/INFOMOV/

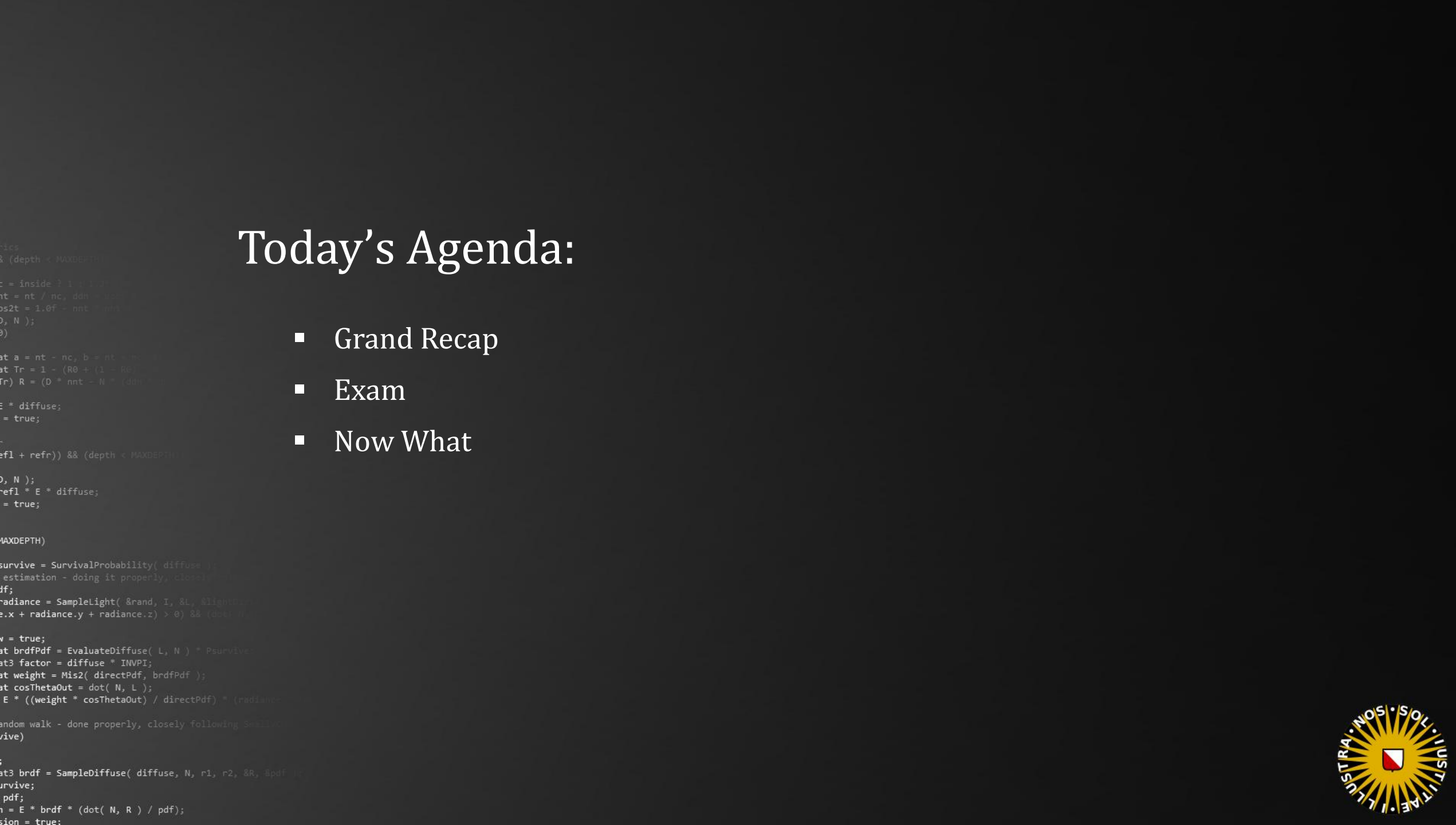
Optimization & Vectorization

J. Bikker - Sep-Nov 2018 - Lecture 15: “Grand Recap”

Welcome!

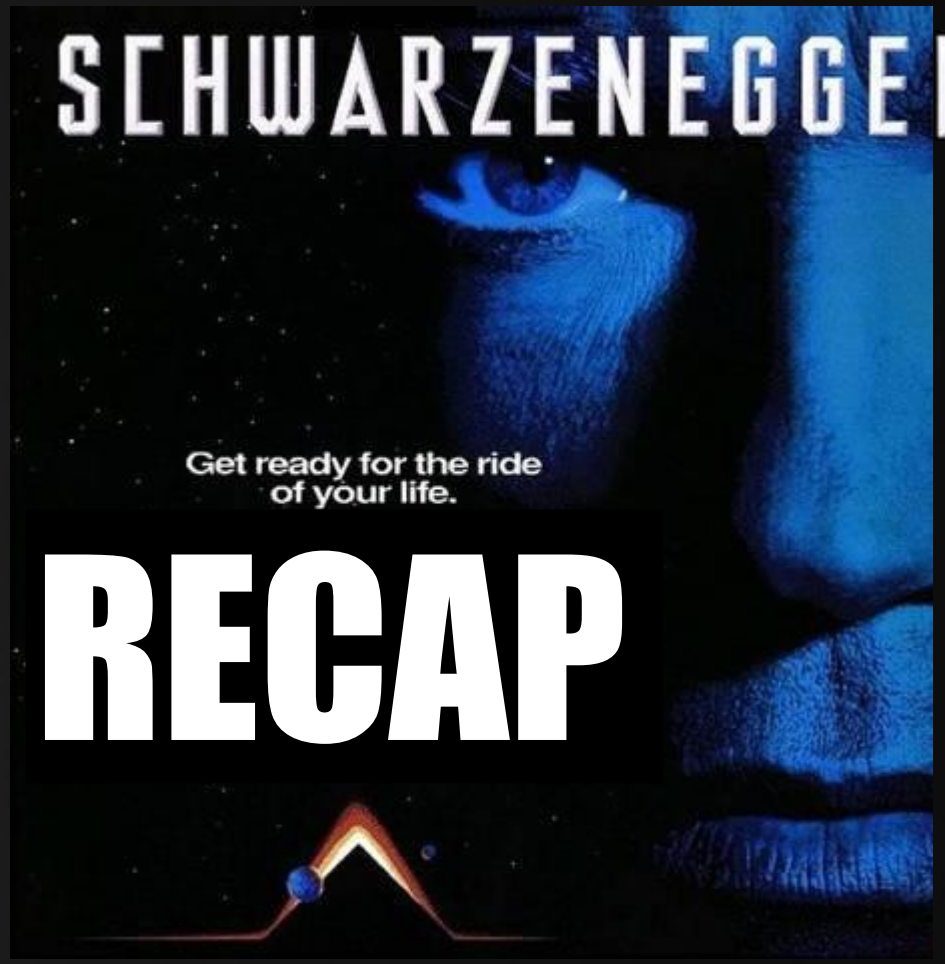
Today’s Agenda:

- Grand Recap
- Exam
- Now What



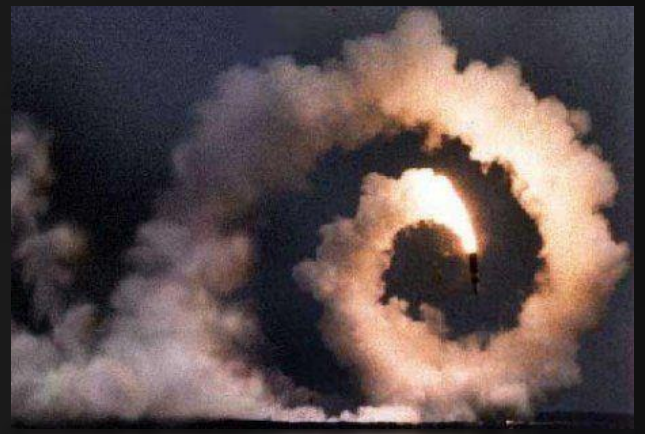
Today's Agenda:

- Grand Recap
- Exam
- Now What



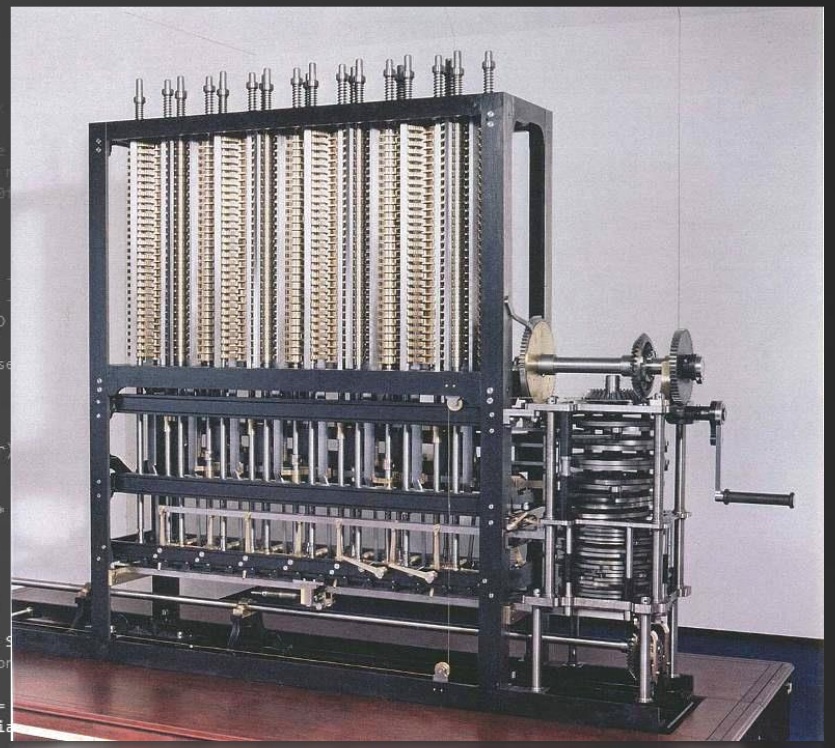
TOTAL RECAP

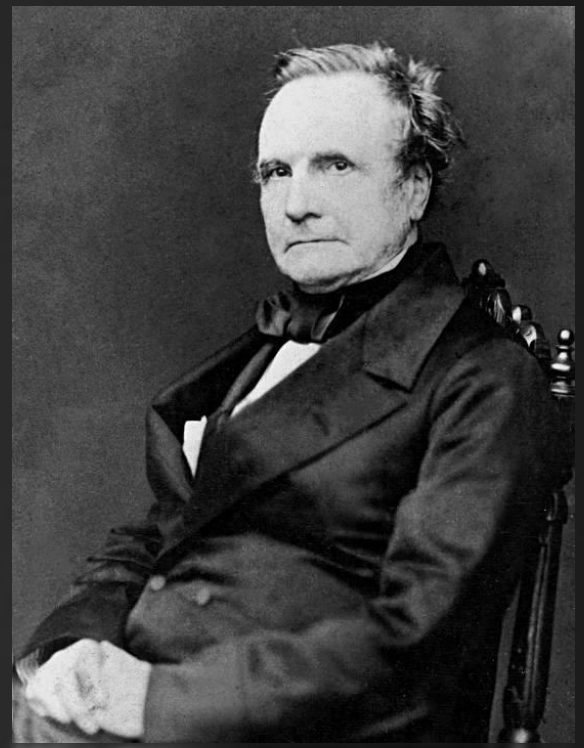
Recap



Recap

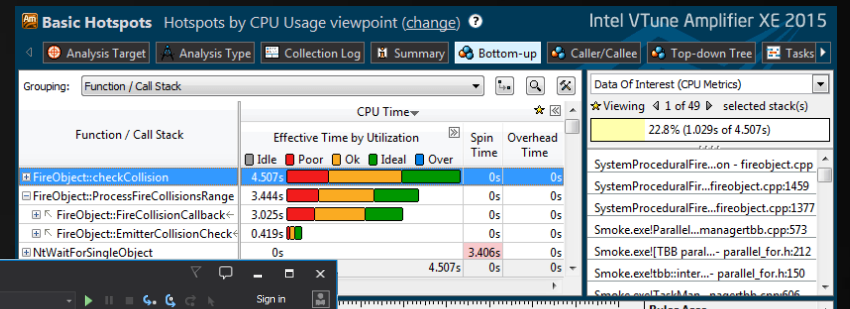
Recap – lecture 1

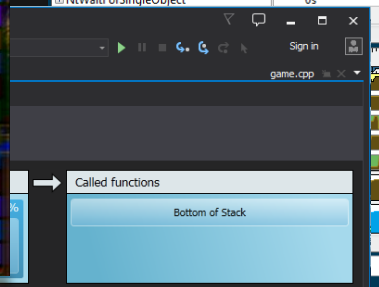


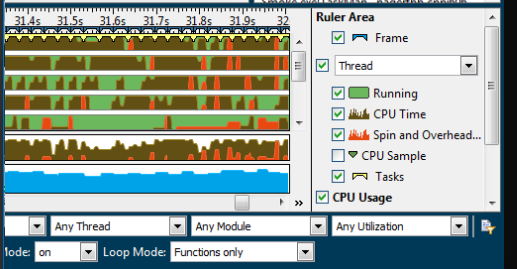


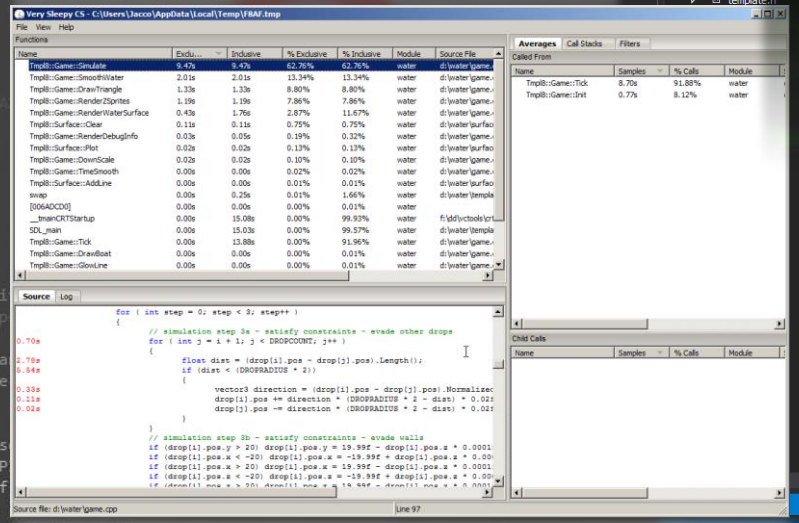
- Profiling
- High Level
- Basic Low Level
- **Cache & Memory**
- Data-centric
- Compilers
- Fixed-point Arithmetic
- CPU architecture
- **SIMD**
- GPGPU

