Applications of Array Pointers (1A)

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1/7/19

Pointer to Multi-dimensional Arrays

Integer pointer types

(int **)

a pointer to a **integer pointer**
size = 8 bytes

(int *)

a pointer to an **int**
size = 8 bytes

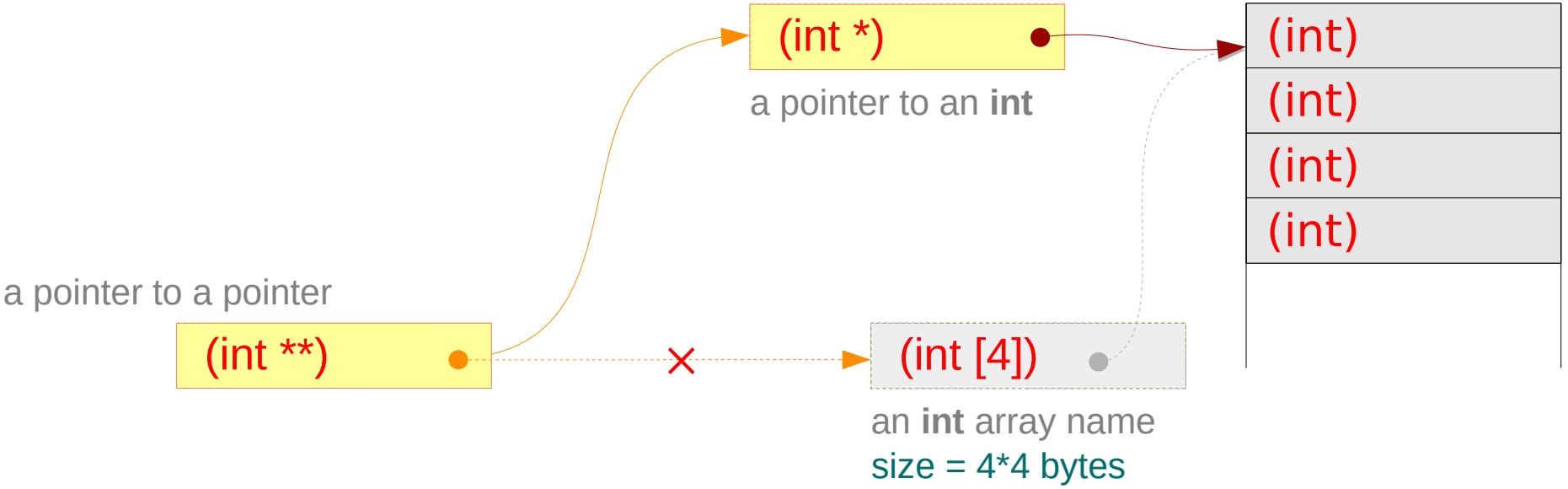
(int (*)[4])

a pointer to a **1-d array**
size = 8 bytes

(int [4])

an **int array** name
size = 4*4 bytes

Integer pointer type : (int **)



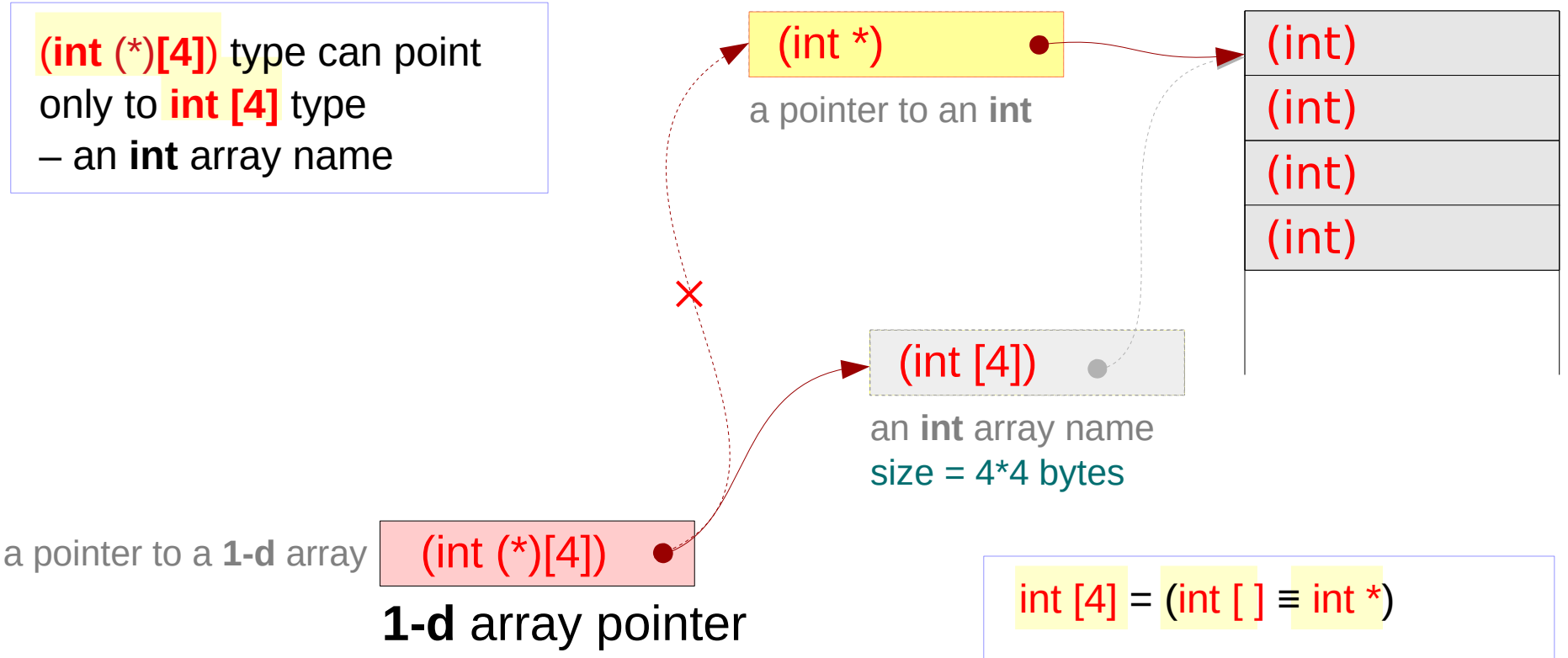
(**int** **) type can point only to (**int ***) type – an **int** array name

int [4] = (int [ ] ≡ int *)

each of these types points to an **int** type data

Integer pointer type : (int (*)[4])

(int (*)[4]) type can point only to **int [4]** type
– an **int** array name



int [4] = (int [ ] ≡ int *)

each of these types points to an **int** type data

Integer pointer types

```
#include <stdio.h>

void func(int d[])
{

}

int main(void) {
  int a[4];
  int *b;
  int **c;

  int (*p)[4];

  func(a);


}
```

```
sizeof(a)=16 = 4*4      // array size
sizeof(*a)=4            // int size

sizeof(b)=8             // pointer size
sizeof(*b)=4            // int size

sizeof(c)=8             // pointer size
sizeof(*c)=8            // pointer size

sizeof(d)=8             // pointer size
sizeof(*d)=4            // int size

sizeof(p)=8             // pointer size
sizeof(*p)=16=4*4       // array size
```

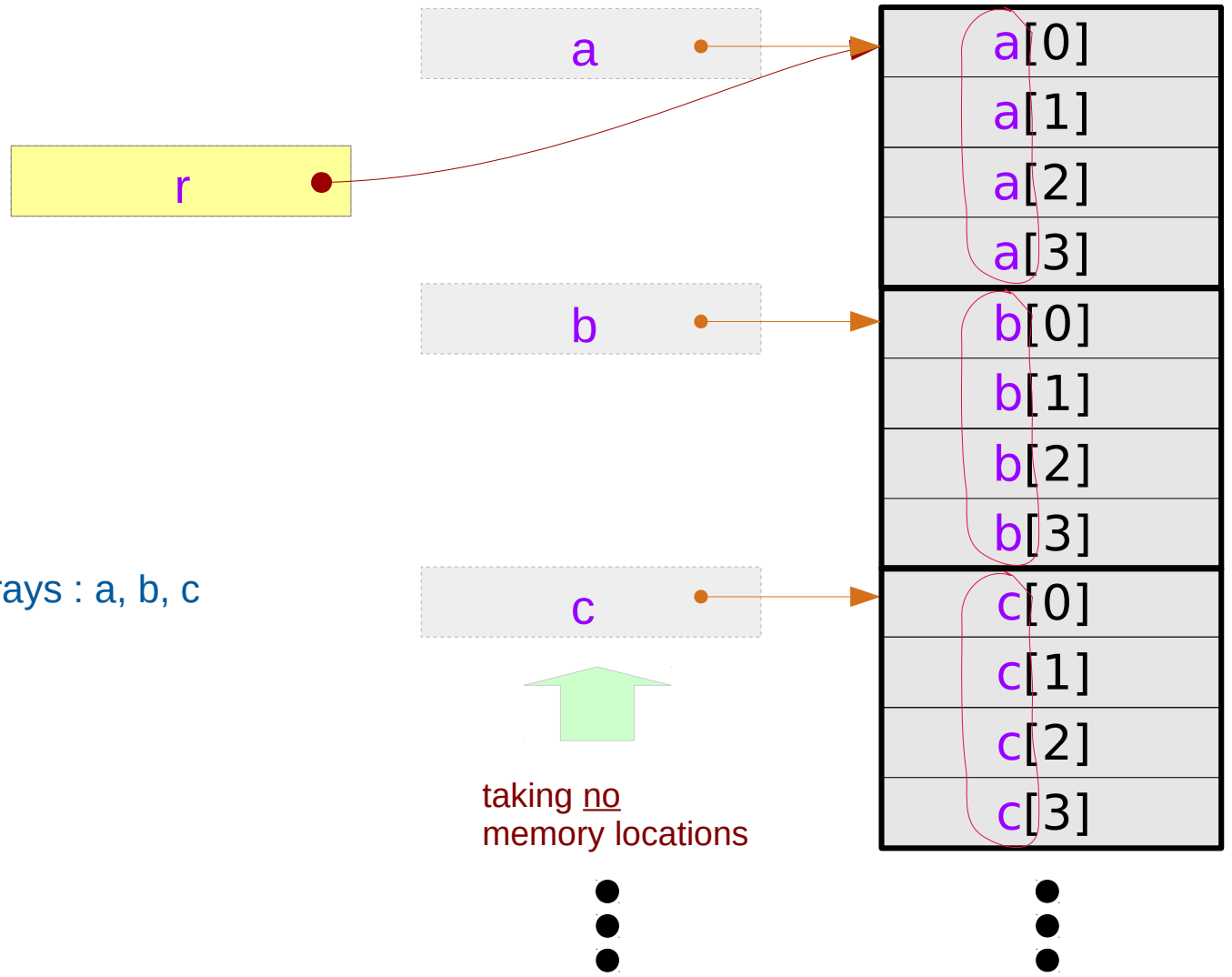
Series of **1-d** arrays

series of 1-d array pointers

- extending a dimension
- enabling a 2-d access of 1-d arrays

Contiguous **1-d** arrays **a**, **b**, **c** are assumed

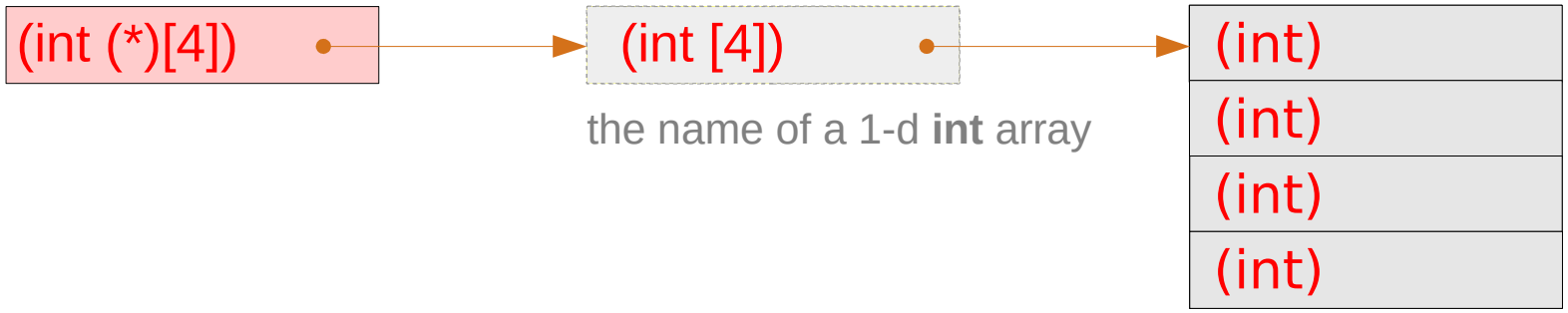
```
int a[4];  int  (*r);
int b[4];
int c[4];
```



assume contiguous 1-d arrays : a, b, c

a **1-d** array pointer – a type view

a pointer to a 1-d array



the name of a 1-d **int** array

the array name
has a size of 0

does not take
any memory location

assigning series of array pointers **p1**, **p2**, **p3**

```
int a[4];
int b[4];
int c[4];
```

```
int (*p1)[4];
int (*p2)[4];
int (*p3)[4];
```

```
int  (*r);
```

```
int (*q)[4][4];
```

