0.201 ± 0.008	19.417 ± 0.474
LuaJIT2 (2.0.0)	0.014 ± 0.006	0.879 ± 0.016
CPython (2.7.3)	0.368 ± 0.010	35.072 ± 0.537
Jython (2.5.3)	1.820 ± 0.029	28.432 ± 0.466
PyPy–nonopt (1.9*)	0.127 ± 0.006	5.898 ± 0.071
PyPy (1.9)	0.069 ± 0.008	1.085 ± 0.014
Ruby (1.9.3-p327)	0.312 ± 0.008	29.819 ± 0.257
JRuby (1.7.1)	2.050 ± 0.039	10.576 ± 0.304

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Lua (5.2.1)	0.665	± 0.024	6.574	± 0.139
LuaJIT2 (2.0.0)	0.085	± 0.006	0.763	± 0.010
CPython (2.7.3)	1.585	± 0.022	15.698	± 0.227
Jython (2.5.3)	2.820	± 0.069	13.870	± 0.345
PyPy–nonopt (1.9*)	0.515	± 0.010	2.839	± 0.016
PyPy (1.9)	0.267	± 0.006	0.544	± 0.008
Ruby (1.9.3-p327)	0.793	± 0.018	7.159	± 0.061
JRuby (1.7.1)	2.130	± 0.025	3.640	± 0.053

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CPython (2.7.3)	1.585	± 0.022	15.698	± 0.227
Jython (2.5.3)	2.820	± 0.069	13.870	± 0.345
PyPy–nonopt (1.9*)	0.515	± 0.010	2.839	± 0.016
PyPy (1.9)	**0.267**	± 0.006	**0.544**	± 0.008
Ruby (1.9.3-p327)	0.793	± 0.018	7.159	± 0.061
JRuby (1.7.1)	2.130	± 0.025	3.640	± 0.053

Richards benchmark

	10		100	
C (GCC 4.6.3)	0.012	± 0.006	0.079	± 0.006
HotSpot (1.7.0_09)	**0.109**	± 0.010	**0.169**	± 0.014
Converge1 (git #68c795d2be)	9.931	± 0.102	100.216	± 1.356
Converge2 (2.0)	0.637	± 0.006	2.850	± 0.014
Lua (5.2.1)	0.665	± 0.024	6.574	± 0.139
LuaJIT2 (2.0.0)	0.085	± 0.006	0.763	± 0.010
CPython (2.7.3)	1.585	± 0.022	15.698	± 0.227
Jython (2.5.3)	2.820	± 0.069	13.870	± 0.345
PyPy–nonopt (1.9*)	0.515	± 0.010	2.839	± 0.016
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JRuby (1.7.1)	**2.130**	± 0.025	**3.640**	± 0.053

Fannkuch-redux benchmark

	10		11	
C (GCC 4.6.3)	0.163	± 0.006	1.992	± 0.010
HotSpot (1.7.0_09)	0.350	± 0.008	3.448	± 0.029
Converge1 (git #68c795d2be)	†		†	
Converge2 (2.0)	2.658	± 0.041	33.484	± 0.517
Lua (5.2.1)	7.683	± 0.321	100.536	± 2.475
LuaJIT2 (2.0.0)	0.339	± 0.008	4.180	± 0.010
CPython (2.7.3)	9.167	± 0.237	114.001	± 2.189
Jython (2.5.3)	7.776	± 0.419	76.069	± 4.753
PyPy–nonopt (1.9*)	1.402	± 0.022	16.989	± 0.220
PyPy (1.9)	1.256	± 0.024	15.239	± 0.223
Ruby (1.9.3-p327)	13.152	± 0.200	172.098	± 2.168
JRuby (1.7.1)	6.313	± 0.127	61.934	± 1.513

Meta-tracing composition

- Composition of interpreters is feasible.

Meta-tracing composition

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- Challenges:

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  1. Isolation.

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  2. Communication.

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  3. Performance.

Meta-tracing composition

- Composition of interpreters is feasible.
- Challenges:
  1. Isolation.
  2. Communication.
  3. Performance.
- EPSRC ‘Cooler’ project starting June 2013.

Put it together

Compose:

- parsers
- virtual machines

Put it together

Compose:

- parsers *Incremental parsing*
- virtual machines

Put it together

Compose:

- parsers *Incremental parsing*
- virtual machines *Meta-tracing / Truffle*

Summary

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- The status quo needn’t be so.

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Summary

- The status quo needn’t be so.
- Language composition might offer a way forward.
- We’re not very good at it yet.
- Incremental parsing and meta-tracing *might* save us.

Further reading

- *Parsing: the solved problem that isn't*, Tratt
- The impact of meta-tracing on VM design and implementation, Bolz, Tratt
- Converge: http://convergepl.org/

Thank you for listening