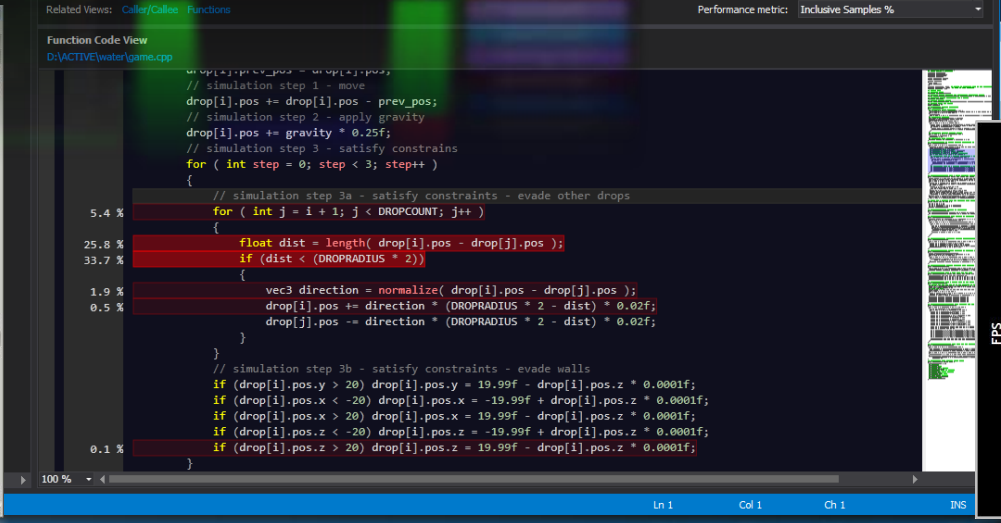
Recap – lecture 1

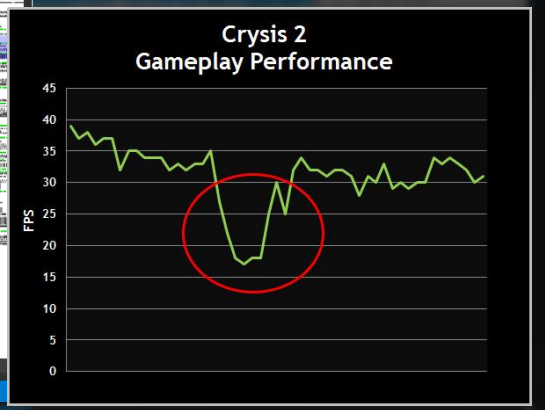




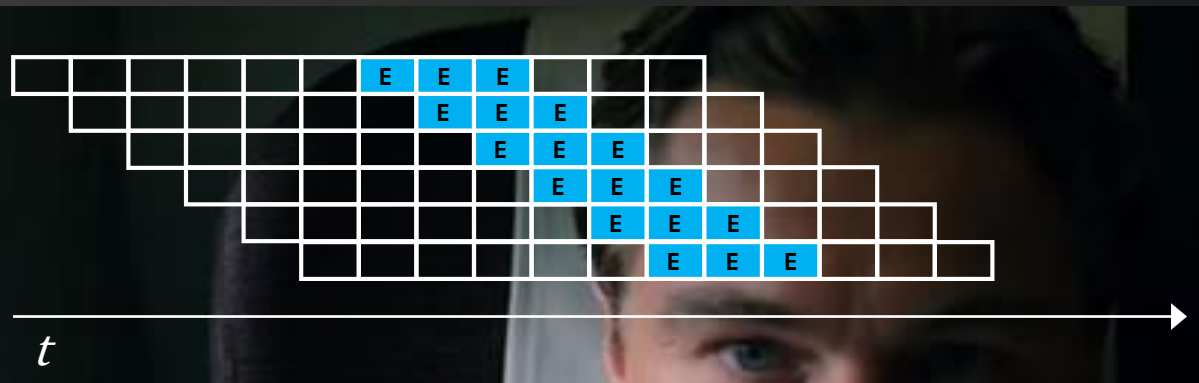








Recap – lecture 2



Red = u4 & (255 << 16);
Green = u4 & (255 << 8);
Blue = u4 & 255;

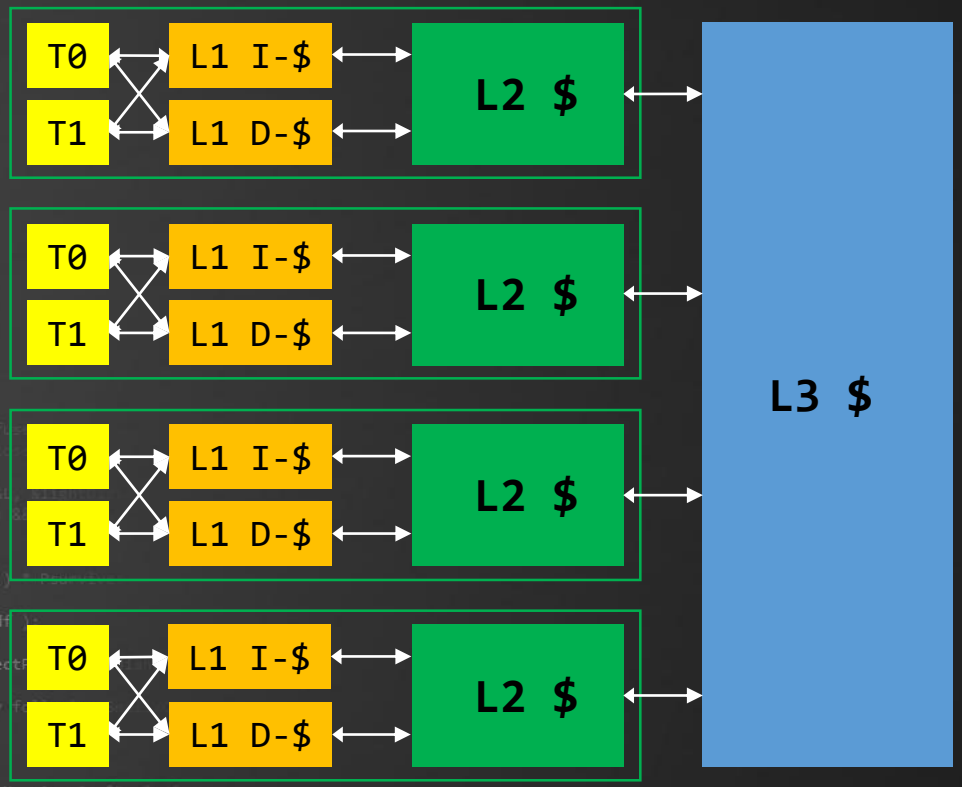

```
fldz
xor ecx, ecx
fld dword ptr ds:[405290h]
mov edx, 28929227h
fld dword ptr ds:[40528Ch]
push esi
mov esi, 0C350h    = 50000
```

```
add ecx, edx
mov eax, 91D2A969h
xor edx, 17737352h
shr ecx, 1
mul eax, edx
fld st(1)
faddp st(3), st
```

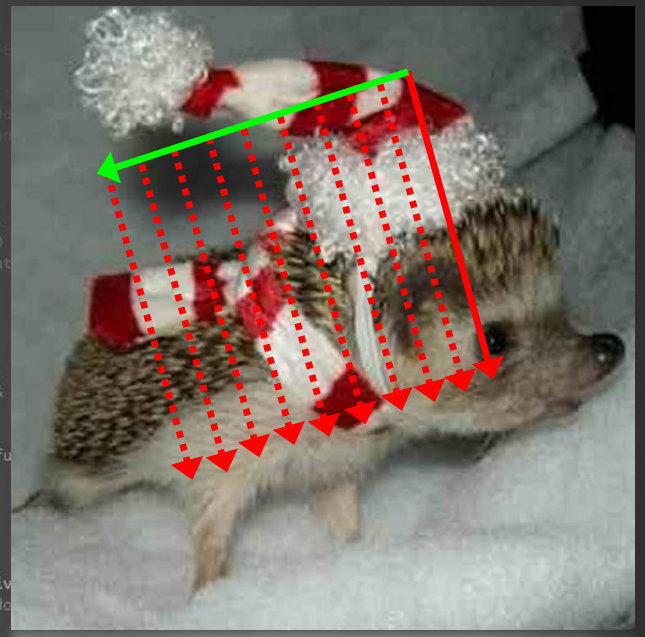
$= \frac{2^{46}}{28763}$ (!!)

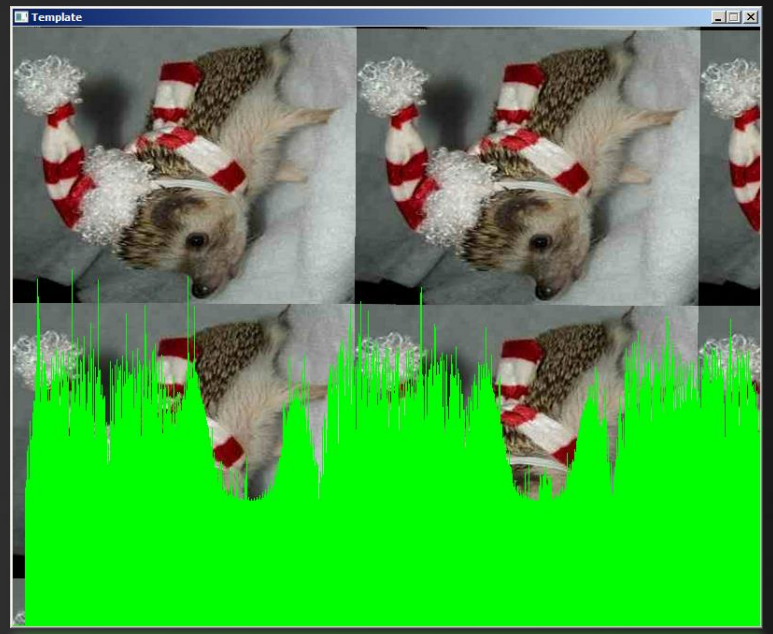
```
mov eax, 91D2A969h
shr edx, 0Eh
add ecx, edx
fmul st(1),st
xor edx, 17737352h
shr ecx, 1
mul eax, edx
shr edx, 0Eh
dec esi
jne tobetimed<0>+1Fh
```

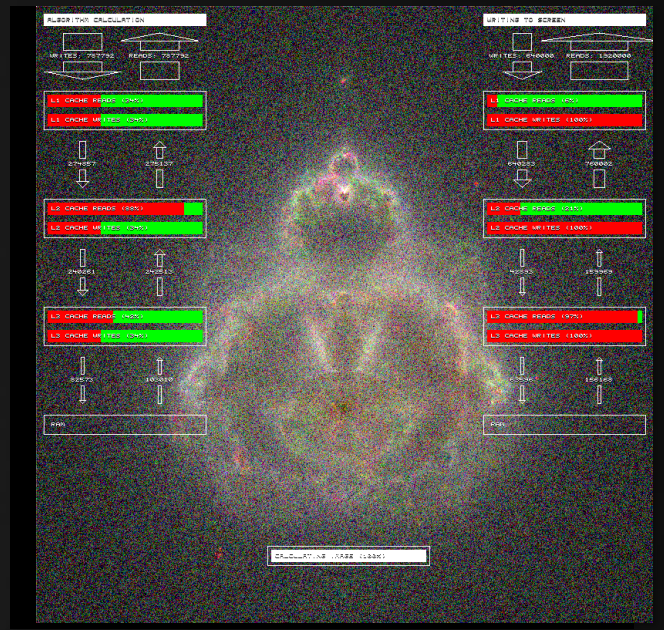
Recap – lecture 3



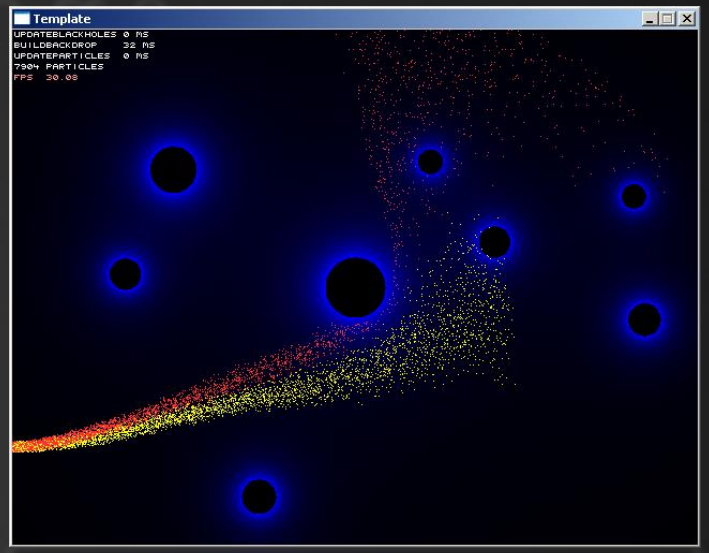
Recap – lecture 4

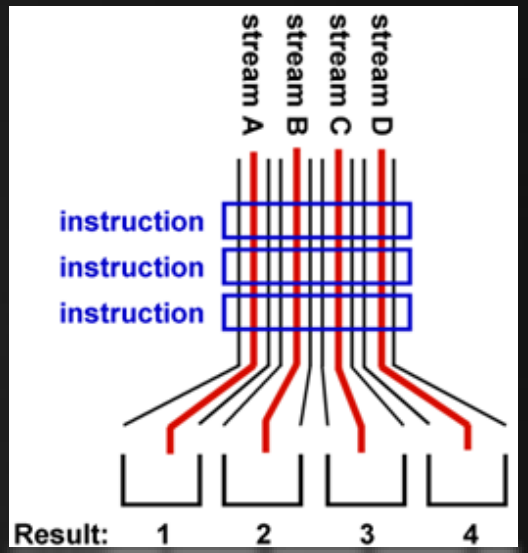






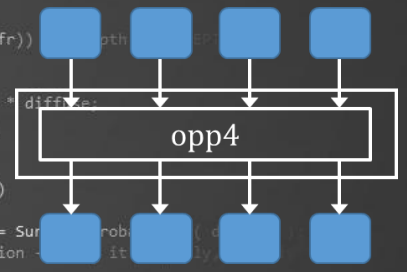
Recap – lecture 5 & 6





Agner says:
“Automatic vectorization is the easiest way of generating SIMD code, and I would recommend to use this method when it works. Automatic vectorization may fail or produce suboptimal code in the following cases:

- when the algorithm is too complex.
- when data has to be re-arranged in order to fit into vectors and it is not obvious to the compiler how to do this or when other parts of the code needs to be changed to handle the re-arranged data.
- when it is not known to the compiler which data sets are bigger or smaller than the vector size.
- when it is not known to the compiler whether the size of a data set is a multiple of the vector size or not.
- when the algorithm involves calls to functions that are defined elsewhere or cannot be inlined and which are not readily available in vector versions.
- when the algorithm involves many branches that are not easily vectorized.
- when floating point operations have to be reordered or transformed and it is not known to the compiler whether these transformations are permissible with respect to precision, overflow, etc.
- when functions are implemented with lookup tables.