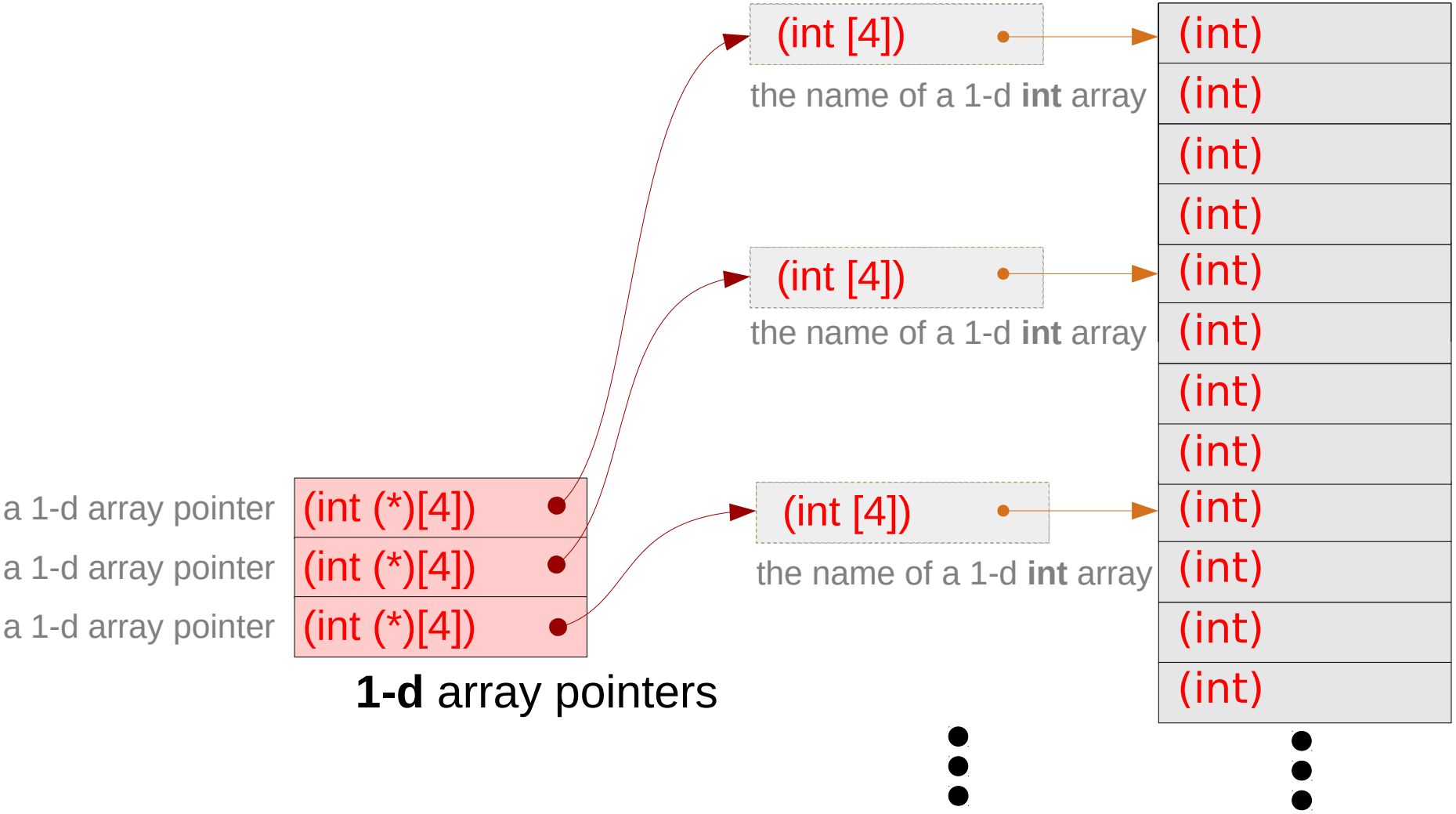
assignment

p1 = &a
p2 = &b
p3 = &c

equivalence

(*p1) ≡ p1[0] ≡ a
(*p2) ≡ p2[0] ≡ b
(*p3) ≡ p3[0] ≡ c

type view of array pointers

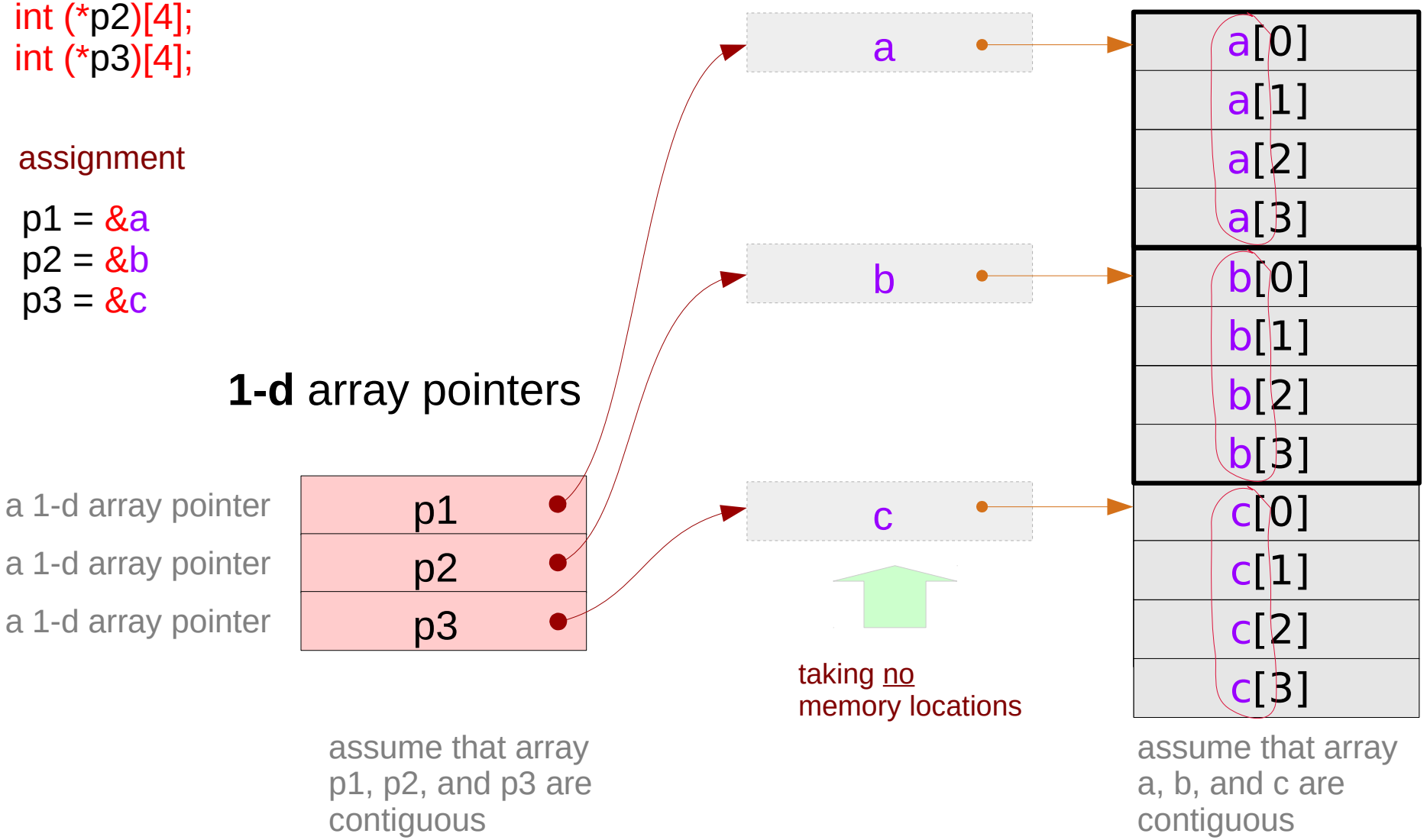


1-d array pointers p1, p2, p3

```
int (*p1)[4];
int (*p2)[4];
int (*p3)[4];
```

assignment

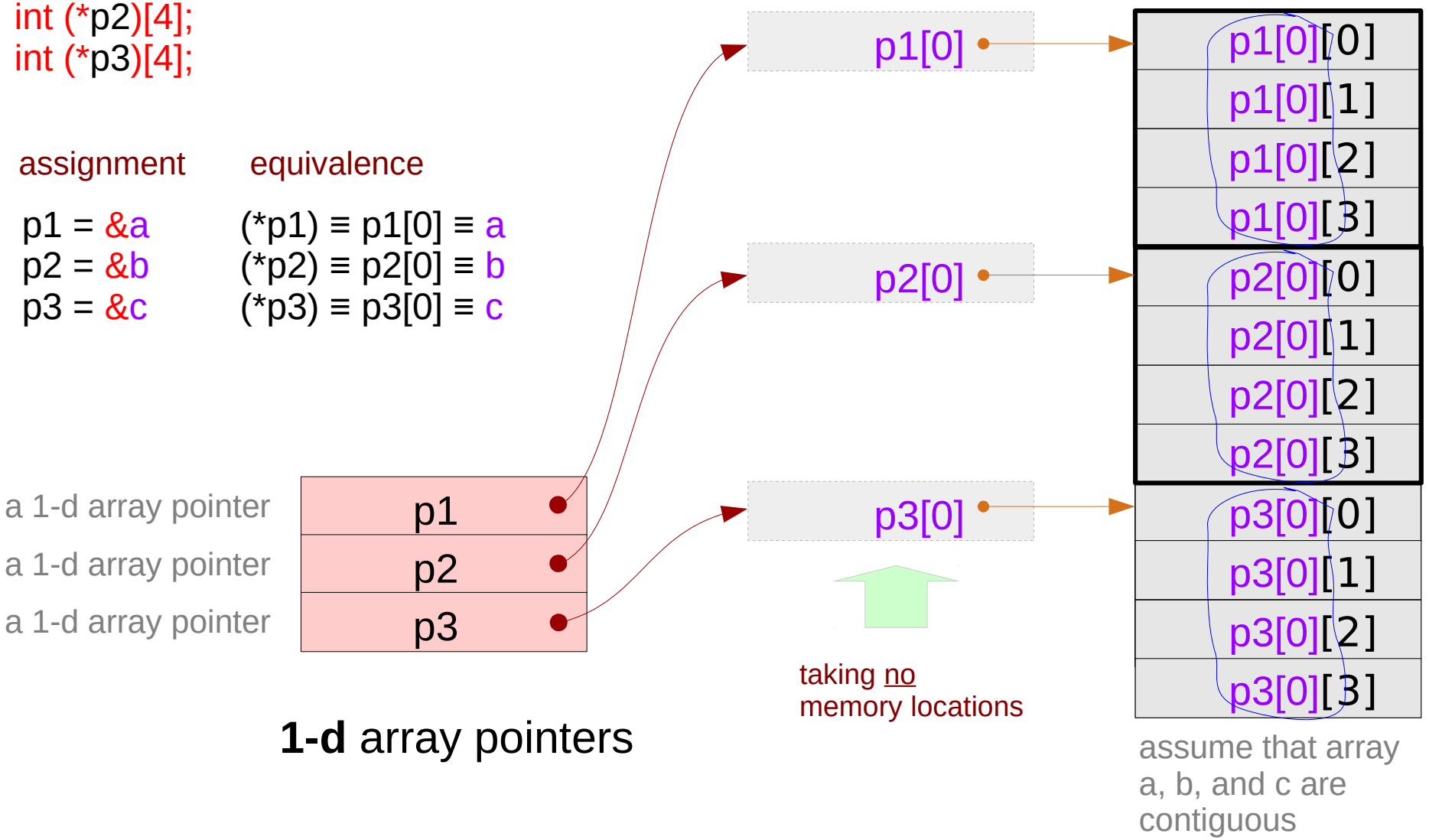
```
p1 = &a
p2 = &b
p3 = &c
```



1-d arrays via **p1**, **p2**, **p3**

```
int (*p1)[4];
int (*p2)[4];
int (*p3)[4];
```

assignment	equivalence
p1 = &a	(*p1) ≡ p1[0] ≡ a
p2 = &b	(*p2) ≡ p2[0] ≡ b
p3 = &c	(*p3) ≡ p3[0] ≡ c



