ARRAY PROGRAMMING
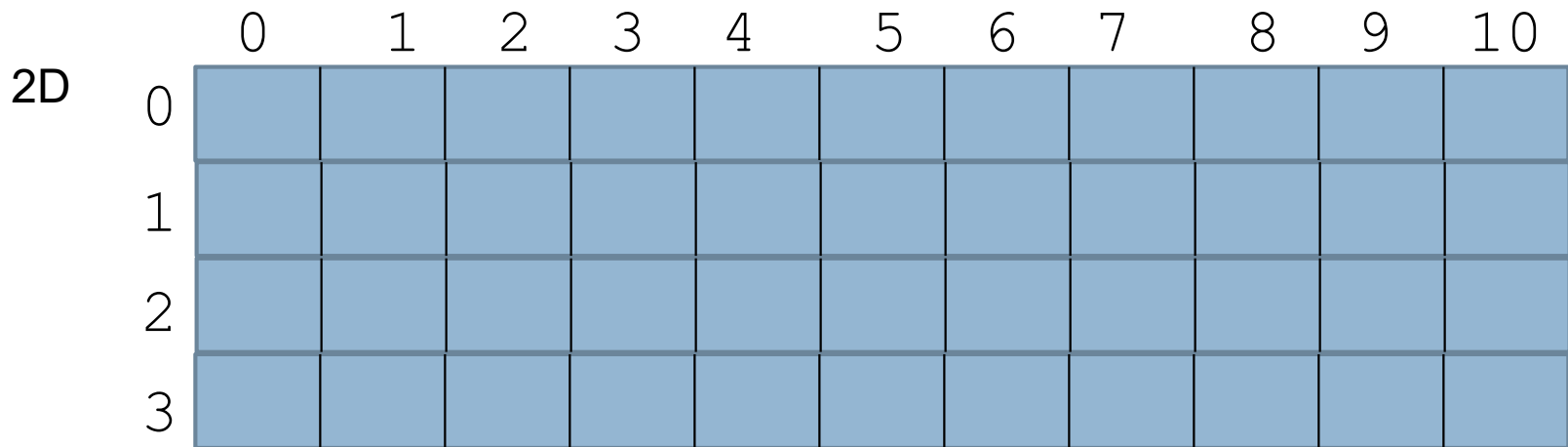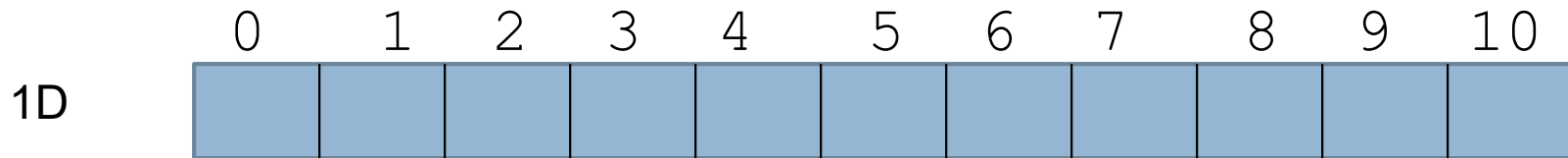
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Arrays

- Fixed-size collection of elements [of the same type], occupying contiguous memory

1D

0	1	2	3	4	5	6	7	8	9	10

2D

	0	1	2	3	4	5	6	7	8	9	10
0											
1											
2											
3											

...