AoS

SoA

SIMD Basics

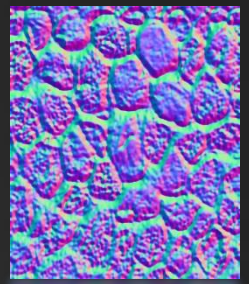
Other instructions:

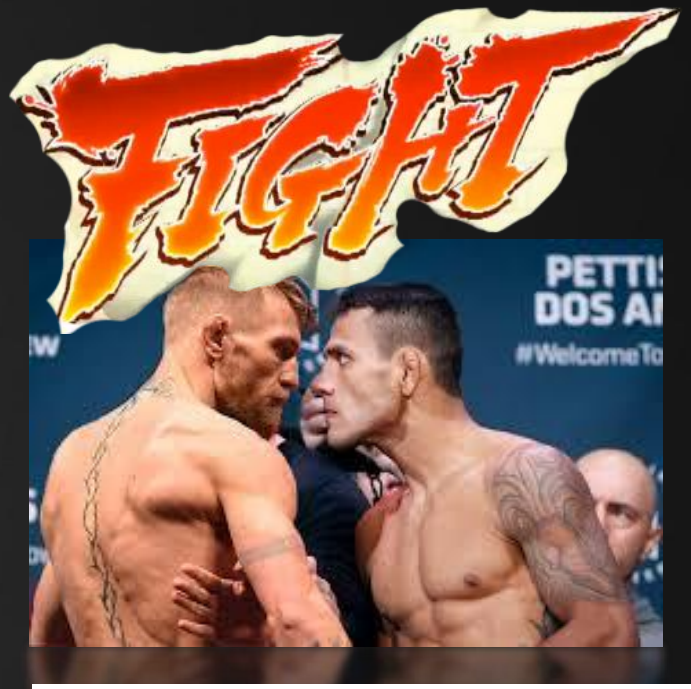
```
__m128 c4 = _mm_div_ps( a4, b4 ); // component-wise division
__m128 d4 = _mm_sqrt_ps( a4 );    // four square roots
__m128 d4 = _mm_rcp_ps( a4 );     // four reciprocals
__m128 d4 = _mm_rsqrt_ps( a4 );   // four reciprocal square roots (!)

__m128 d4 = _mm_max_ps( a4, b4 );
__m128 d4 = _mm_min_ps( a4, b4 );
```

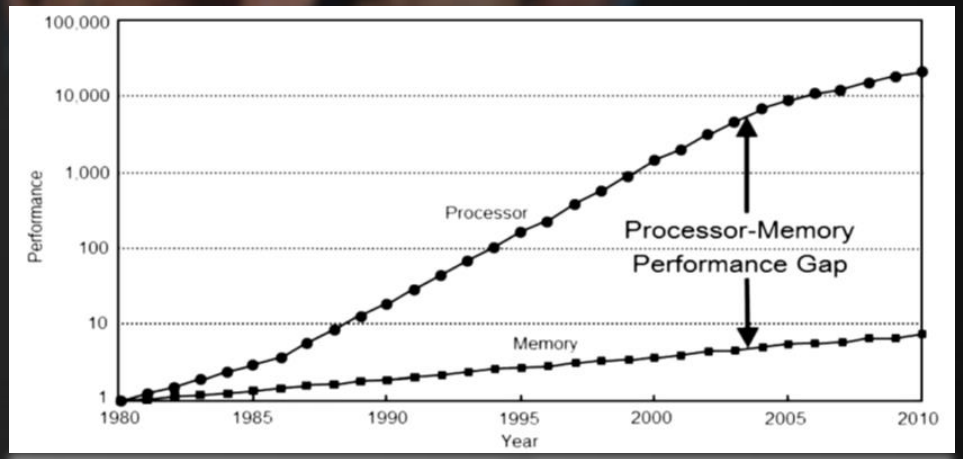
Keep the assembler-like syntax in mind:

```
__m128 d4 = dx4 * dx4 + dy4 * dy4;
```

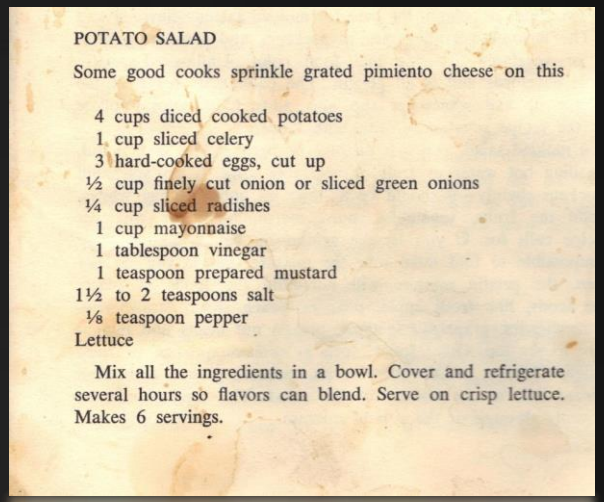
Recap – lecture 7







Recap – lecture 8

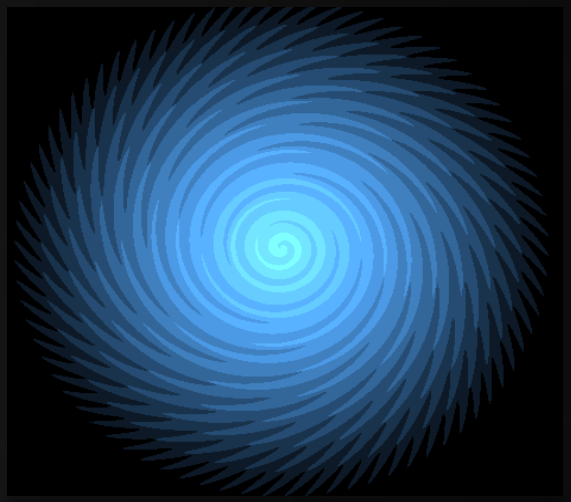


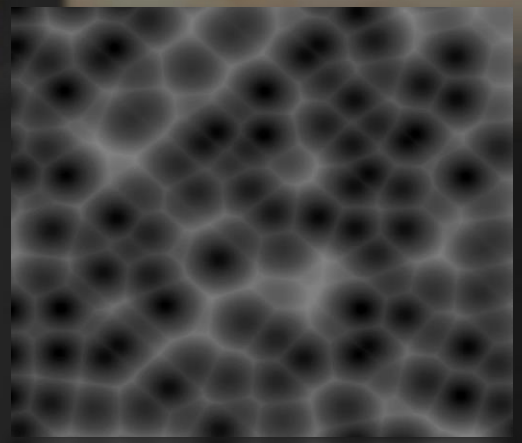
POTATO SALAD

Some good cooks sprinkle grated pimiento cheese on this

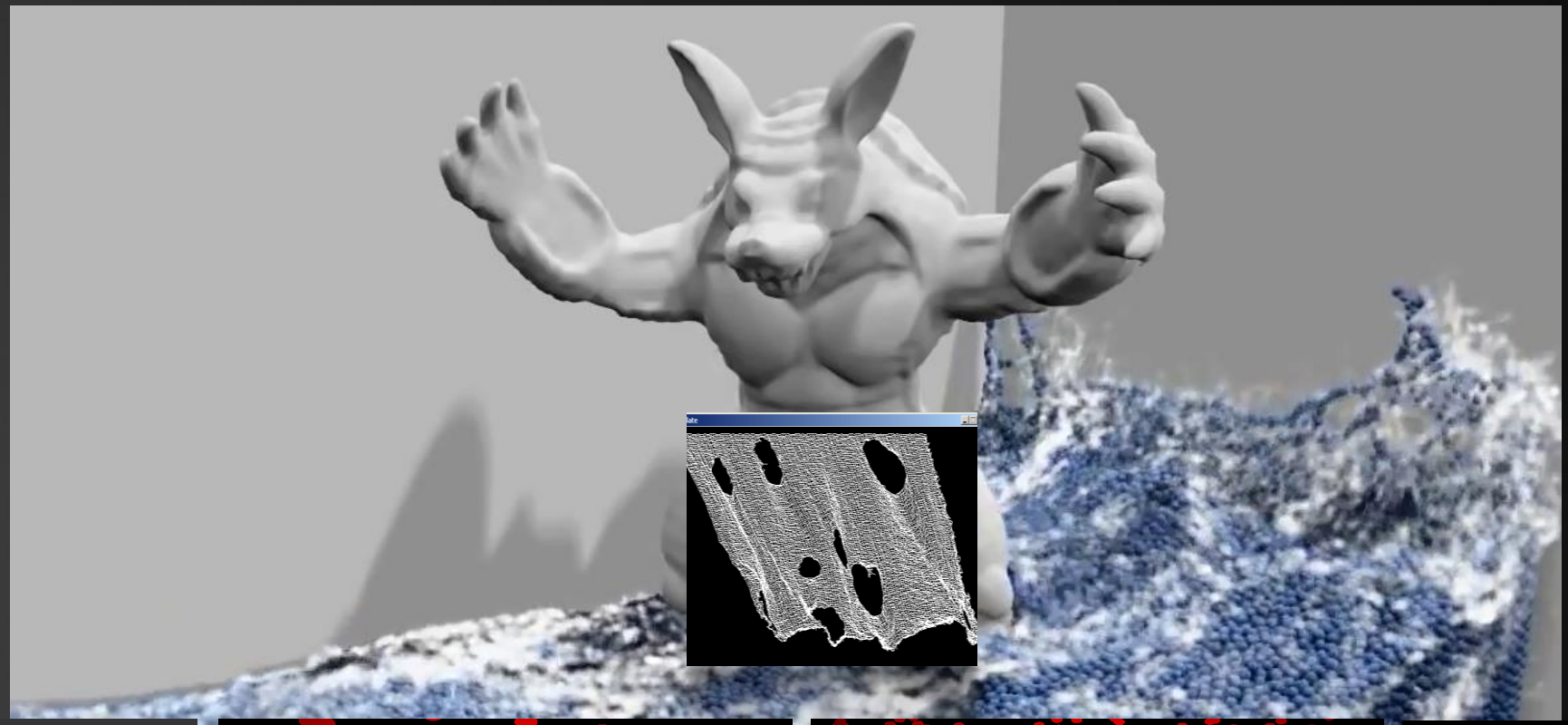
4 cups diced cooked potatoes
1 cup sliced celery
3 hard-cooked eggs, cut up
½ cup finely cut onion or sliced green onions
¼ cup sliced radishes
1 cup mayonnaise
1 tablespoon vinegar
1 teaspoon prepared mustard
1½ to 2 teaspoons salt
⅛ teaspoon pepper
Lettuce

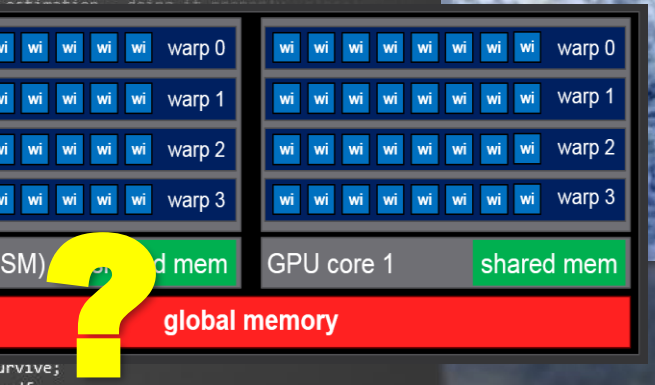
Mix all the ingredients in a bowl. Cover and refrigerate several hours so flavors can blend. Serve on crisp lettuce. Makes 6 servings.