1-d array pointers

1-d array pointer p

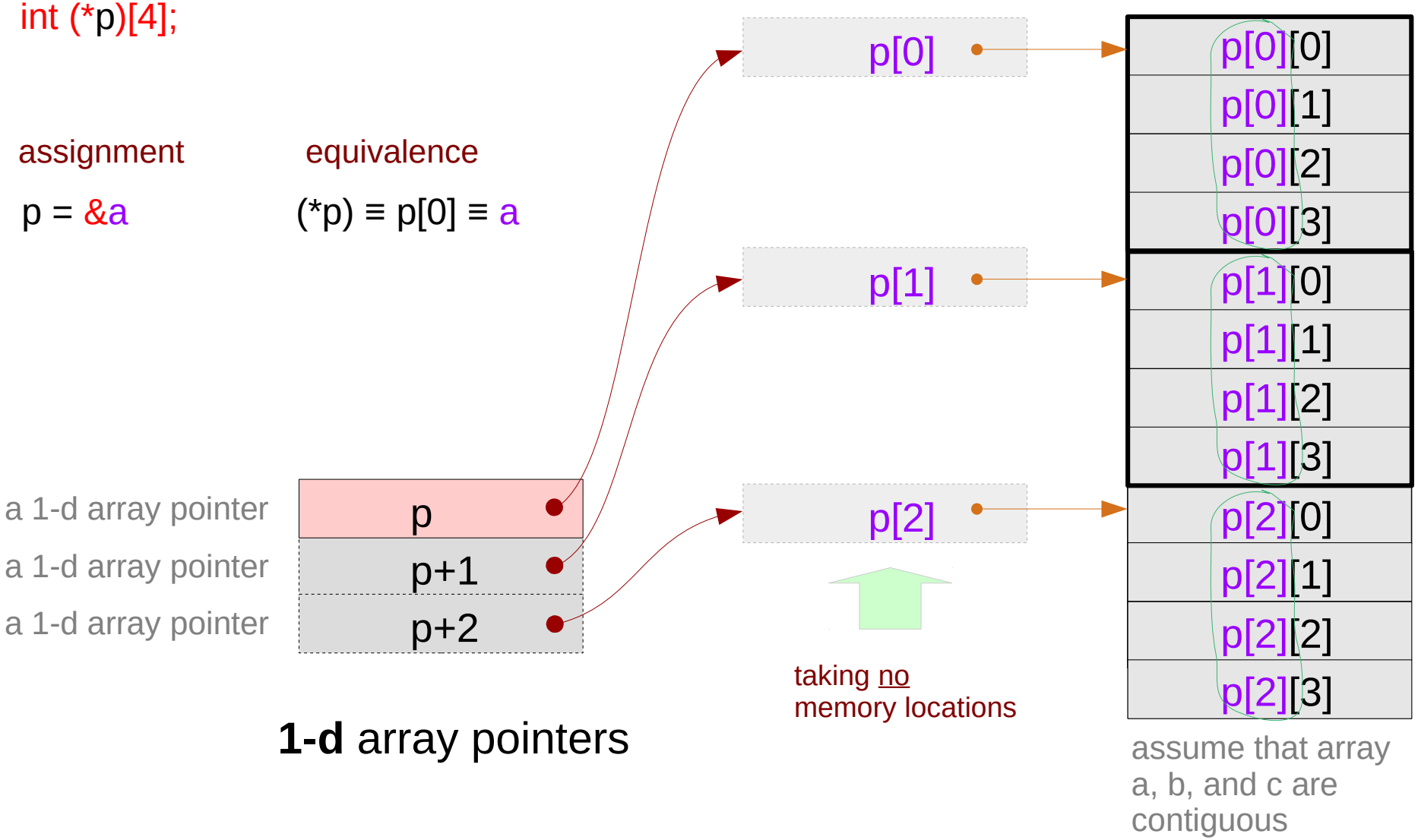
int (*p)[4];

assignment

p = &a

equivalence

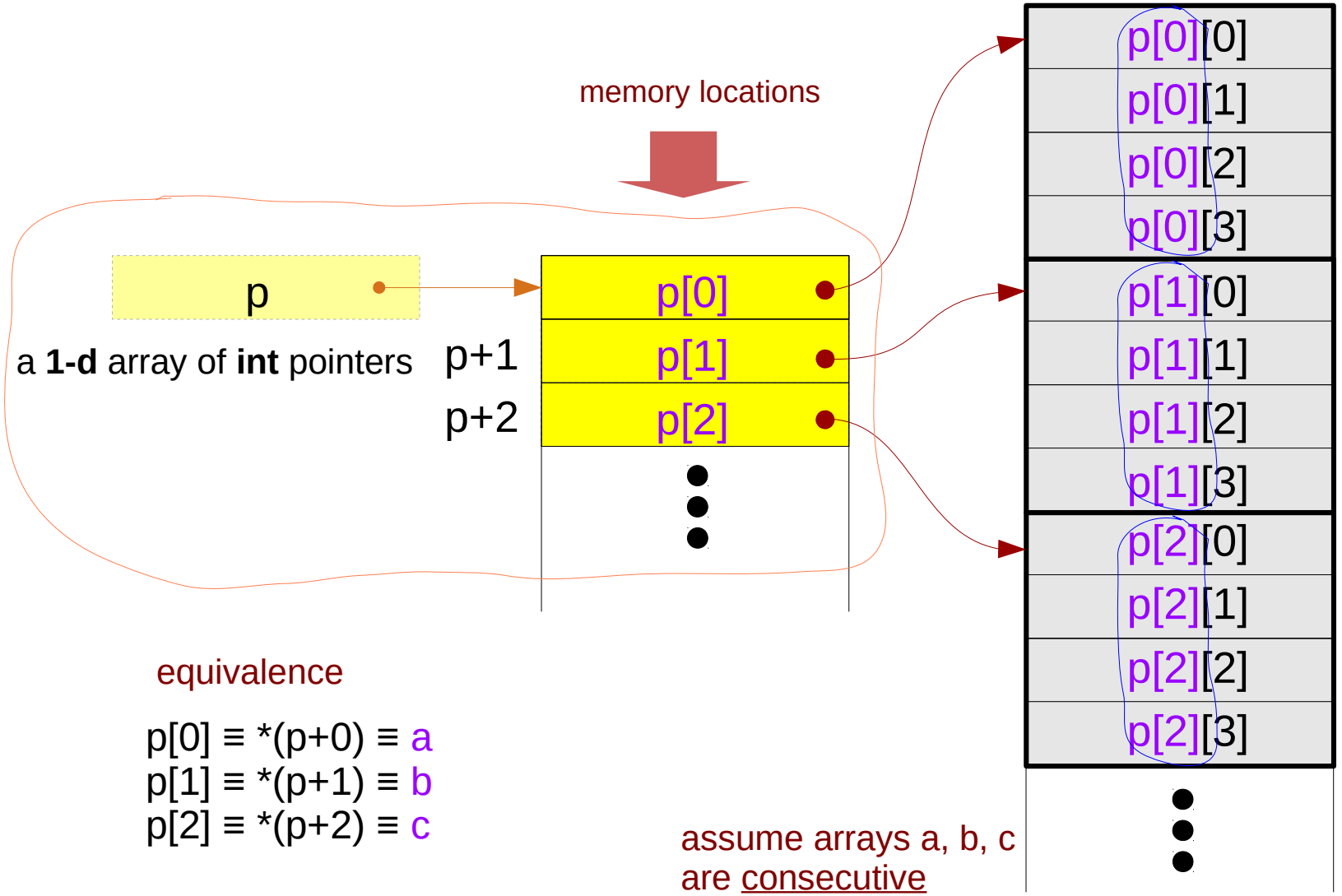
(*p) ≡ p[0] ≡ a



1-d array pointers

1-d array p of integer pointers

int *p[4];



assignment

p[0] = a
p[1] = b
p[2] = c

equivalence

p[0] ≡ *(p+0) ≡ a
p[1] ≡ *(p+1) ≡ b
p[2] ≡ *(p+2) ≡ c

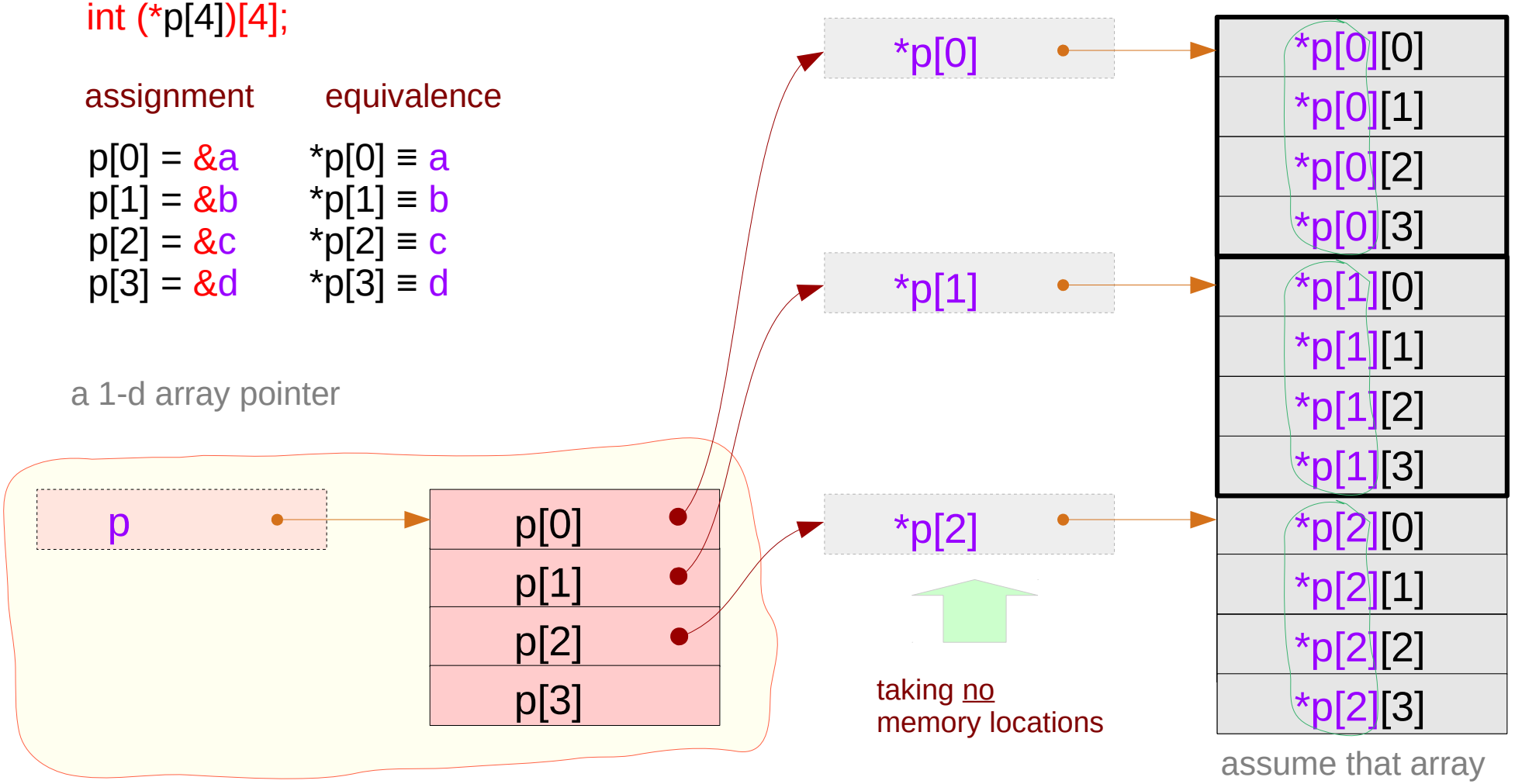
assume arrays a, b, c
are consecutive

an array **p** of array pointers

```
int (*p[4])[4];
```

assignment	equivalence
p[0] = &a	*p[0] ≡ a
p[1] = &b	*p[1] ≡ b
p[2] = &c	*p[2] ≡ c
p[3] = &d	*p[3] ≡ d