Arrays

□ Fixed-size collection of elements of the same type, occupying contiguous memory
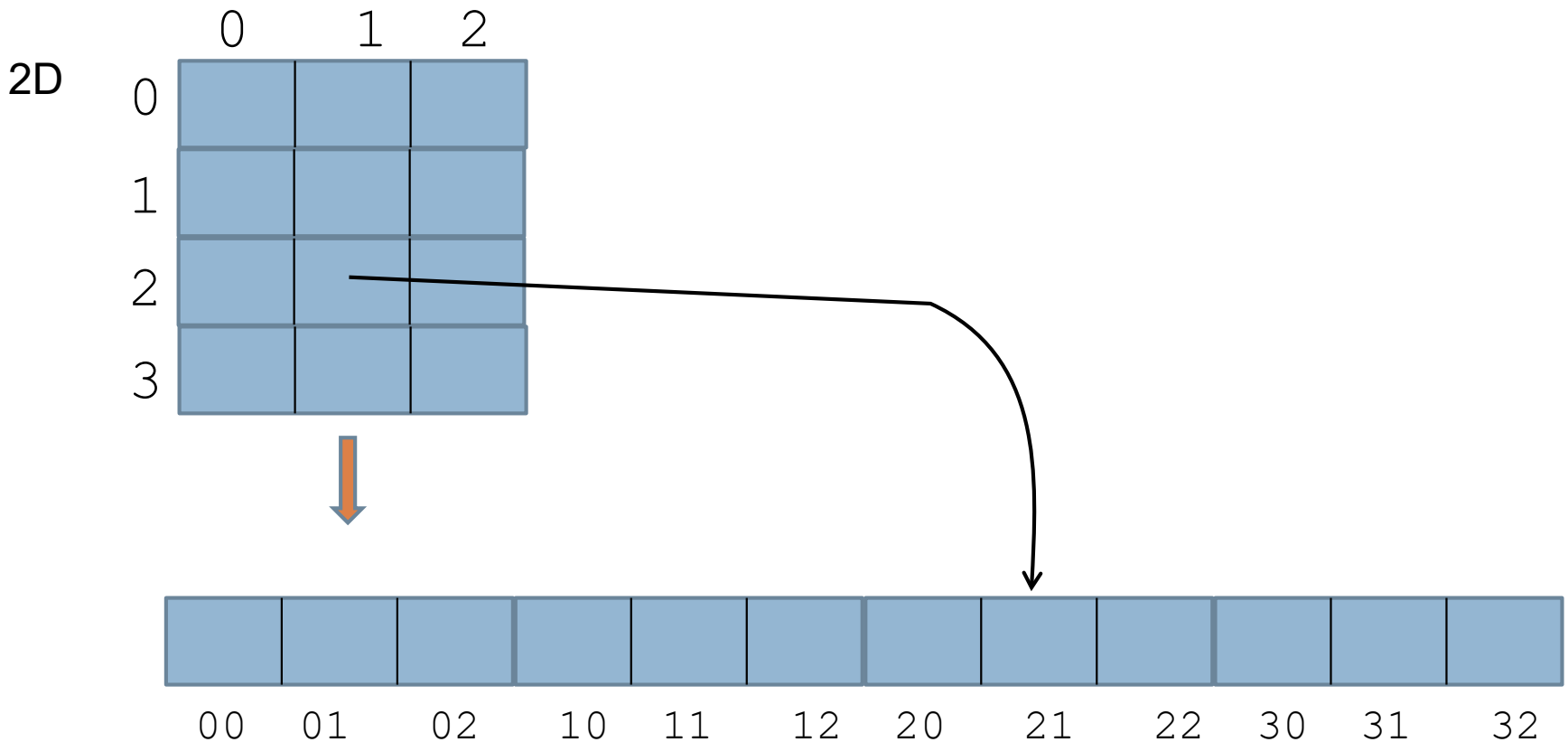
Array Programming

- Application of operations to an entire array, at once
  - Concise primitives about data manipulation
  - Highly parallelizable
  - Can be done by specialized processors, e.g. GPUs

Tired 😐

```
String[] cars={"Volvo", "BMW", "Ford", "Mazda"};

for (int i = 0; i < cars.length; i++) {
  cars[i] = cars[i].toLowerCase();
}


List<String> oslice = new List<String>();
for (int i = 0; i < cars.length; i++) {
  if (cars[i].contains('o'))
    oslice.append(cars[i])
}
```

Iteration, scalar languages

Wired ☺

```
String[] cars={"Volvo", "BMW", "Ford", "Mazda"};

cars = ToLowerCase(cars)

oslice = Where(cars.contains('o'))
```

Explicit iteration replaced by powerful declarative expressions within in the array ➔ vectorization opportunities

Tired ☹ vs. Wired ☺

```
List<String> oslice = new List<String>();
for (int i = 0; i < cars.length; i++) {
  if (cars[i].contains('o'))
    oslice.append(cars[i])
}


oslice = Where(cars.contains('o'))
```

- Shorter, more concise
- Abstraction of implementation details allows for optimized implementations (e.g. in GPUs)

Tired 😐 vs. Wired 🙂

```
for (i = 0; i < n; i++)
    for (j = 0; j < n; j++)
        a[i][j] += b[i][j];
```

a = a + b

- Shorter, more concise

- Abstraction of implementation details allows for optimized implementations (e.g. in GPUs)

Languages with Array Ops

- APL (1960s)
- BASIC (1960s)
- S (1970s) [precursor of R]
- Matlab (1980s)
- Fortran 90 (early 1990s)
- R (1990s)
- Python's Numpy (2000s)
- Julia (2010s)

Applications

- Scientific computing
  - Linear algebra
- Graphics
  - Images, videos ← large, fixed-size data
- Machine Learning

APL

A Programming Language, 1962

Kenneth E. Iverson (Turing Award 1979)

Specialized keyboard (IBM 2741)

Main Features

- Basic data type: multidimensional array
- Special graphic symbols for math notation

https://aplwiki.com/Examples

https://tryapl.org/

Array Programming Style

Constraints

- Main data type: array – a fixed-sized collection of elements

- Iteration is replaced by high-level operations on the array (similar to 'map')

- Computation unfolds as search, selection, and transformation of data