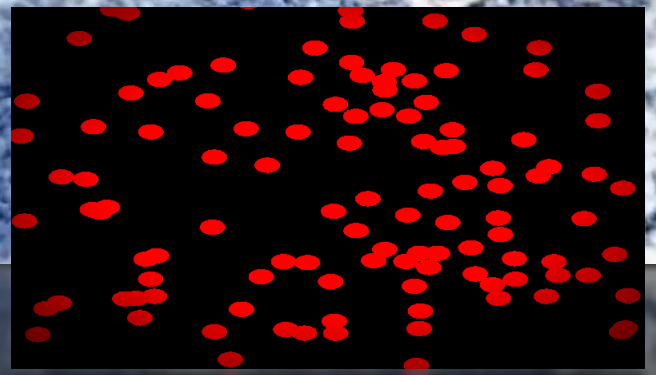


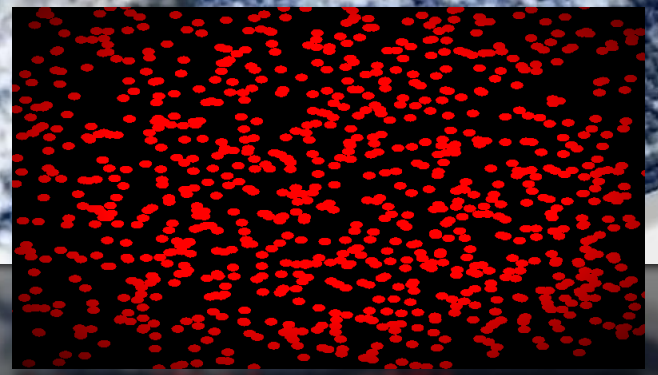


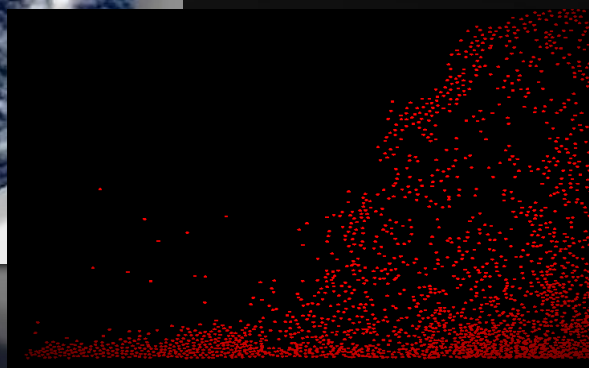
Recap – lecture 9



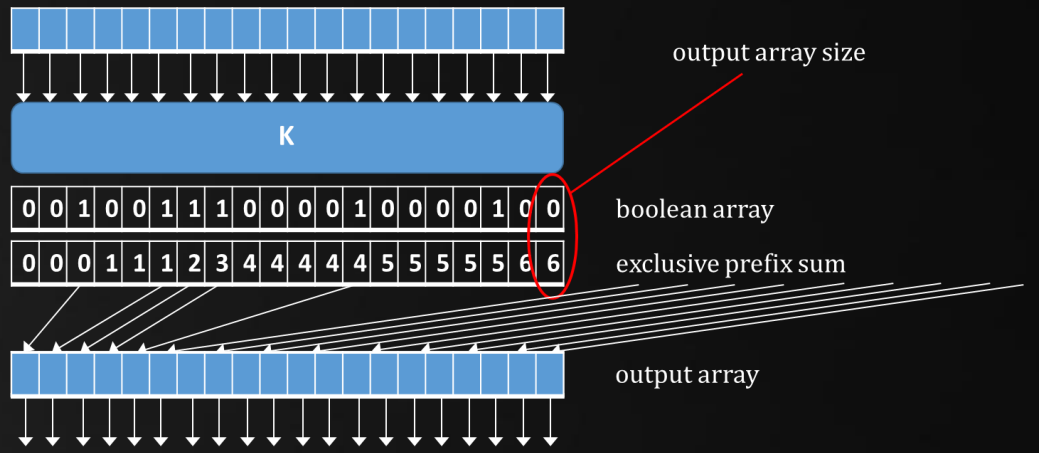


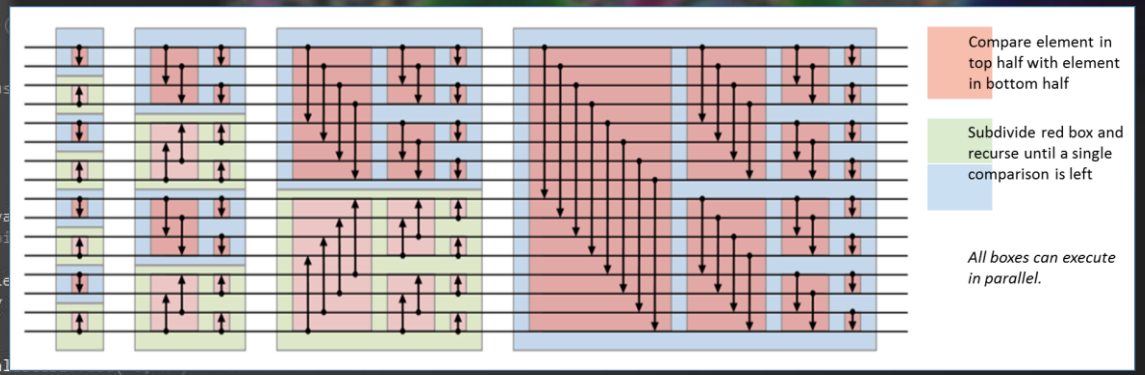


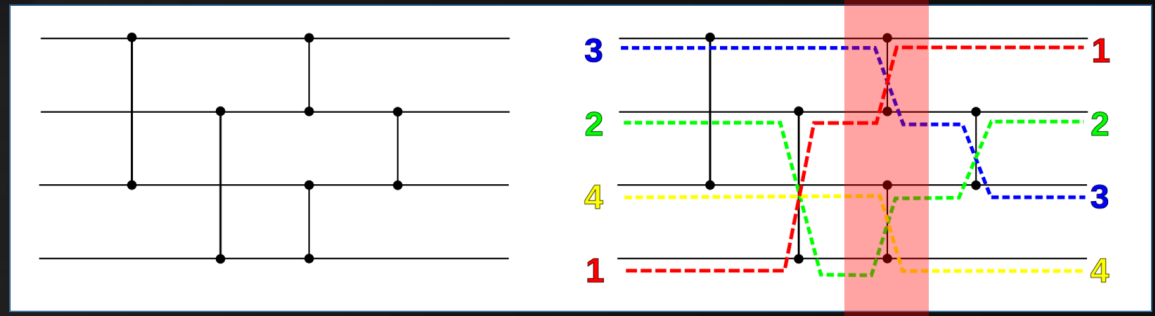




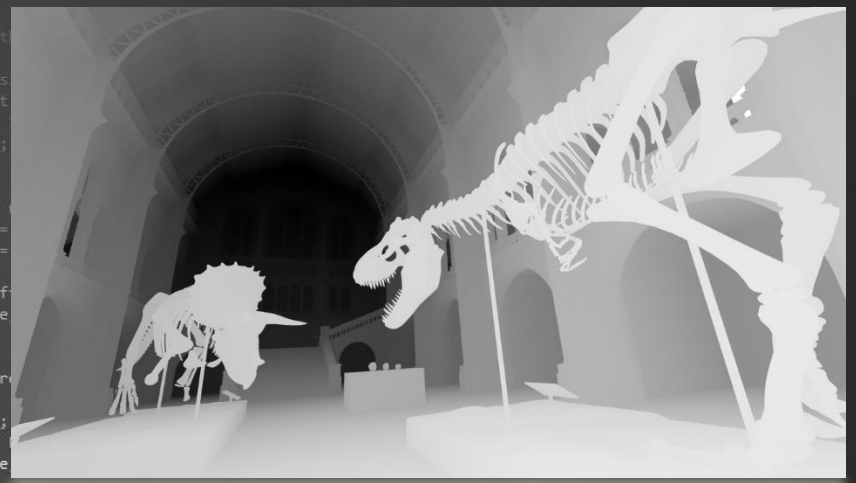
Recap – lecture 10

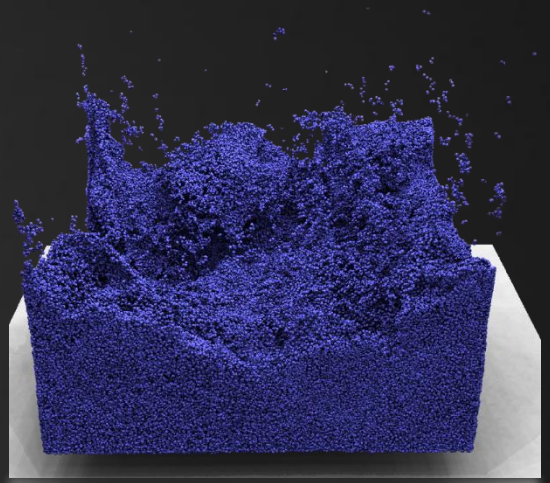


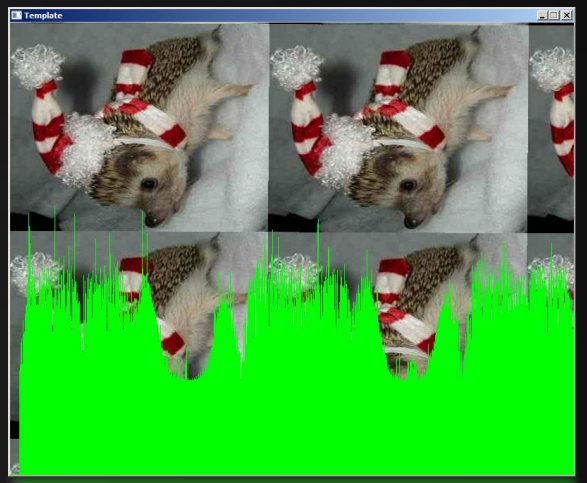


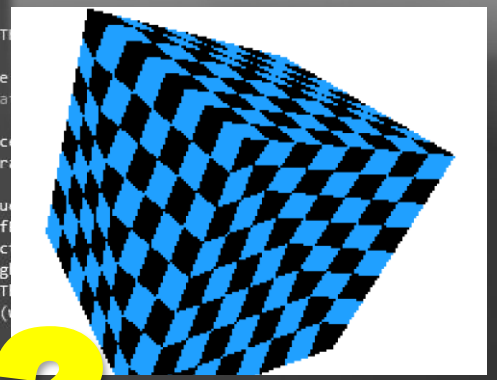


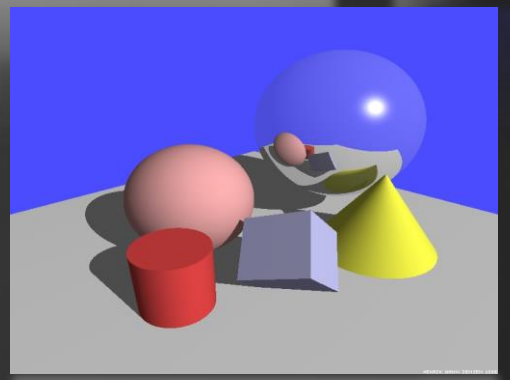
Recap – lecture 11



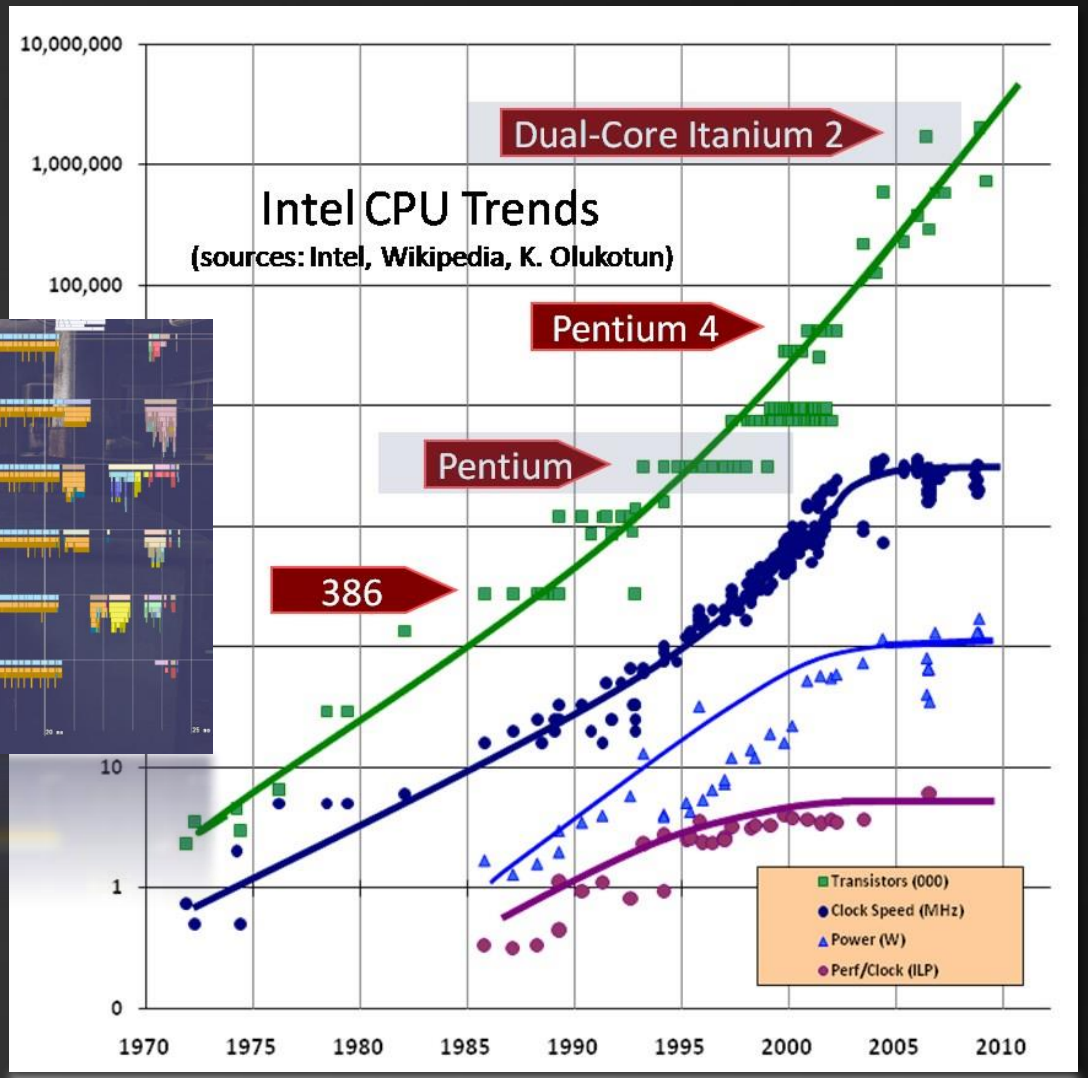


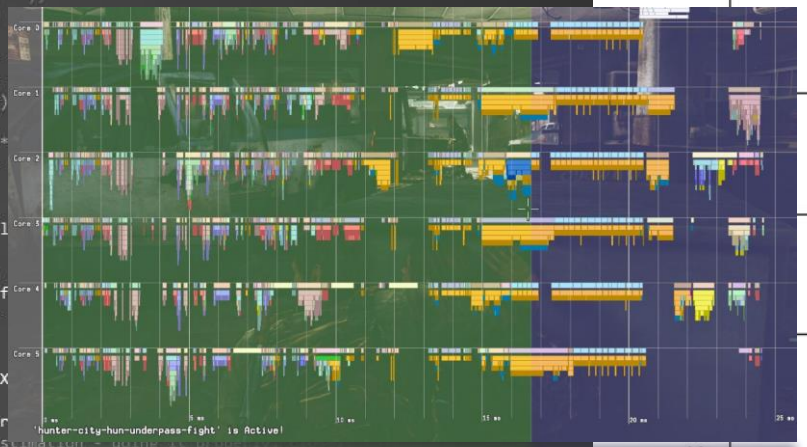


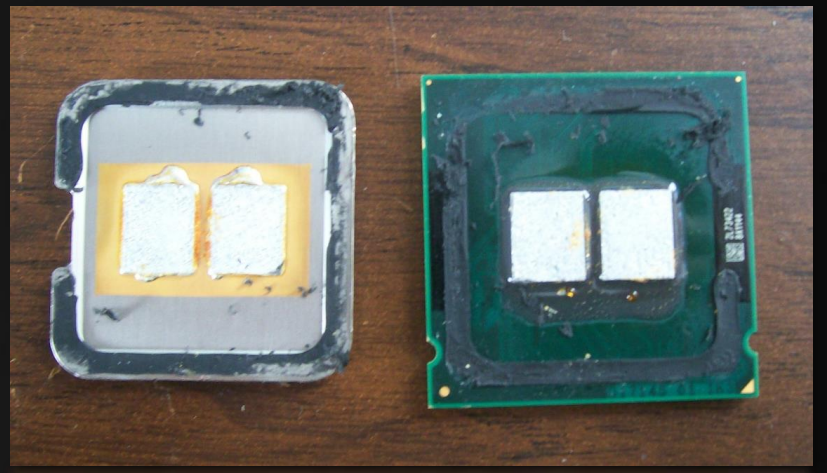