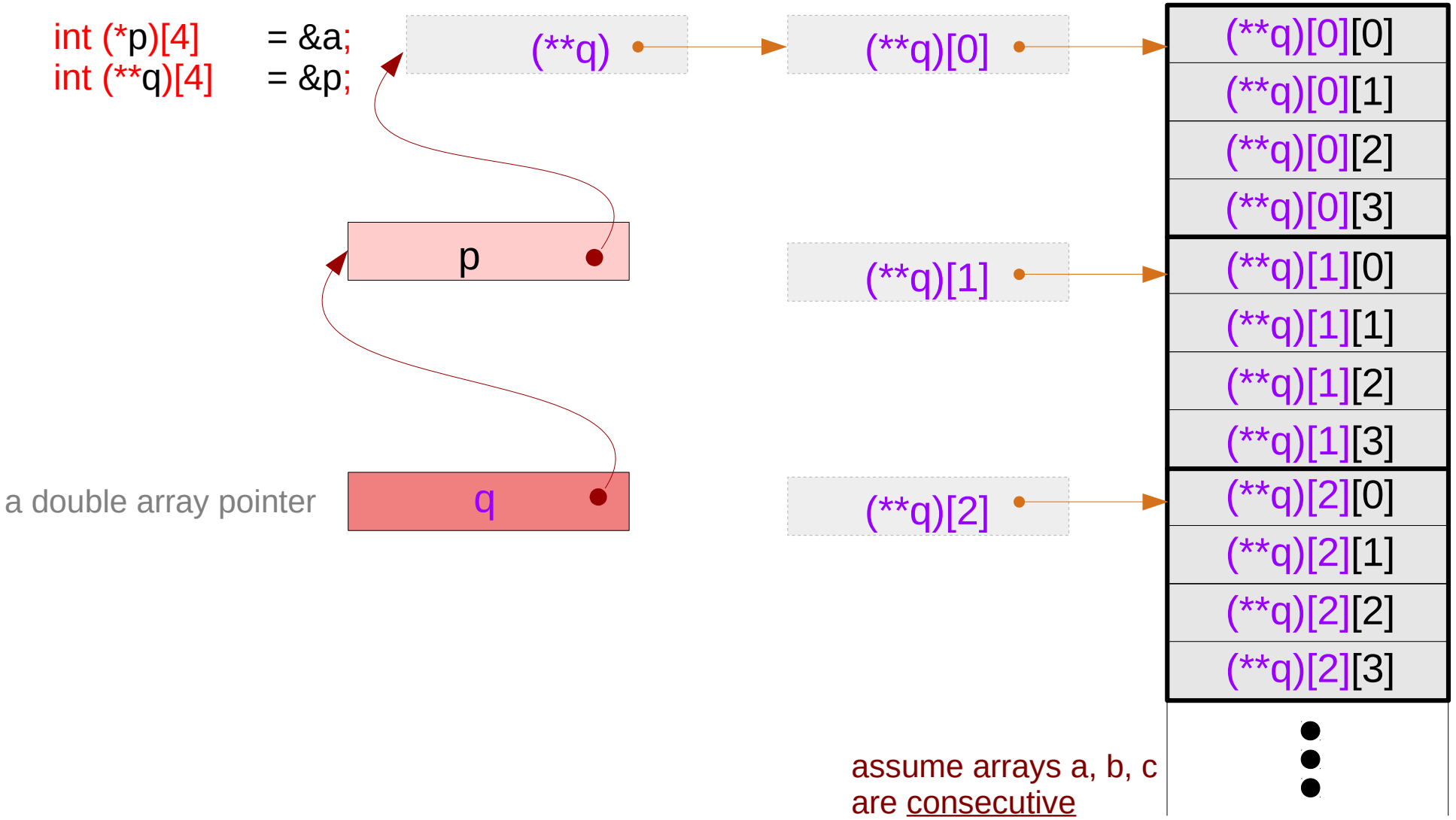
a 1-d array pointer



An array of **1-d** array pointers

assume that array a, b, and c are contiguous

a double array pointer **q**



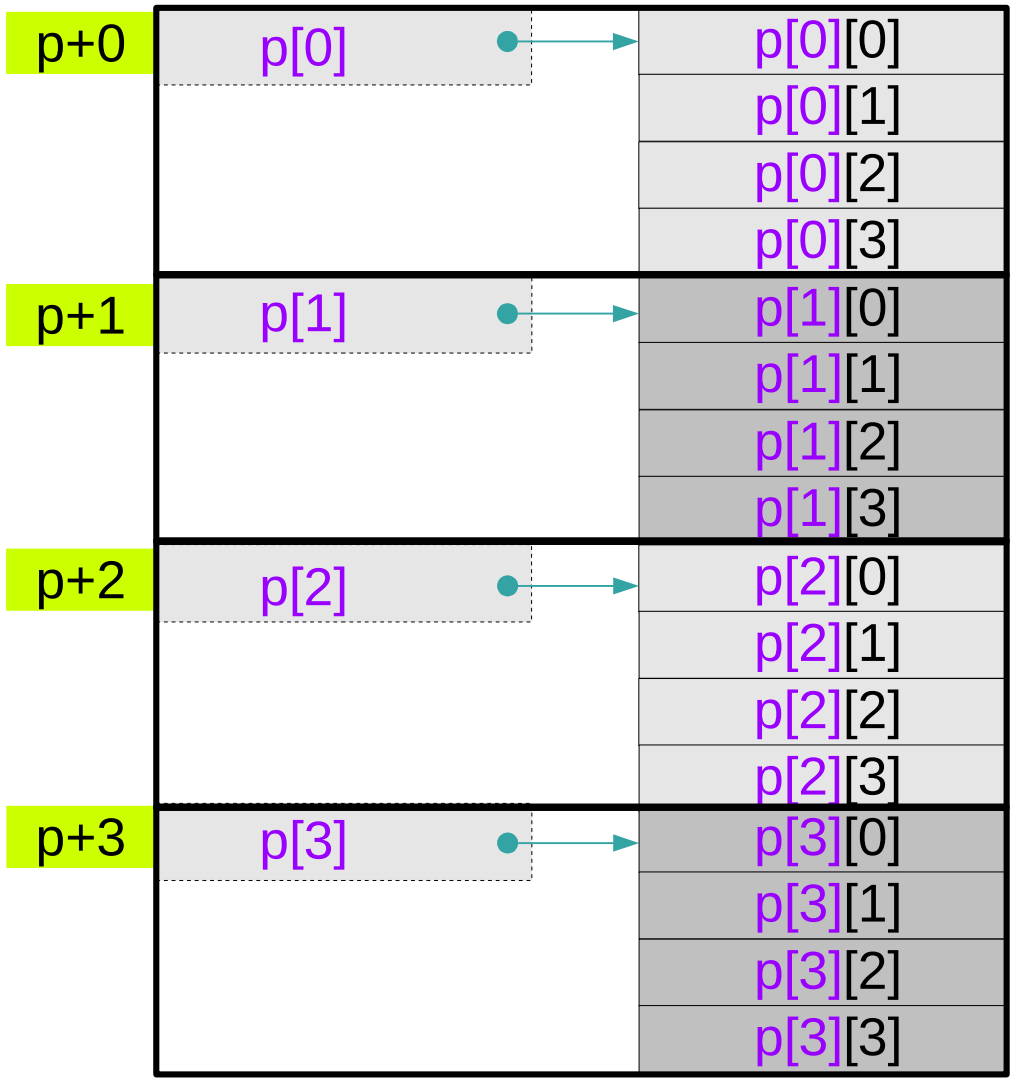
1-d array pointer to consecutive 1-d arrays

int (*p)[4];

a pointer to a pointer array

p

1-d array pointer



assignment

p = &a

equivalence

*(p+0) ≡ p[0] ≡ a
*(p+1) ≡ p[1] ≡ b
*(p+2) ≡ p[2] ≡ c
*(p+2) ≡ p[2] ≡ d

if arrays a, b, c, d
are consecutive

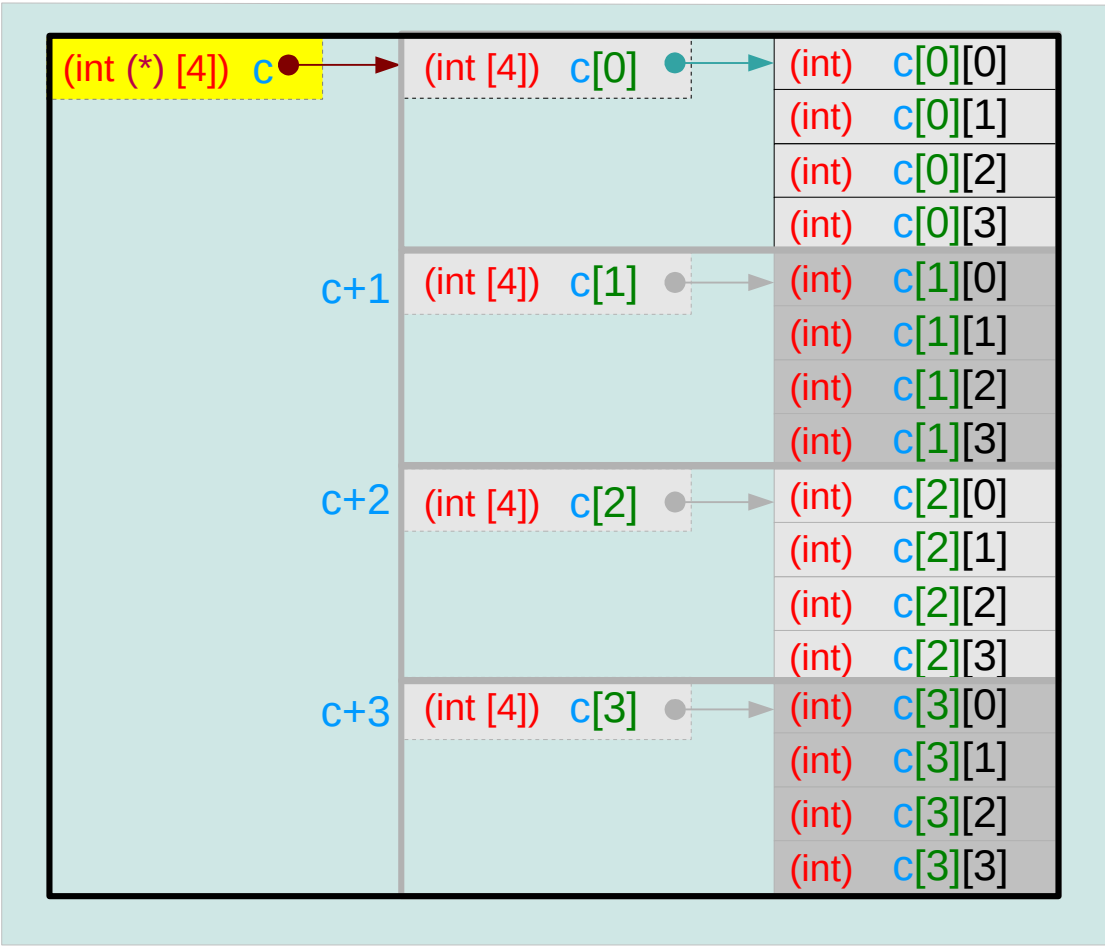
A **2-d** array and its sub-arrays – array name

int c[4][4];

c :

- the **2-d** array name
- the **2-d** array starting address
- the **1-d** array pointer
  points to its 1st **1-d** sub-array

compilers do not allocate
c's memory location



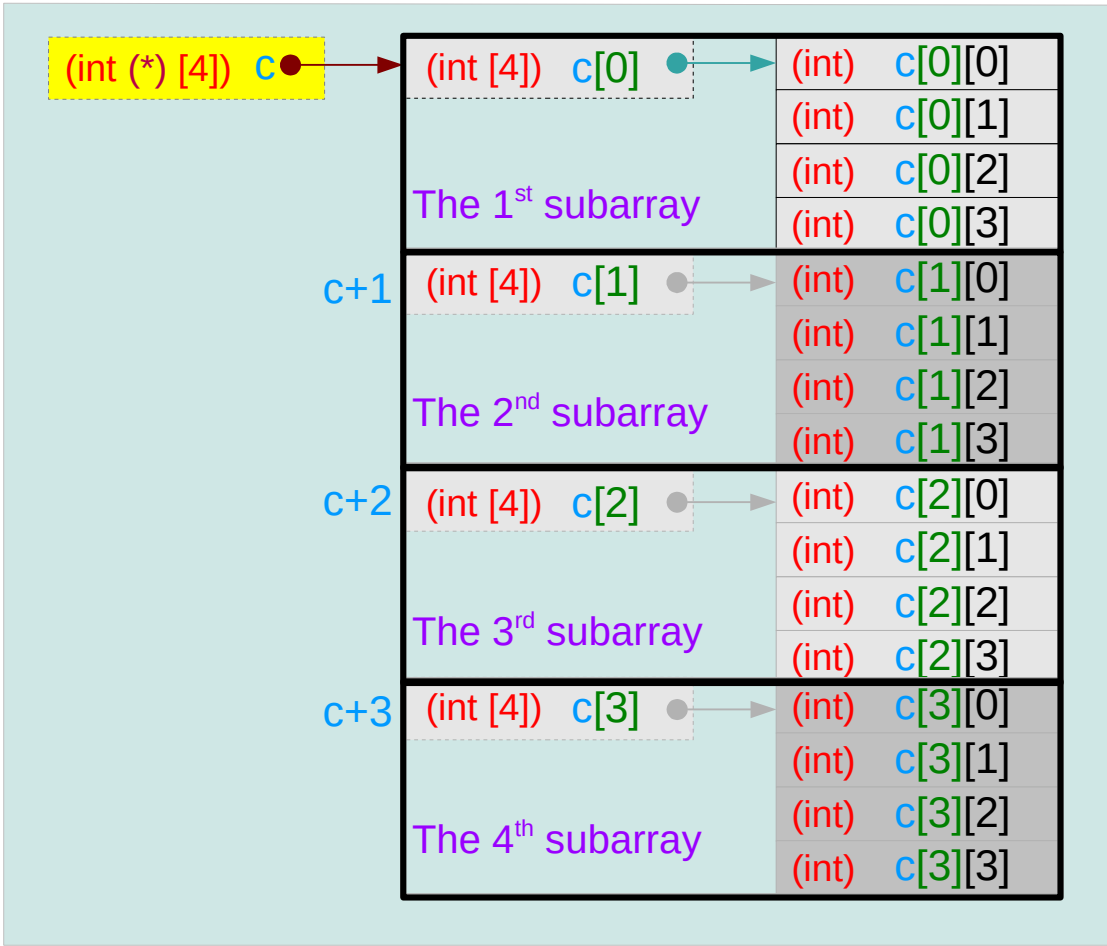
A **2-d** array and its sub-arrays – subarray names