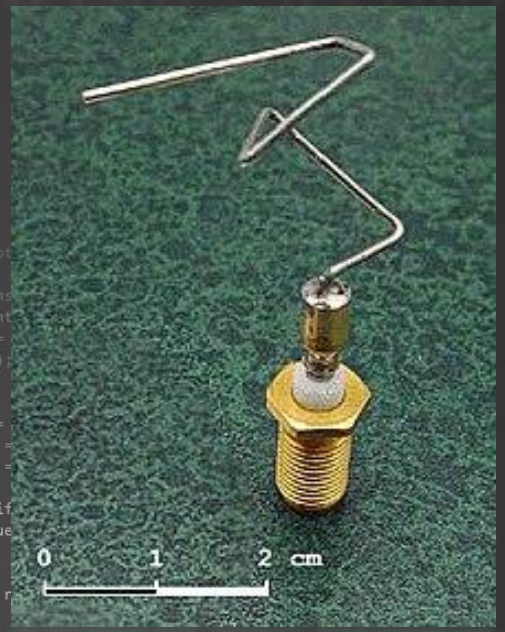
Recap – lecture 12

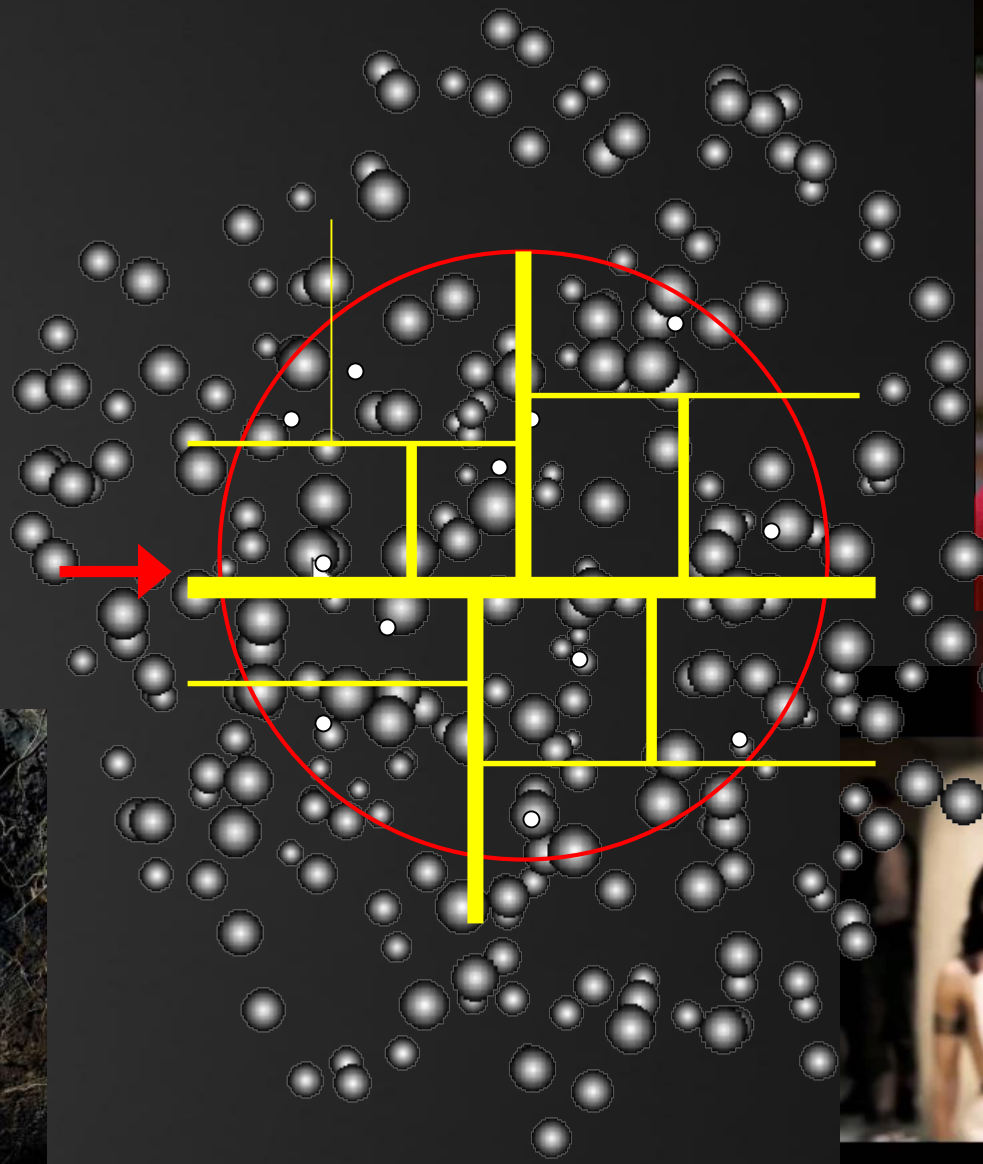


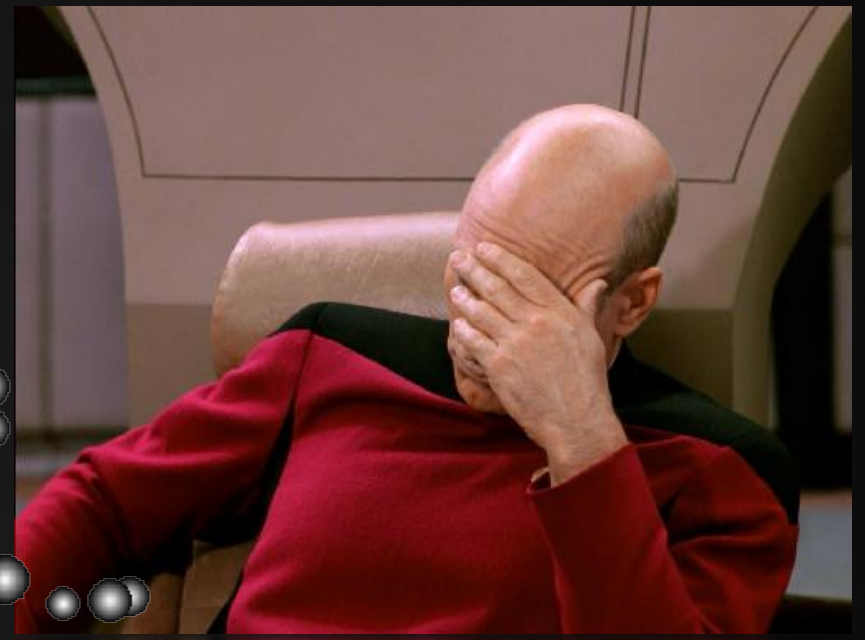




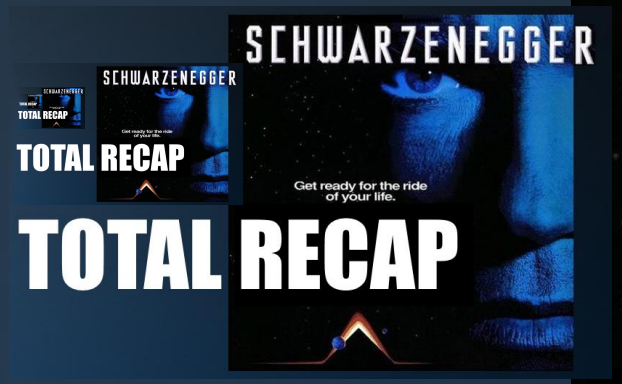
Recap – lecture 13

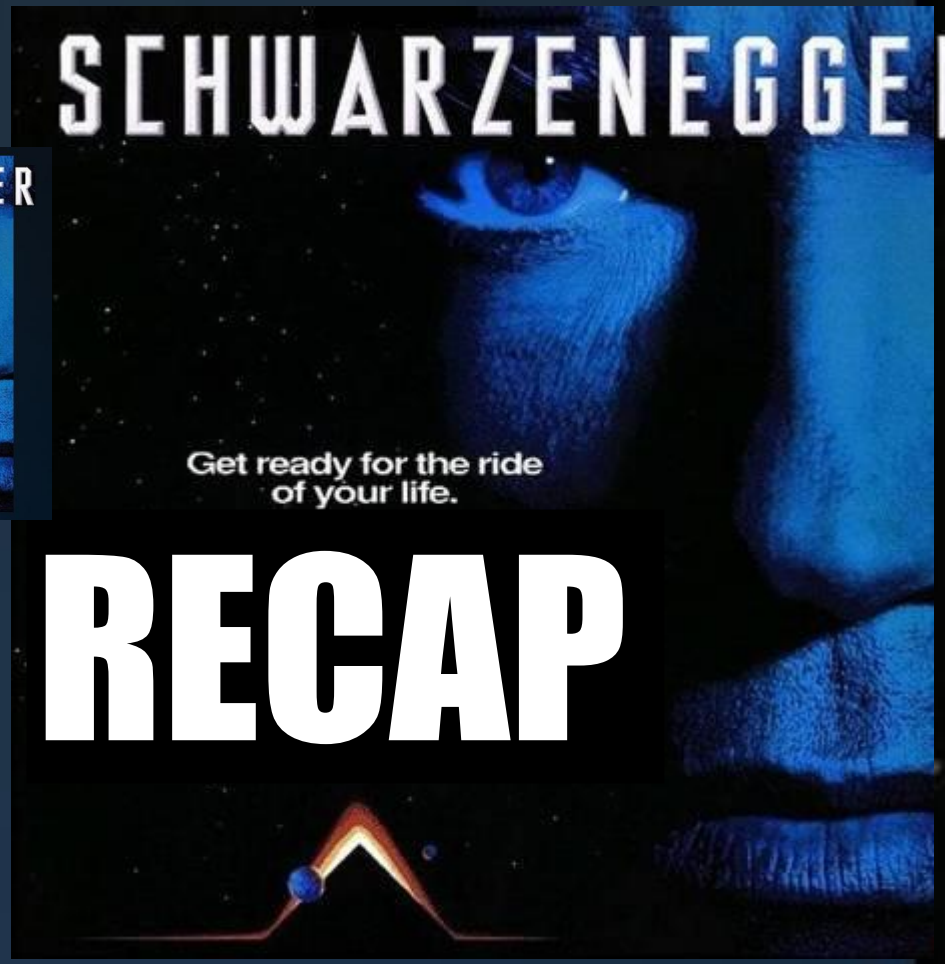






Recap – Lecture 15

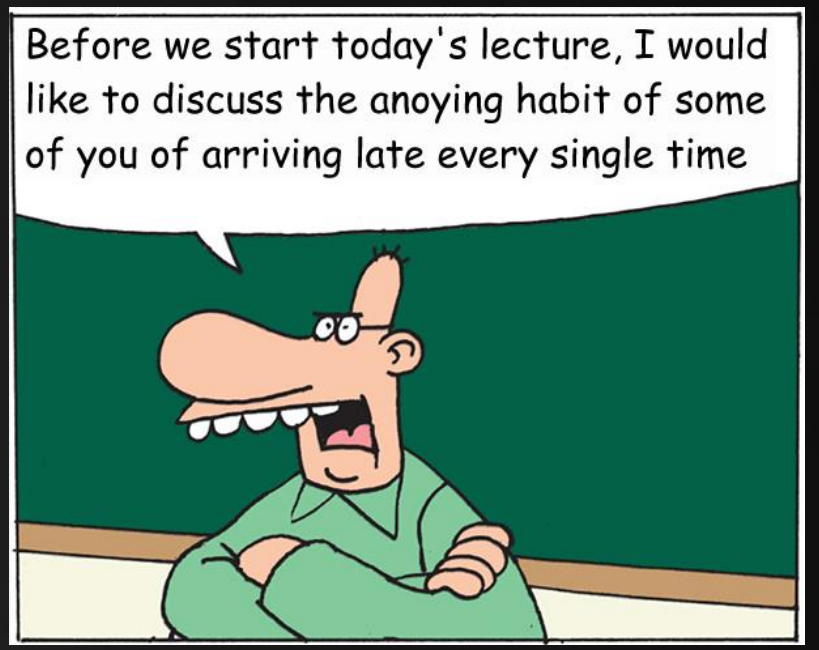




TOTAL RECAP

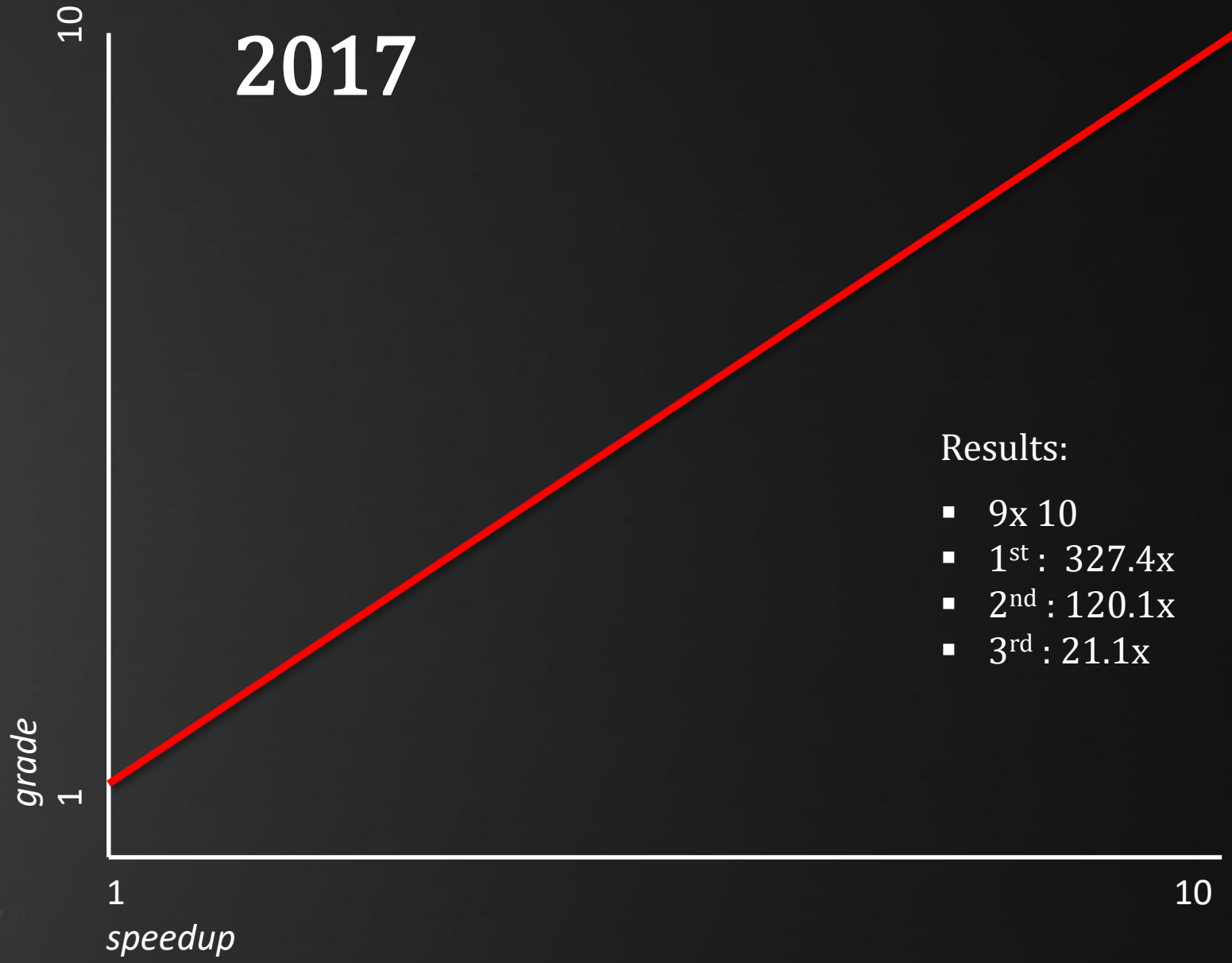
Educational Experiments ®™

Recap


Before we start today's lecture, I would like to discuss the anoying habit of some of you of arriving late every single time


Perhaps it's best to mention that again in half an hour
Yeah that might be better
dirkjan.nl

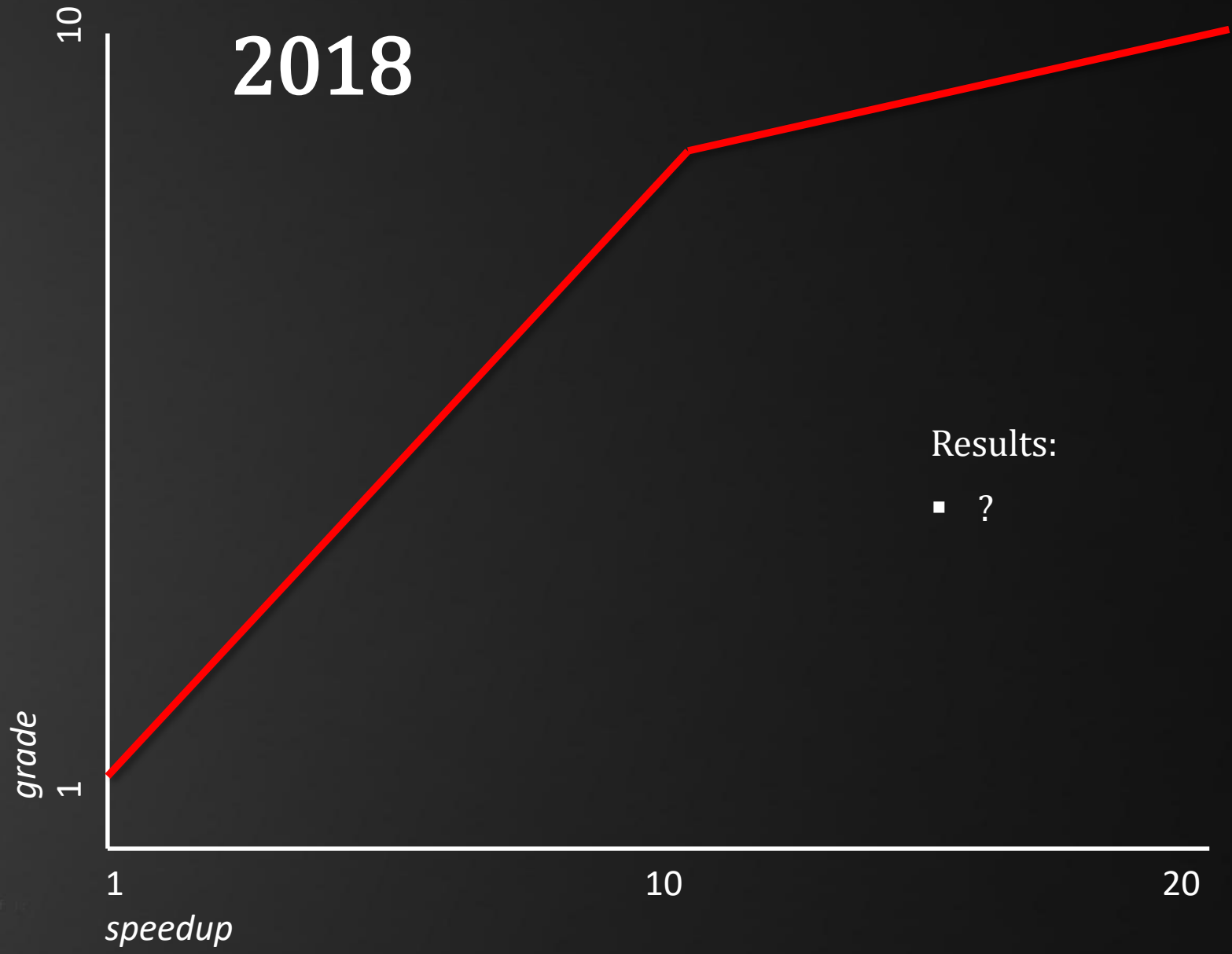