int c[4][4];

c[i]
- the **1-d** array name
- the **1-d** array starting address
- the **0-d** array pointer
  points to its scalar integer

c[0]	the 1st	**1-d** subarray name
c[1]	the 2nd	**1-d** subarray name
c[2]	the 3rd	**1-d** subarray name
c[3]	the 4th	**1-d** subarray name

compilers do not allocate
c[i]'s memory location



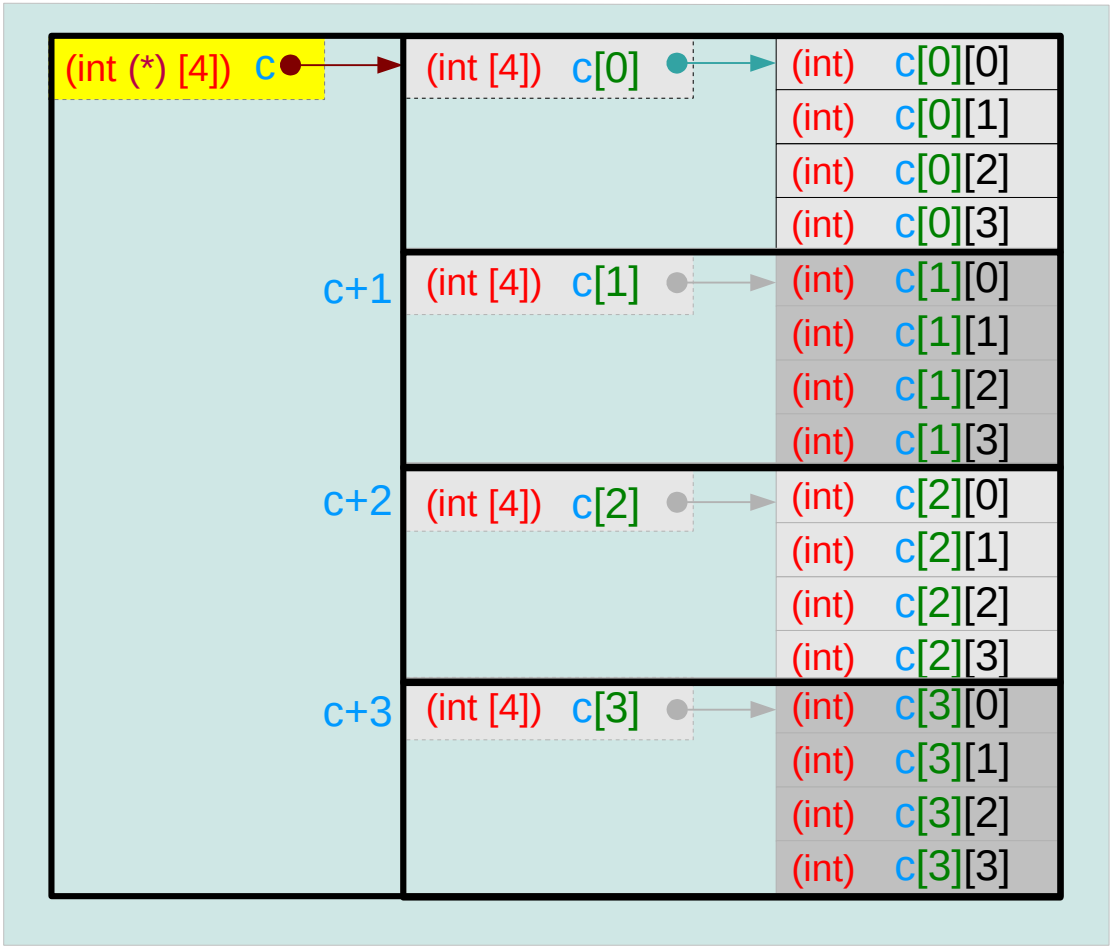
A **2-d** array and its sub-arrays – type sizes

sizeof(c) = 4*4*4 bytes

sizeof(c[i]) = 4*4 bytes

sizeof(c[i][j]) = 4 bytes

c	: the **2-d** array name
c[i]	: the **1-d** array name
c[i][j]	: the **0-d** array name (a scalar integer)



A **2-d** array and its **1-d** sub-arrays – a type view

2-d array name c int (*) [4]

1-d array pointer c int (*) [4]

1-d subarray name c[0] int [4]

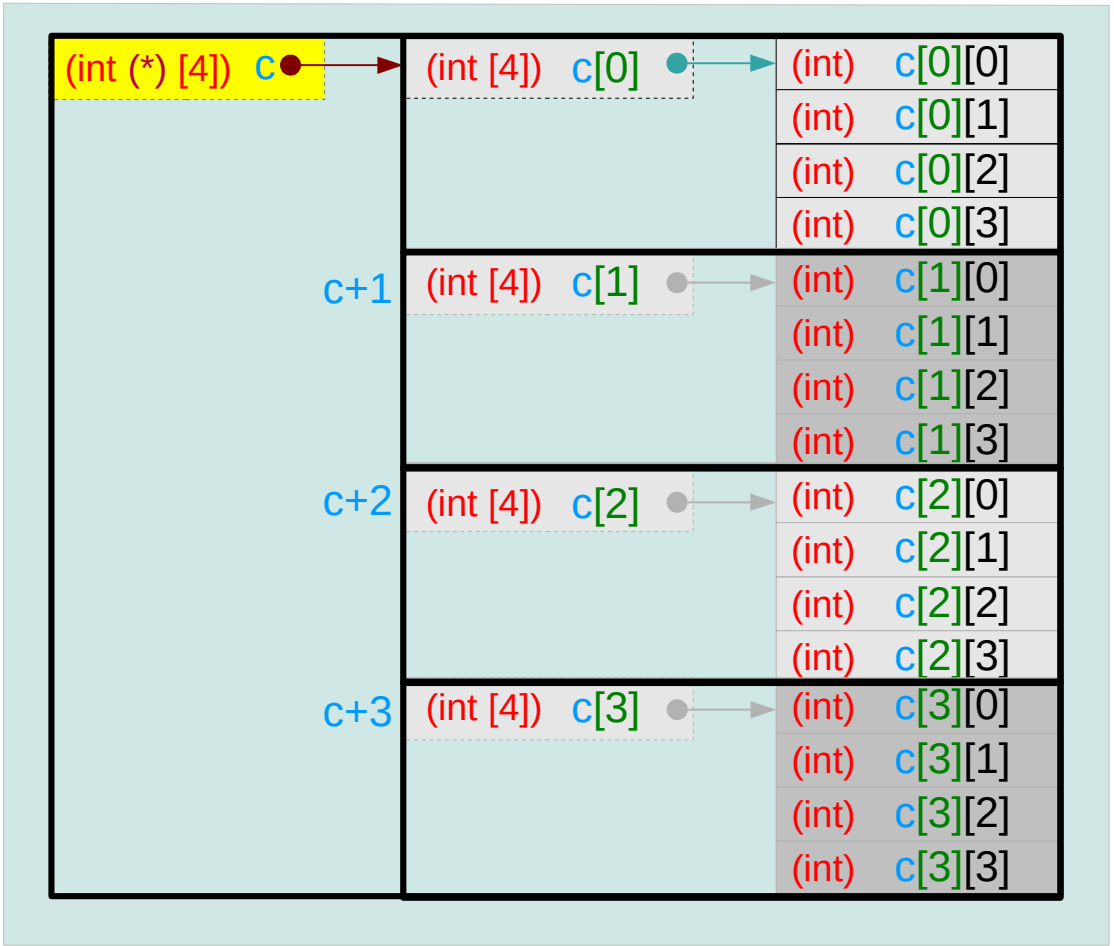
1-d subarray name c[1] int [4]

1-d subarray name c[2] int [4]

1-d subarray name c[3] int [4]

c and c[0]

- different types
- the same address of the starting element



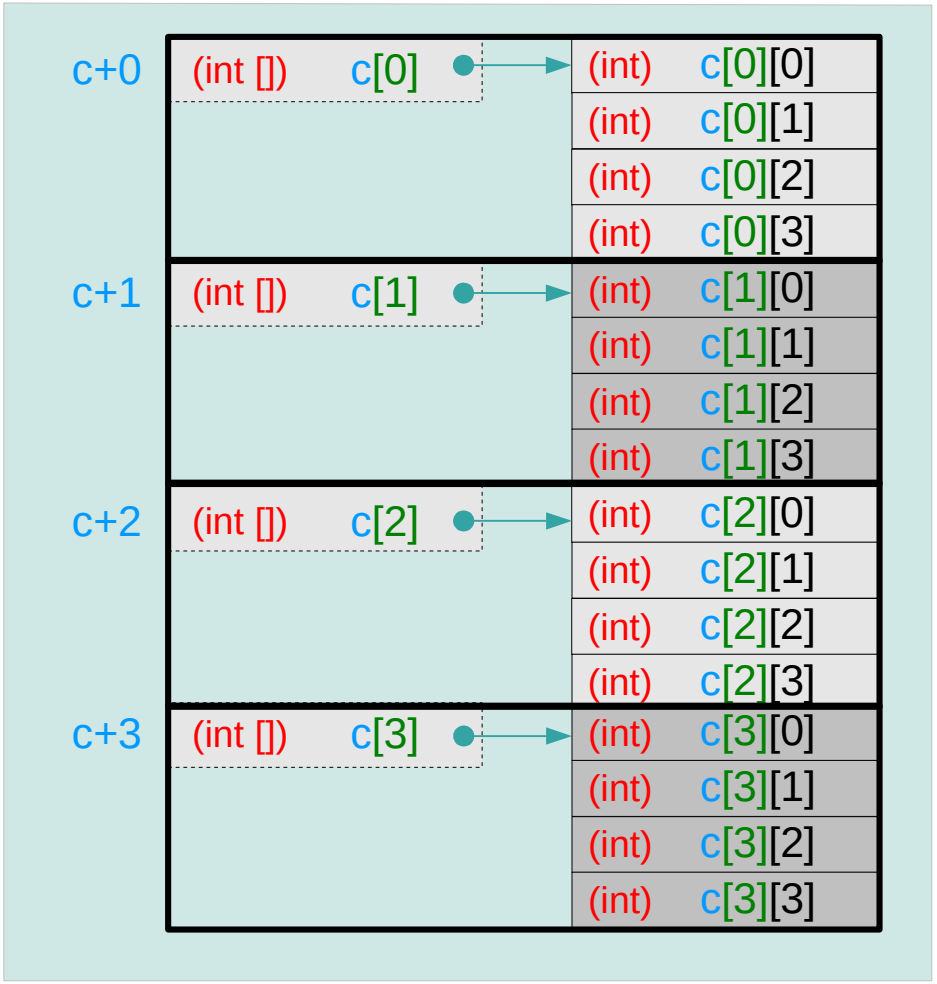
1-d subarray aggregated data type

The 1st subarray c[0] (=subarray name)
sizeof(**c[0]**) = 4*4 bytes
(c+0) : start address

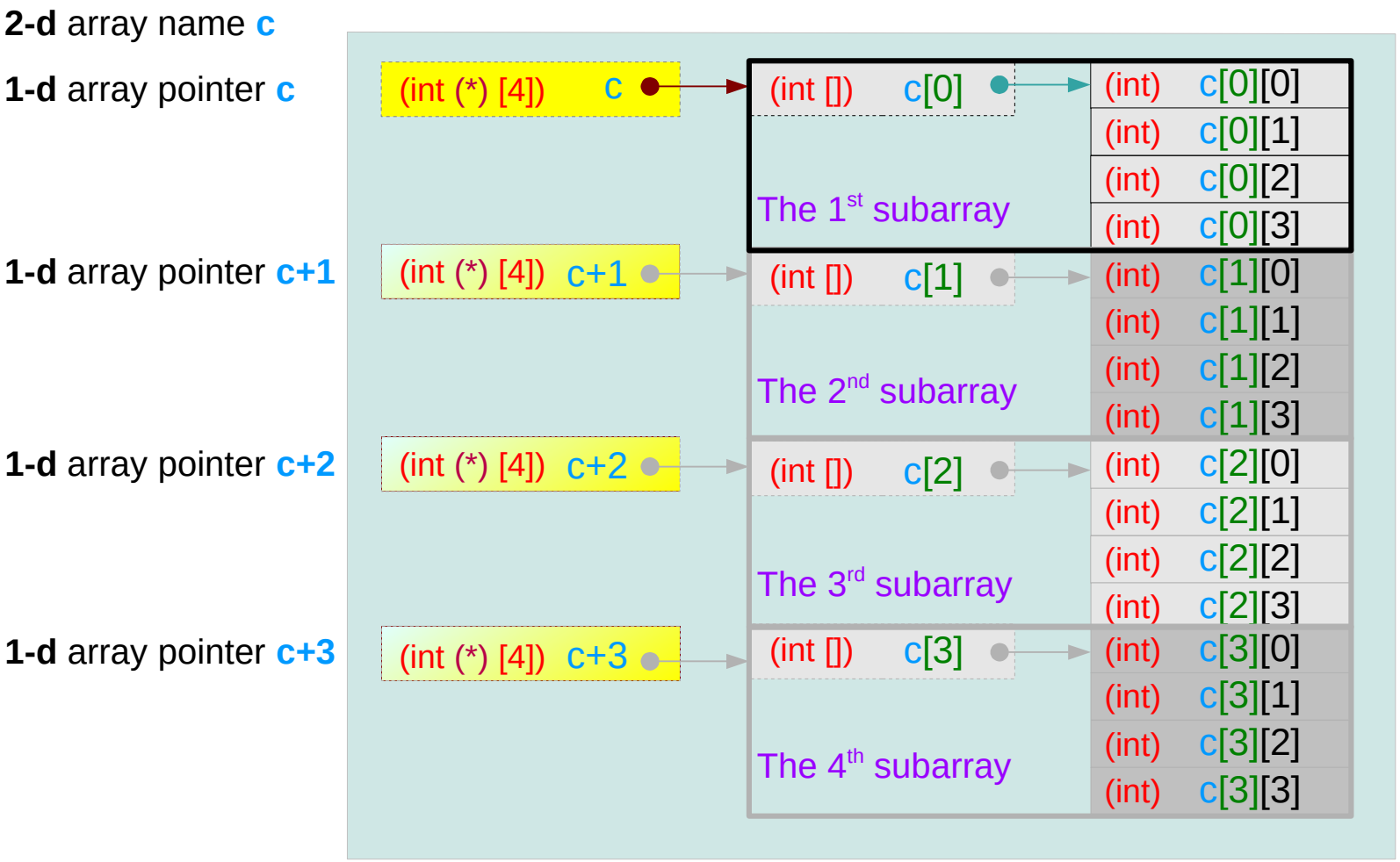
The 2nd subarray c[1] (=subarray name)
sizeof(**c[1]**) = 4*4 bytes
(c+1) : start address

The 3rd subarray c[2] (=subarray name)
sizeof(**c[2]**) = 4*4 bytes
(c+2) : start address

The 4th subarray c[3] (=subarray name)
sizeof(**c[3]**) = 4*4 bytes
(c+3) : start address

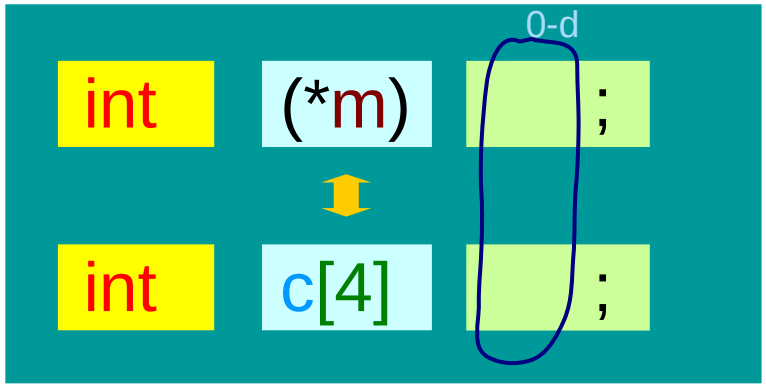


2-d array name as a pointer to a **1-d** subarray



1-d array and **0-d** and **1-d** array pointers

0-d array pointer : int pointer

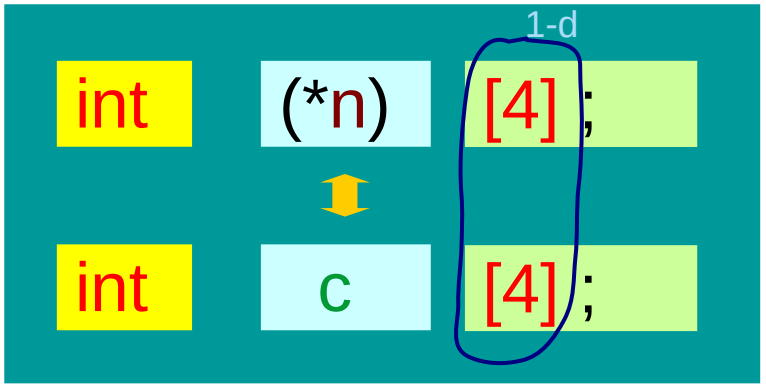


(int (*))

```
m = c;
m = &c[0];
```

m[**i**] ≡ c[**i**]

1-d array pointer



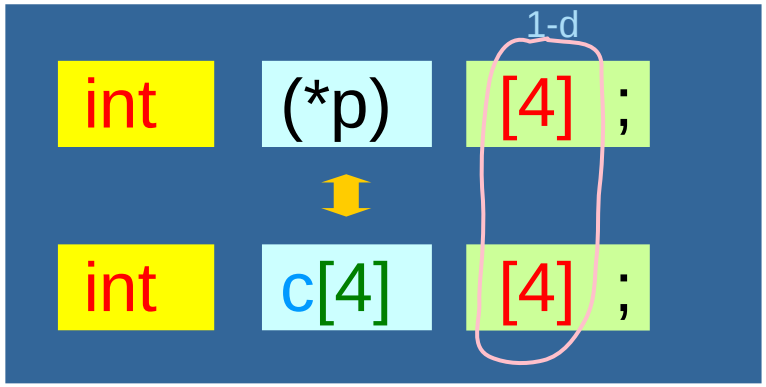
(int(*)[4])

```
n = &c;
```

(*n)[**i**] ≡ n[0][**i**] ≡ c[**i**]

2-d array and **1-d** and **2-d** array pointers

1-d array pointer

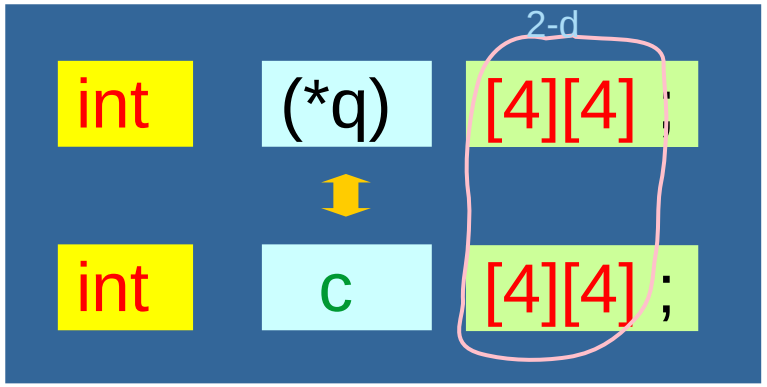


(int (*) [4])

```
p = c;
p = &c[0];
```

p[i] ≡ c[i]

2-d array pointer



(int(*)[4][4])

```
q = &c;
```

(*q)[i][j] ≡ q[0][i][j] ≡ c[i][j]

Using a **1-d** array pointer to a **2-d** array

1-d array pointer

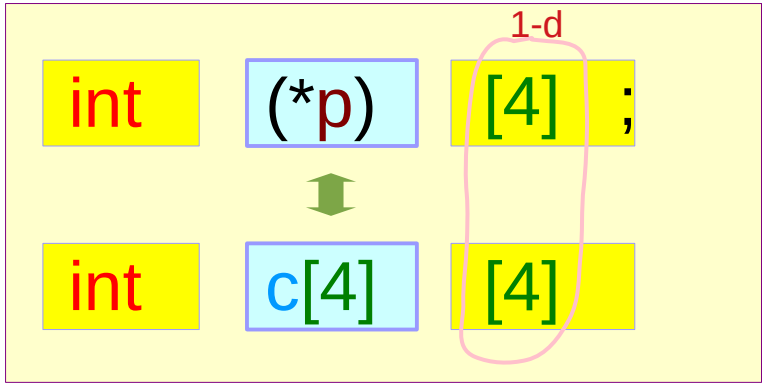
&p (int (*) [4]) p

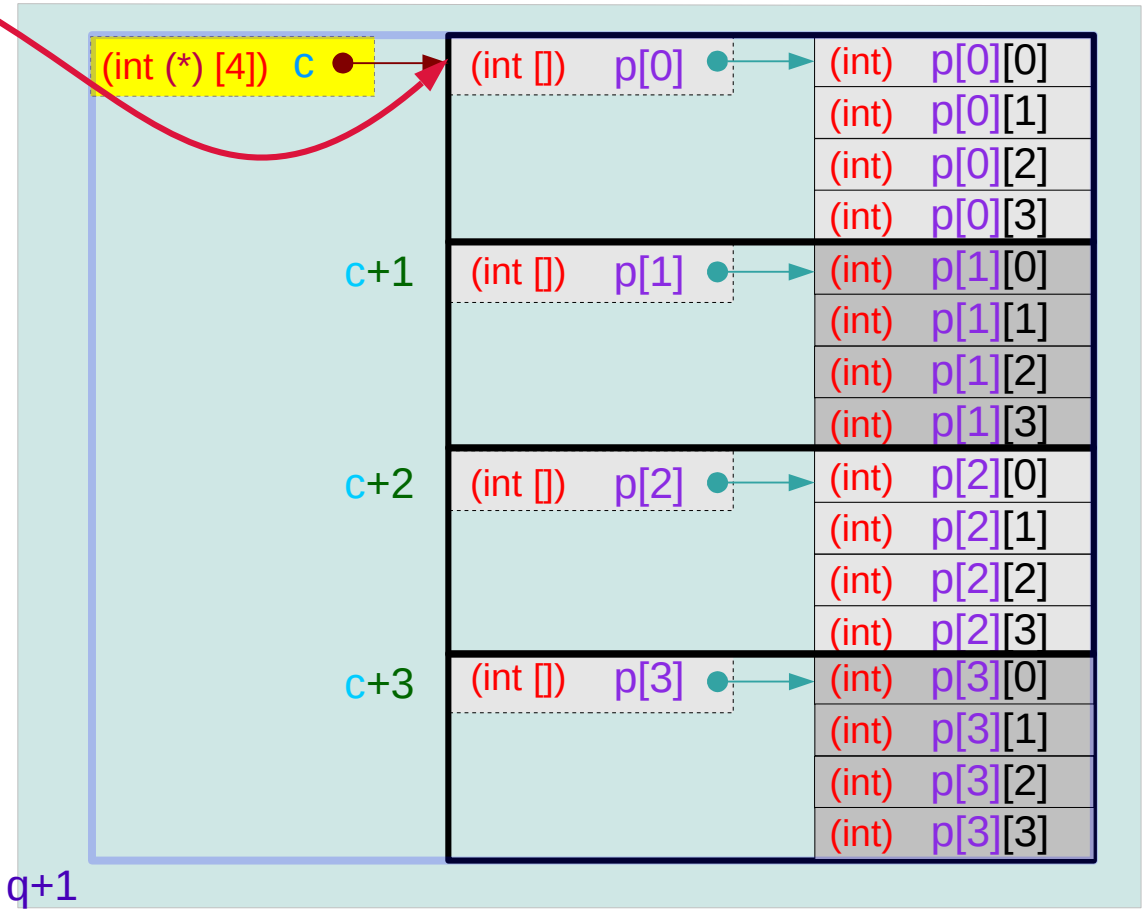
An array pointer:
sizeof(p) = 8 bytes

1-d sub-arrays :
sizeof(*p) = 4*4 bytes

p = c;

p[i] ≡ c[i]