Recap



Results:

- 9x 10
- 1st : 327.4x
- 2nd : 120.1x
- 3rd : 21.1x

Recap



Results:

- ?

Recap

“Dear Charles,

At the end of this course:

You will know how to speed up critical code by a factor 2x to 10x (and more).

- You will be able to do this to virtually any program*.
- Your understanding of higher level optimization approaches will increase.
- You will be able to apply these principles to new / alien hardware.
- You will have a more intimate relationship with your computer.

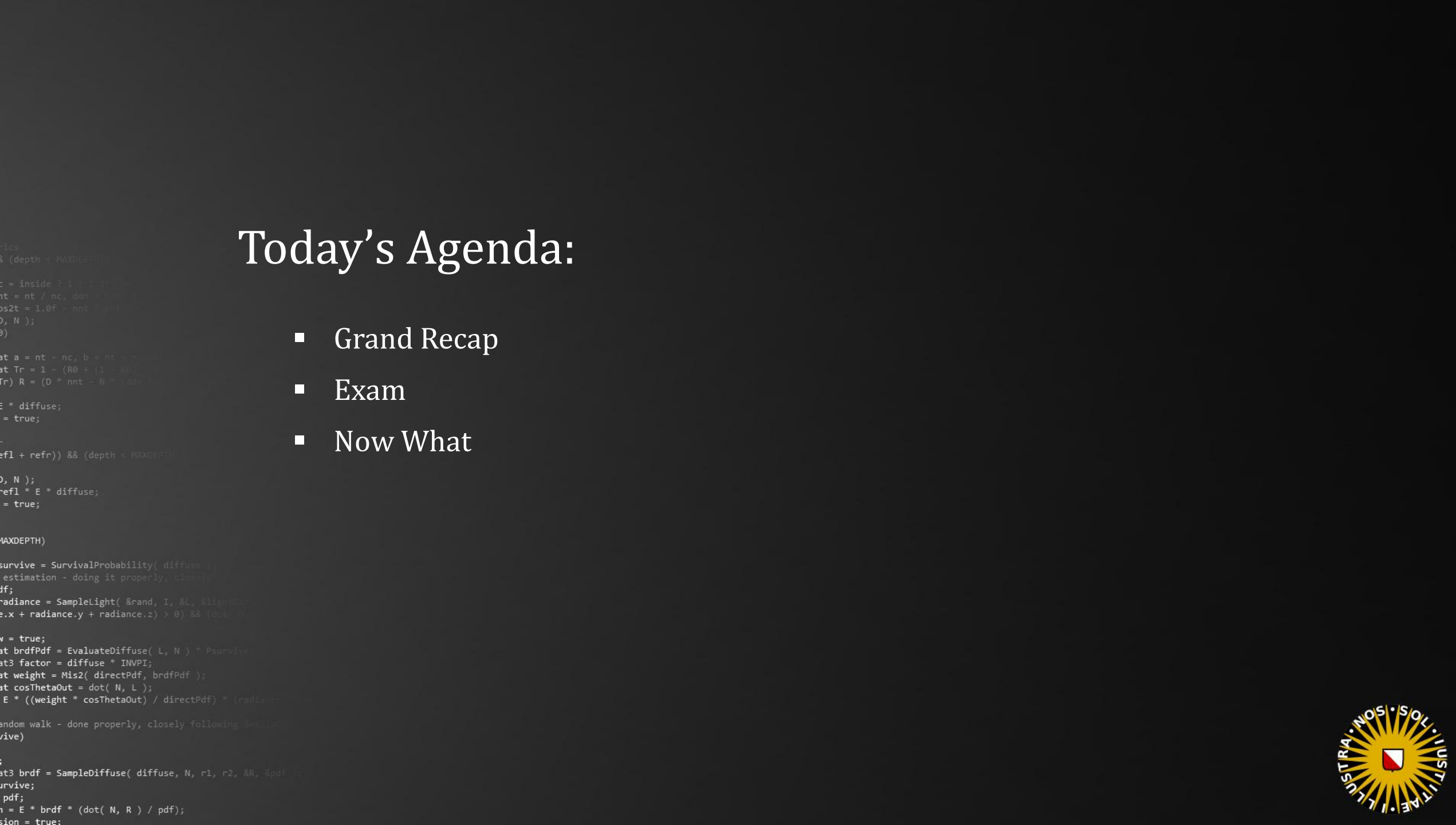
In other words:

We will talk a lot about the ‘C’ in O(N).

* disclaimer: ‘that has not been optimized by an expert’.