Using a **2-d** array pointer to a **2-d** array

2-d array pointer

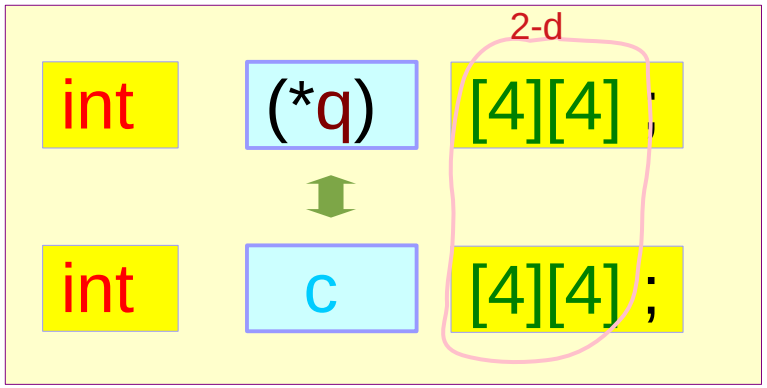
&p (int(*)[4][4]) q

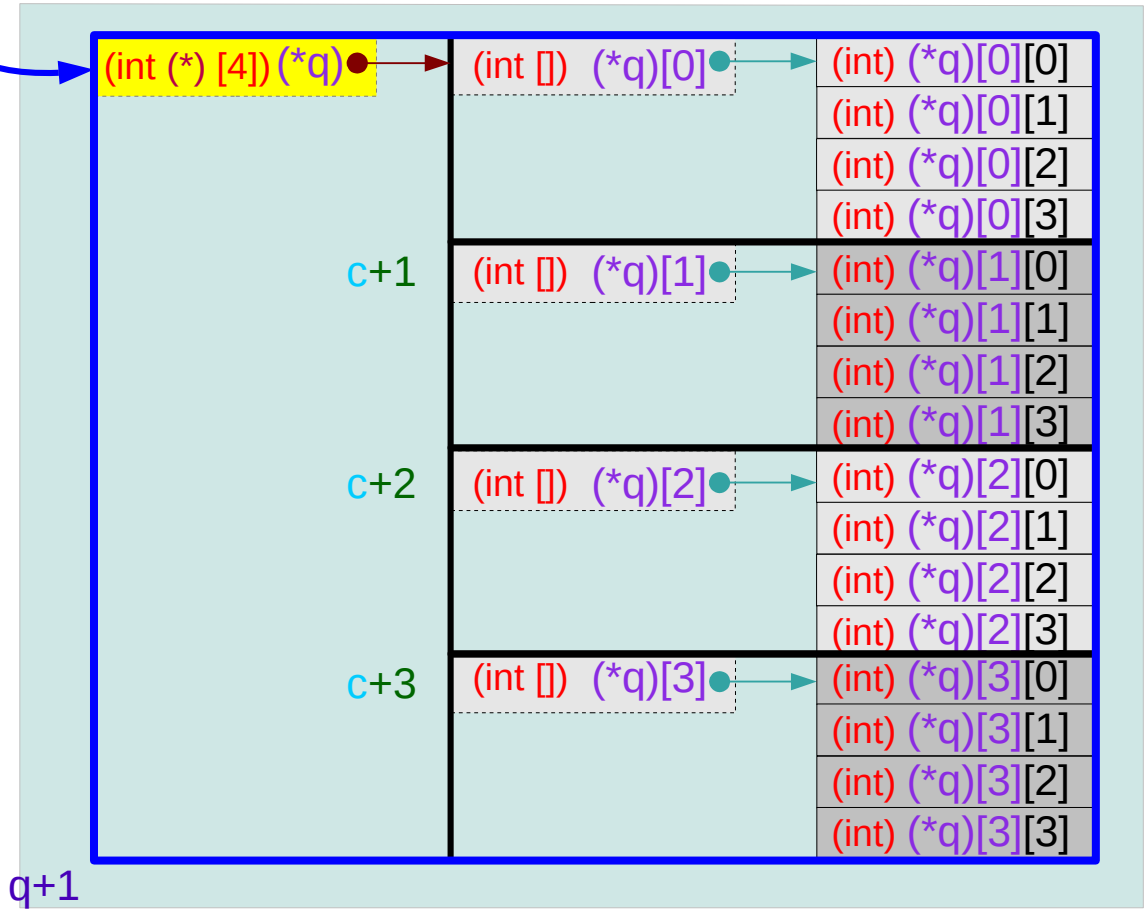
An array pointer:
sizeof(q) = 8 bytes

1-d sub-arrays :
sizeof(*q) = 4*4*4 bytes

q = &c;

(*q)[i] ≡ c[i]





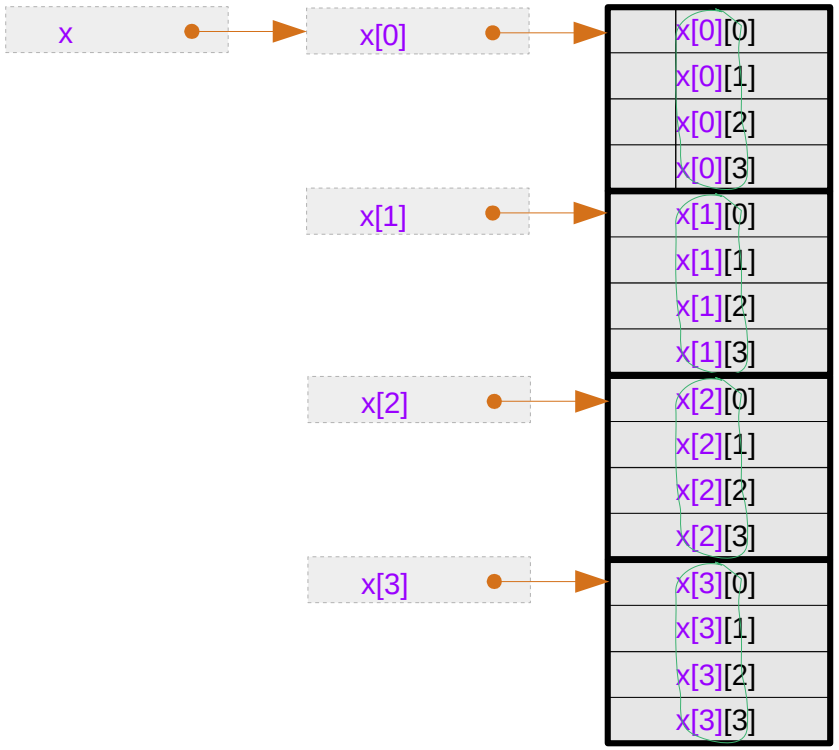
2-d array access using array pointers

- **1-d** array pointer
- **2-d** array pointer
- array of **1-d** array pointers

Accessing a 2-d array

int x[4][4];

A **2-d** array



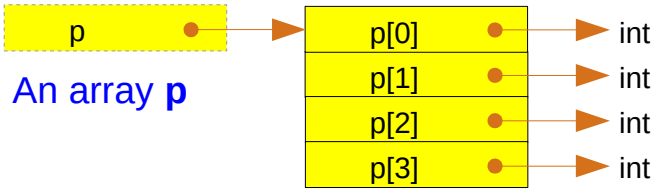
Type definitions

int *p[4];	A **1-d** array **p** of integer pointers
int (*p)[4];	A **1-d** array pointer **p**
int (*p)[4][4];	A **2-d** array pointer **p**
int (*p[4])[4];	An array **p** of **1-d** array pointers

Arrays and Array Pointers **p**

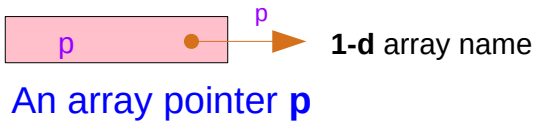
A **1-d** array **p** of integer pointers

int *p[4];



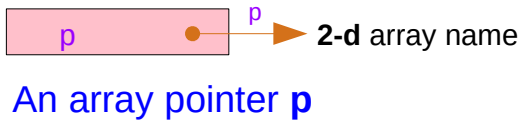
A **1-d** array pointer **p**

int (*p)[4];



A **2-d** array pointer **p**

int (*p)[4][4];



An array **p** of **1-d** array pointers

int (*p[4])[4];

Sizes of p, p[0], (*p), (*p)[0], *p[0]

A **1-d** array **p** of integer pointers

```
int *p[4];
```

sizeof(p)=32 (4*8) an array of int pointers
sizeof(p[0])=8 an int pointer
sizeof(p[0][0])=4 an integer

An array **p**

A **1-d** array pointer **p**

```
int (*p)[4];
```

sizeof(p)=8 a 1-d array pointer
sizeof(*p)=16 (4*4) a 1-d array
sizeof((*p)[0])=4 an integer

An array pointer **p**

A **2-d** array pointer **p**

```
int (*p)[4][4];
```

sizeof(p)=8 a 2-d array pointer
sizeof(*p)=64 a 2-d array (4*4*4)
sizeof((*p)[0])=16 a 1-d array (4*4)

An array pointer **p**

An array **p** of **1-d** array pointers

```
int (*p[4])[4];
```

sizeof(p)=32 (4*8) a 1-d array of 1-d array pointers
sizeof(p[0])=8 a 1-d array pointer
sizeof(*p[0])=16 (4*4) a 1-d array

An array **p**

Initialization

A **1-d** array **p** of integer pointers

```
int *p[4];
```

```
p[0] = x[0];
p[1] = x[1];
p[2] = x[2];
p[3] = x[3];
```

A **1-d** array pointer **p**

```
int (*p)[4];
```

```
p = &x[0]
```

A **2-d** array pointer **p**

```
int (*p)[4][4];
```

```
p = &x
```

An array **p** of **1-d** array pointers

```
int (*p[4])[4];
```

```
p[0] = x[0];
p[1] = x[1];
p[2] = x[2];
p[3] = x[3];
```

Initialization

int *p[4]	= {x[0], x[1], x[2], x[3]};	p[m][n]
int (*p)[4]	= &x[0];	p[m][n]
int (*p)[4][4]	= &x;	(*p)[m][n]
int (*p[4])[4]	= {x[0], x[1], x[2], x[3]};	(*p[m])[n]

Access methods

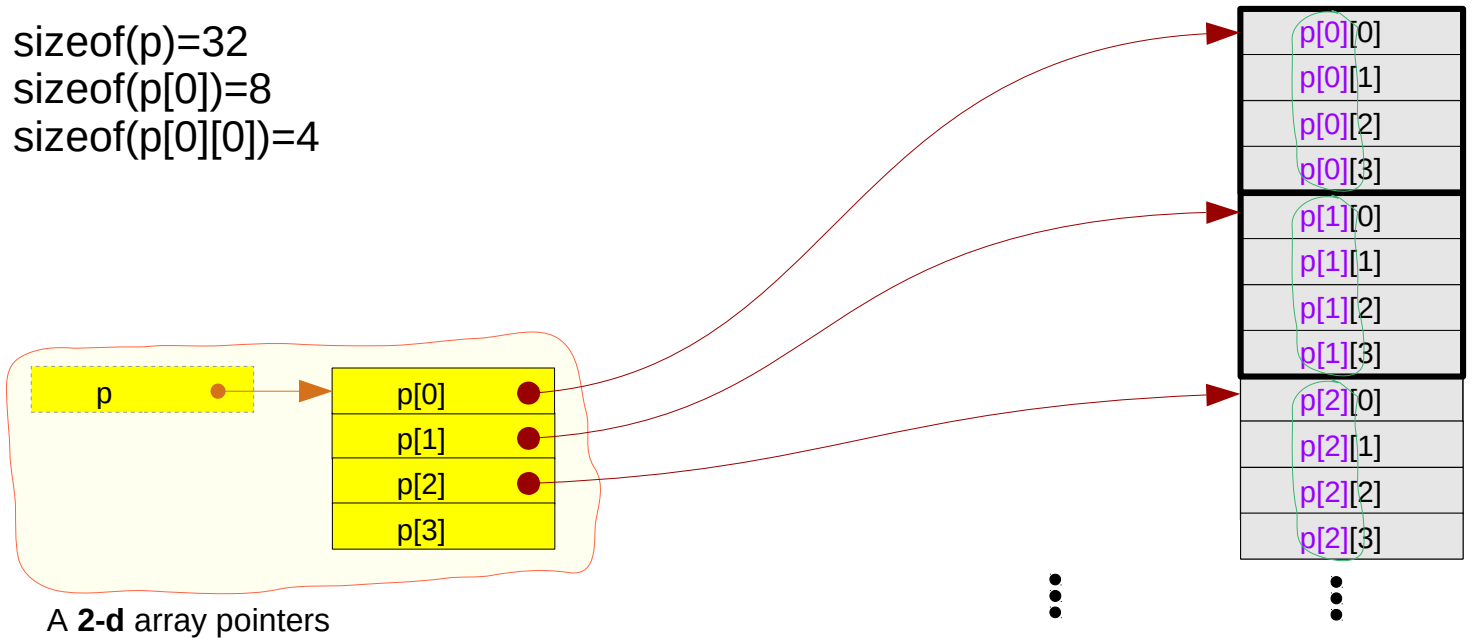
int *p[4];	*p[m]	*(p[m]+n) = p[m][n]
int (*p)[4];	(*p)[n]	(*(p+m))[n] = p[m][n]
int (*p)[4][4];	(*p)[m][n]	
int (*p[4])[4];	(*p[m])[n]	