Today’s Agenda:

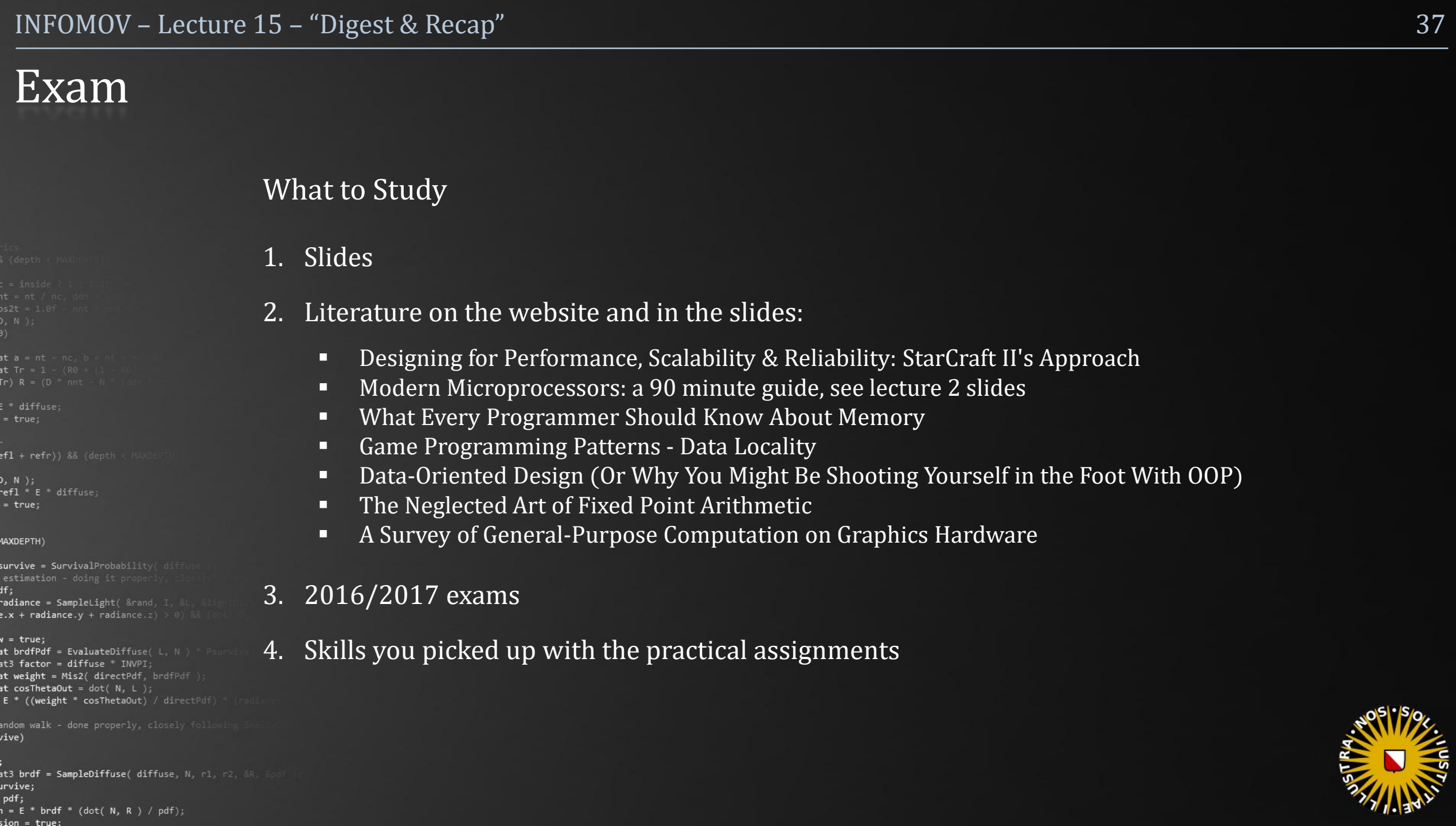
- Grand Recap
- Exam
- Now What



Exam

What to Study

1. Slides
2. Literature on the website and in the slides:
   - Designing for Performance, Scalability & Reliability: StarCraft II's Approach
   - Modern Microprocessors: a 90 minute guide, see lecture 2 slides
   - What Every Programmer Should Know About Memory
   - Game Programming Patterns - Data Locality
   - Data-Oriented Design (Or Why You Might Be Shooting Yourself in the Foot With OOP)
   - The Neglected Art of Fixed Point Arithmetic
   - A Survey of General-Purpose Computation on Graphics Hardware
3. 2016/2017 exams
4. Skills you picked up with the practical assignments



Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

CPUs and GPUs have fundamentally different core strategies for dealing with latencies such as memory access time. What are these strategies?

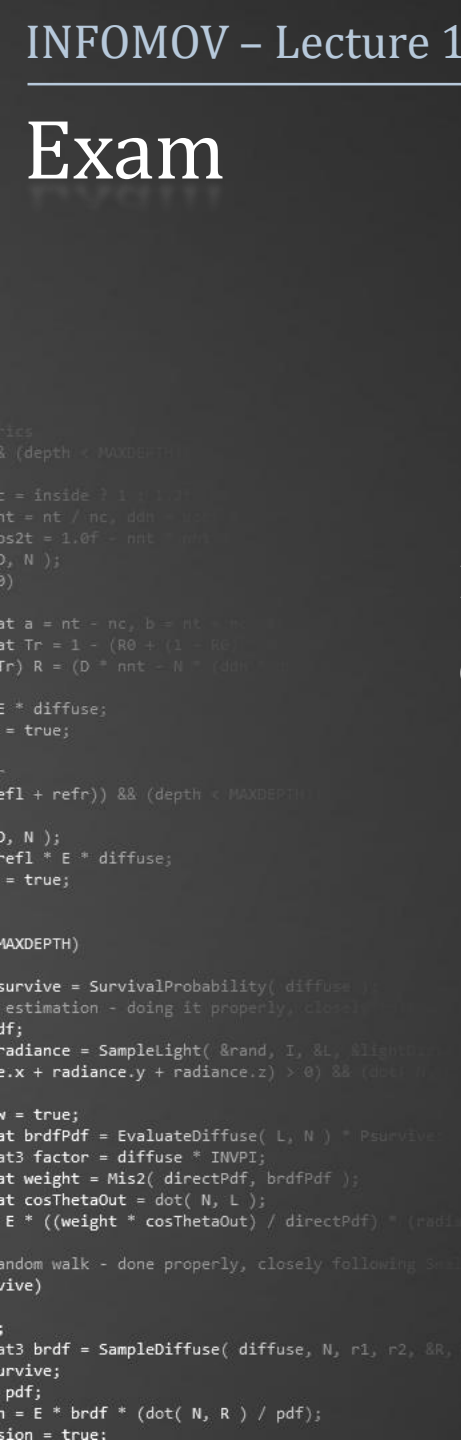
Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

If you were plowing a field, which would you rather use? Two strong oxen,

or 1024 chickens?



Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

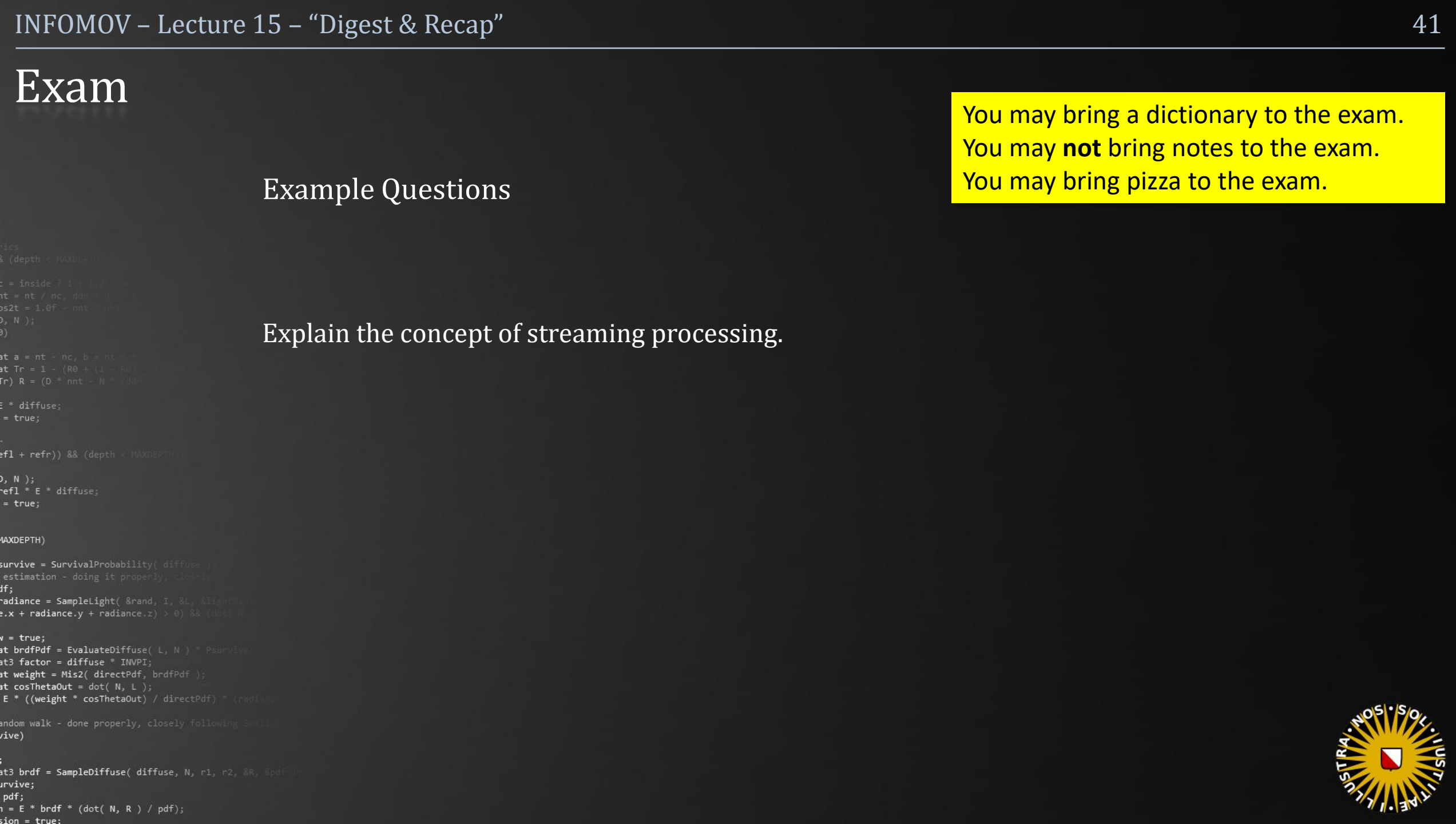
Why is the theoretical peak performance of a GPU typically much higher than that of a CPU?

Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

Explain the concept of streaming processing.



Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

How does a GPU handle conditional code?

Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

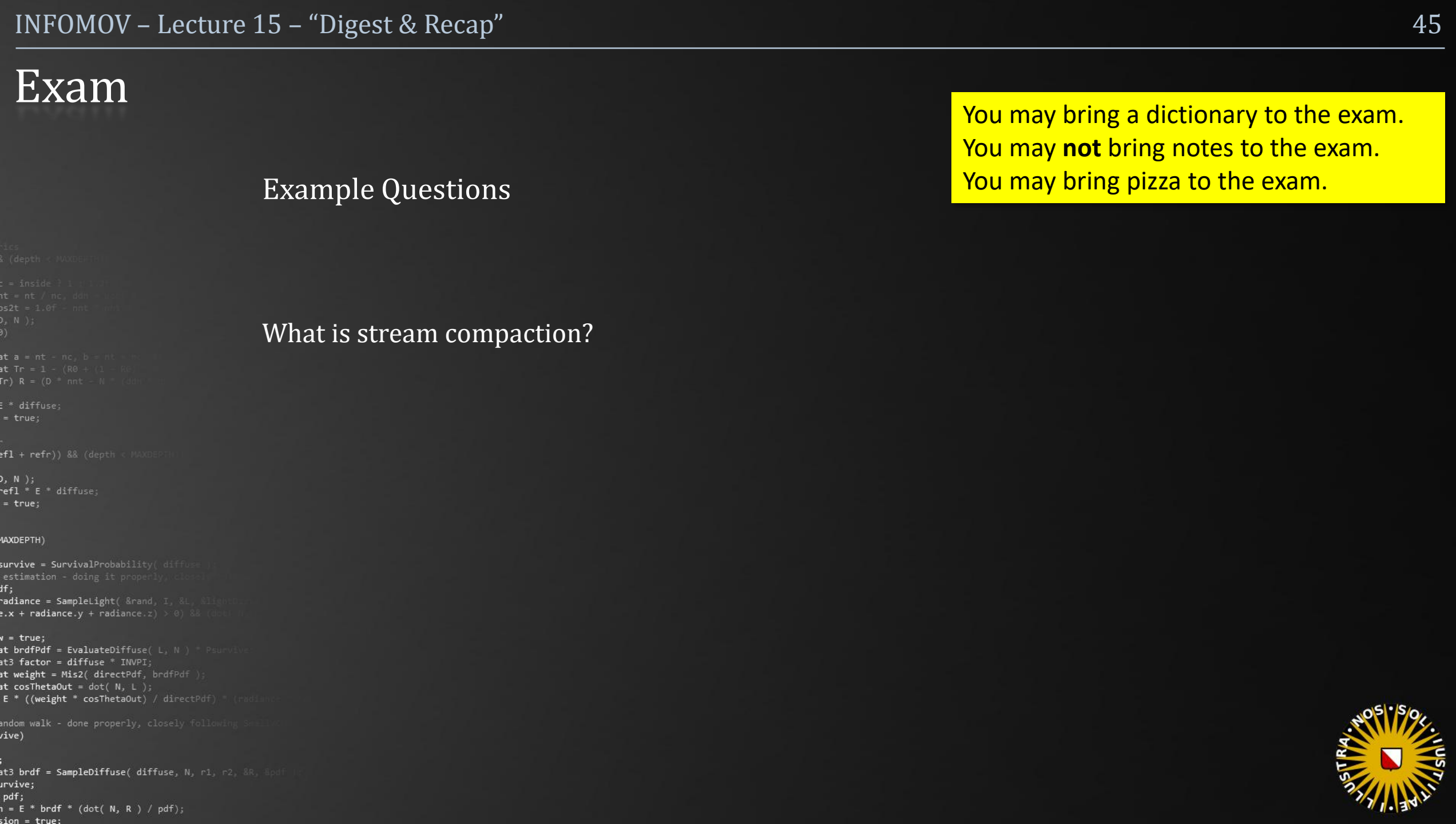
Two kernels executed on the same GPU are executed with different work group sizes: one with 256 threads per work group, one with 512. Why did the programmer not use the same work group size in both cases?

Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

What is stream compaction?



Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

Example Questions

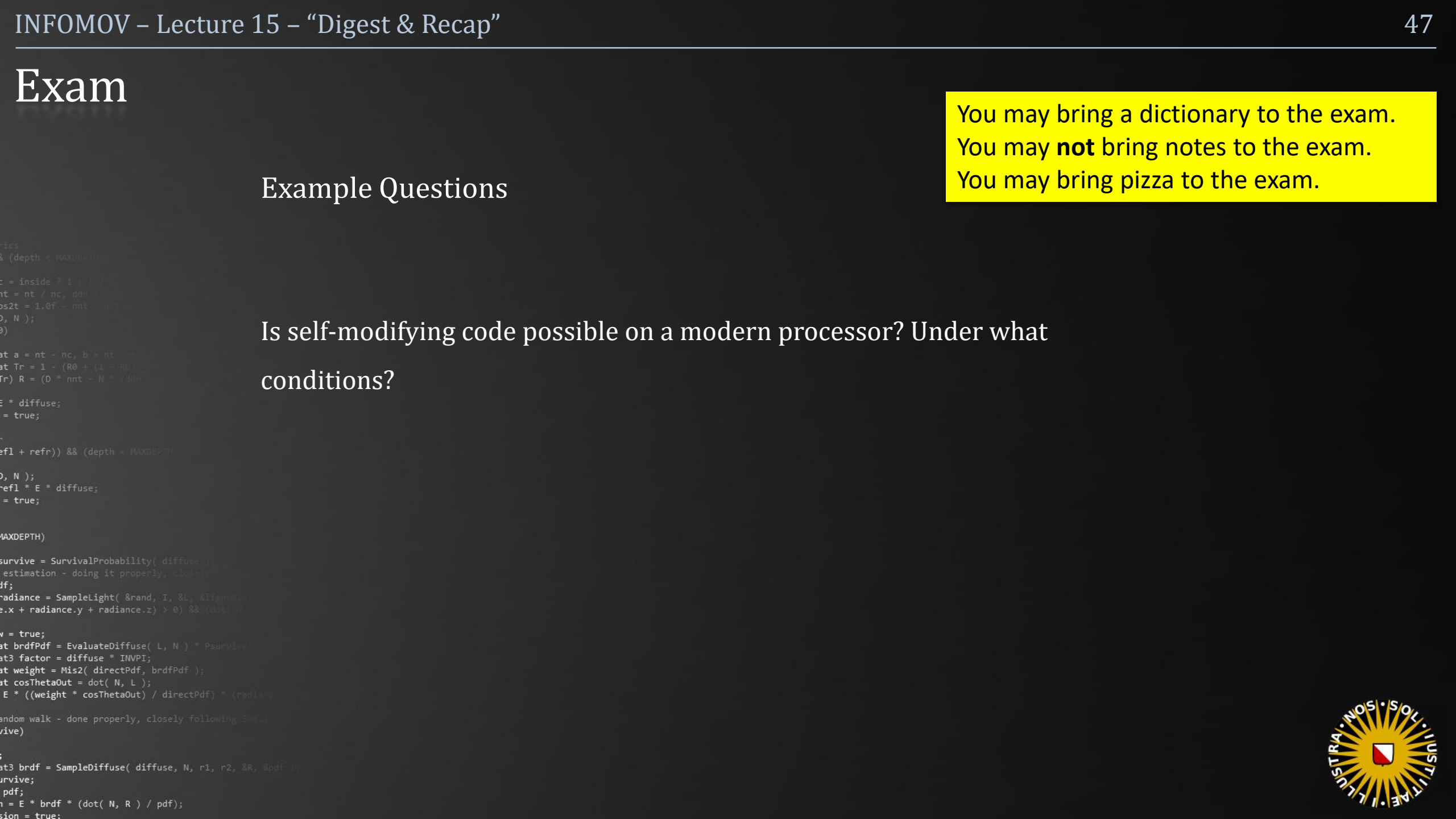
Why does OpenCL have a native_sqrt as well as an sqrtf?

Exam

You may bring a dictionary to the exam.
You may **not** bring notes to the exam.
You may bring pizza to the exam.

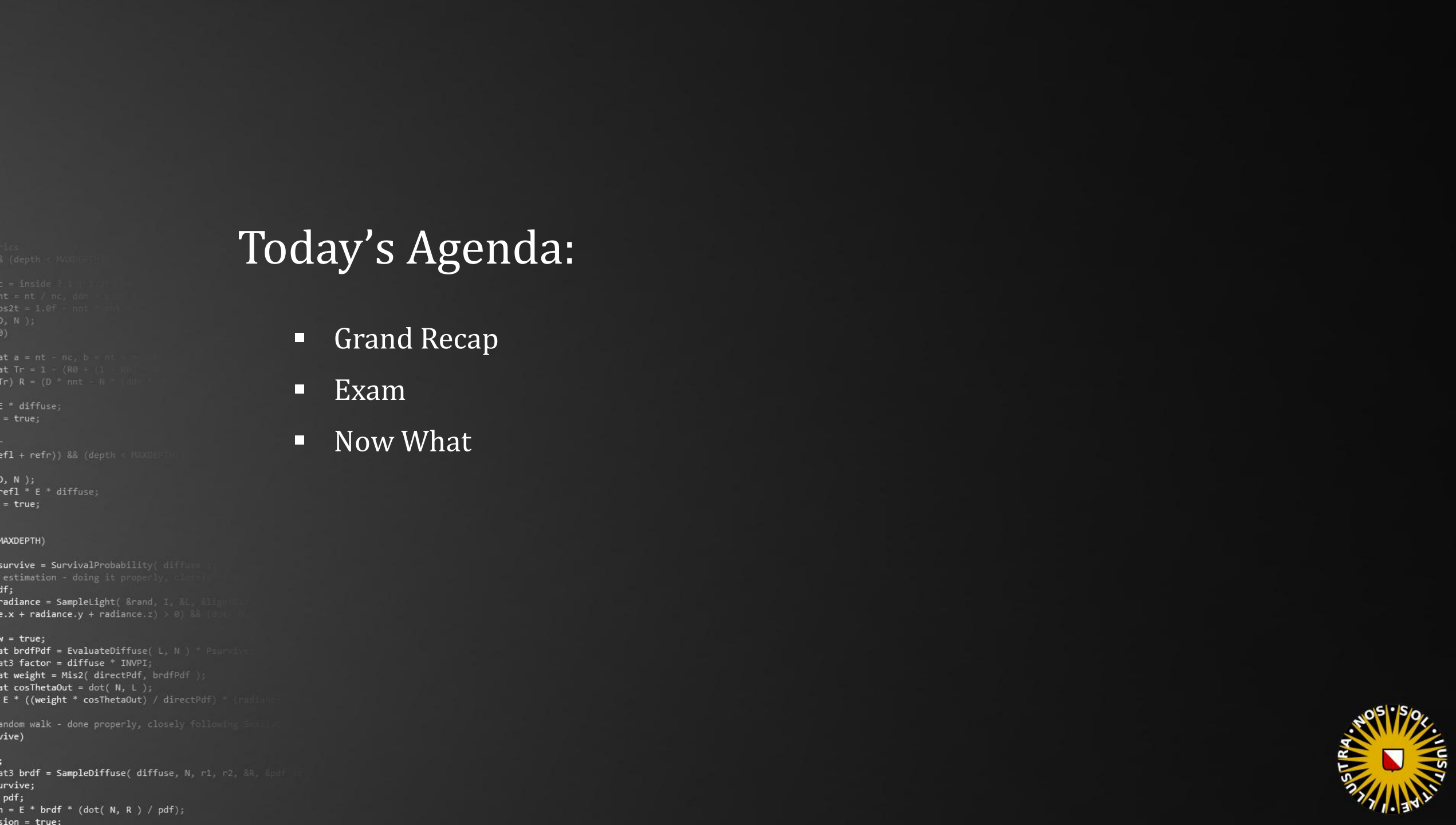
Example Questions

Is self-modifying code possible on a modern processor? Under what conditions?

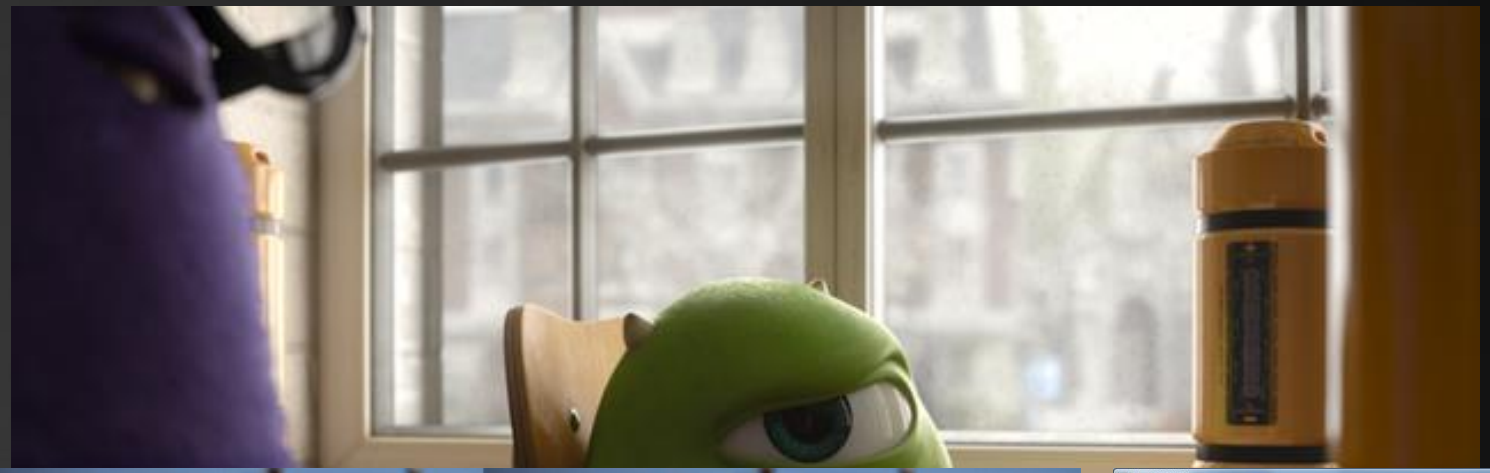


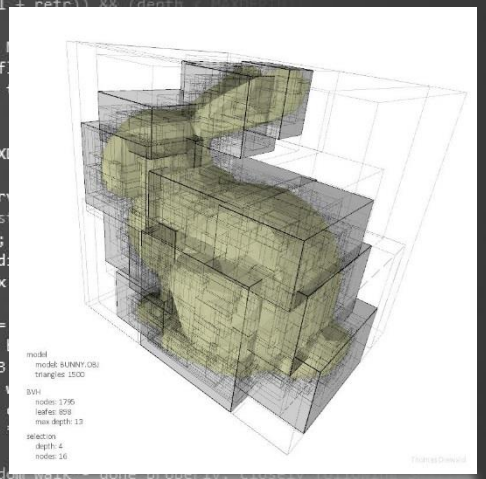
Today’s Agenda:

- Grand Recap
- Exam
- Now What



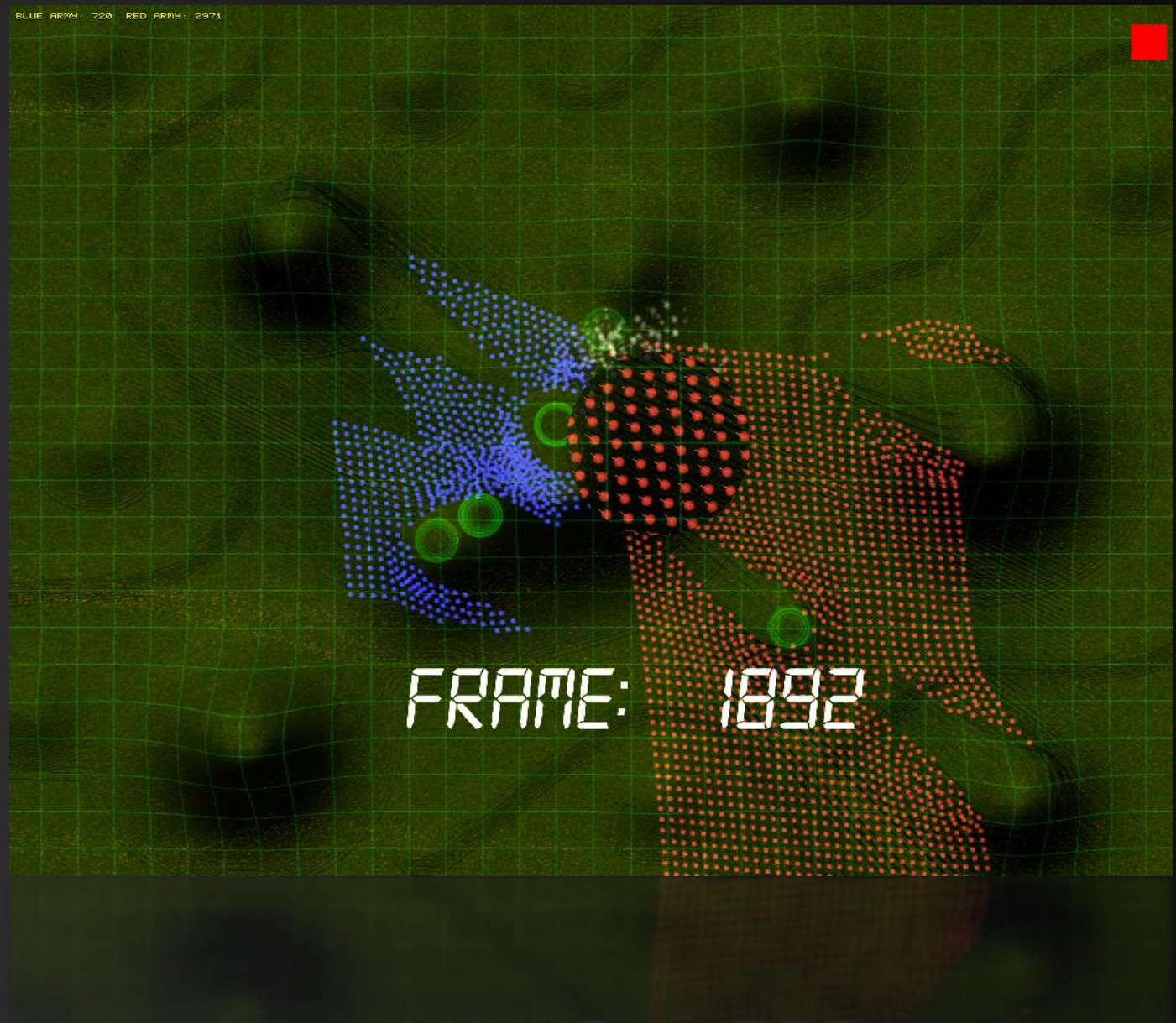
Now What





Now What

Now What



Now What


COMPUTER PROGRAMMER
What my friends think I do
What my mom thinks I do
What society thinks I do
What my spouse thinks I do
What I think I do
What I actually do

/INFOMOV2018/