Using a **1-d** array of integer pointer **: int *p[4]**

int *p[4]; **Type Definition**

*(p[m]+n) ≡ p[m][n] **Access Method**

sizeof(p)=32
sizeof(p[0])=8
sizeof(p[0][0])=4



A **2-d** array pointers

assignment

p=x

equivalence

p[0]=x[0]
p[1]=x[1]
p[2]=x[2]
p[3]=x[3]

Using a **1-d** array pointer : **int (*p)[4]**

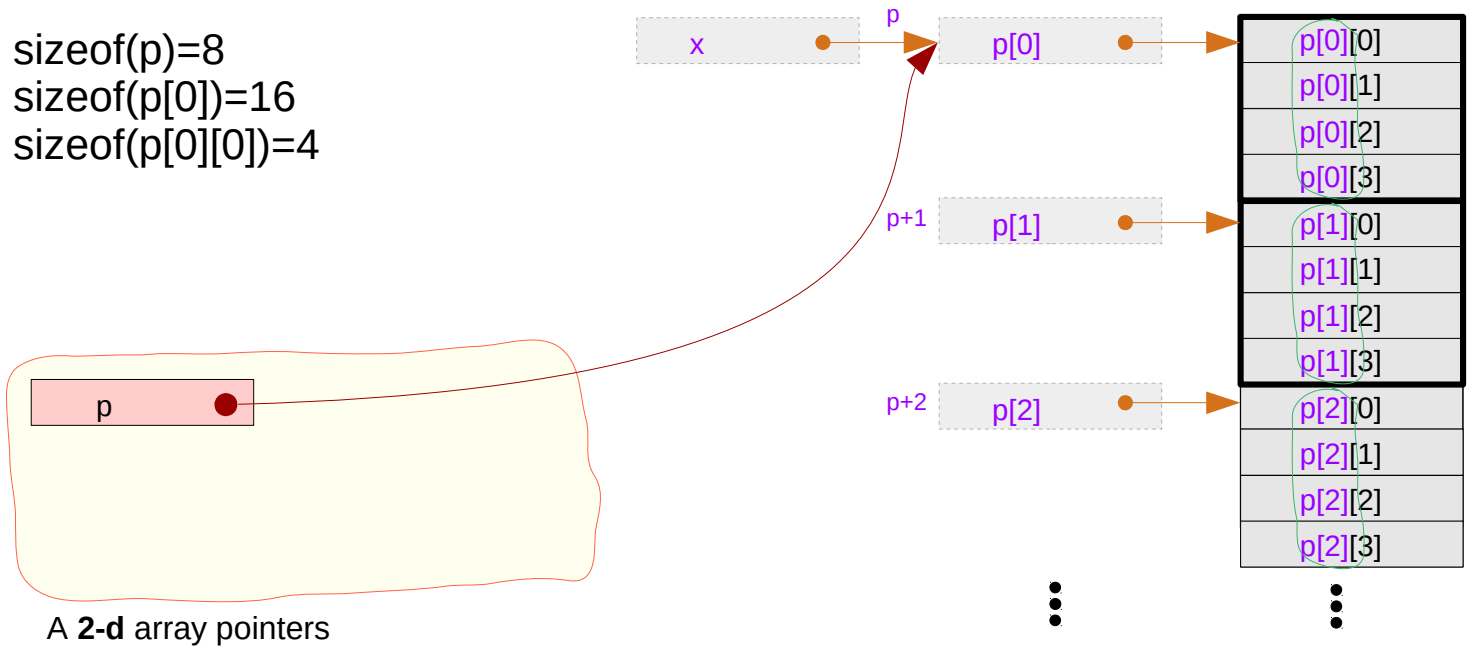
```
int (*p)[4];
```

Type Definition

```
(*(p+i))[j];   ≡   p[i][j];
```

Access Method

sizeof(p)=8
sizeof(p[0])=16
sizeof(p[0][0])=4



A **2-d** array pointers

assignment

p=x

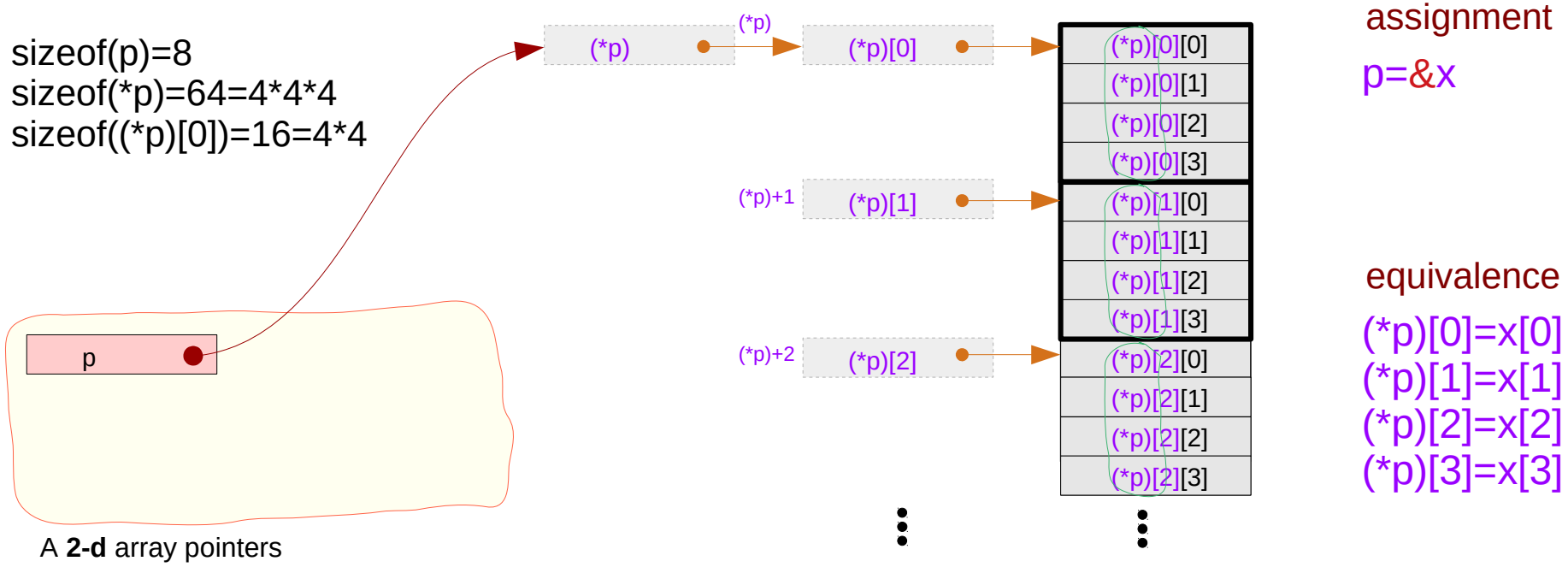
equivalence

p[0]=x[0]
p[1]=x[1]
p[2]=x[2]
p[3]=x[3]

Using a **2-d** array pointer : **int (*p)[4][4]**

int (*p)[4][4]; ≡ int ((*p)[4])[4]; **Type Definition**

(*p)[i][j]; ≡ ((*p)[i])[j]; **Access Method**

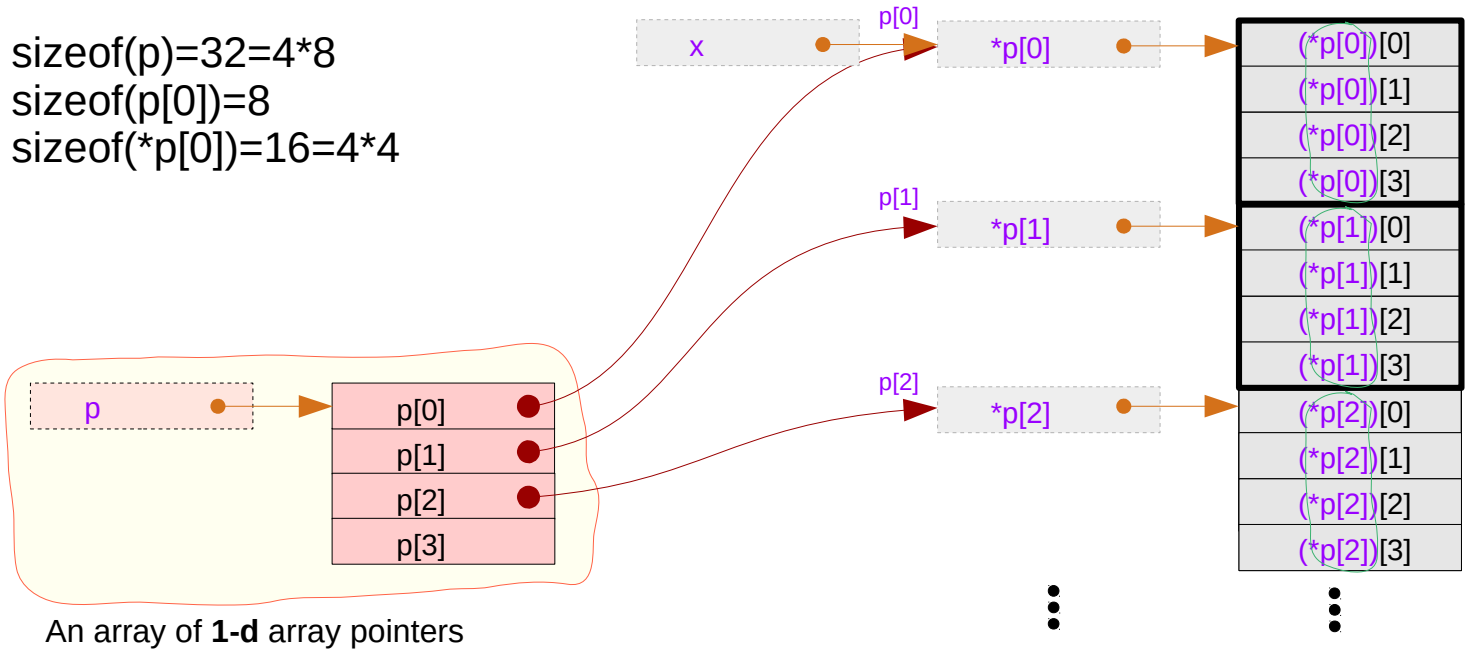


Using an array of **1-d** array pointers : **int (*p[4])[4]**

int (*p[4])[4]; ≡ int (*(p[4]))[4]; **Type Definition**

(*p[i])[j]; ≡ (*(p[i]))[j]; **Access Method**

sizeof(p)=32=4*8
sizeof(p[0])=8
sizeof(*p[0])=16=4*4



An array of **1-d** array pointers

assignment

p[0]=&x[0]
p[1]=&x[1]
p[2]=&x[2]
p[3]=&x[3]

equivalence

*p[0]=x[0]
*p[1]=x[1]
*p[2]=x[2]
*p[3]=x[3]

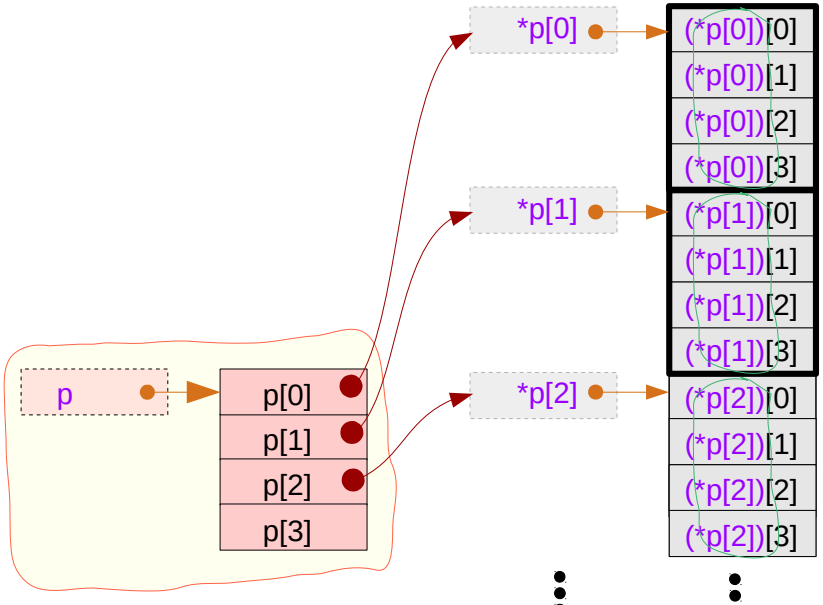
int (*p[4])[4] and (*p)[i][j] : OK

int (*p[4])[4];

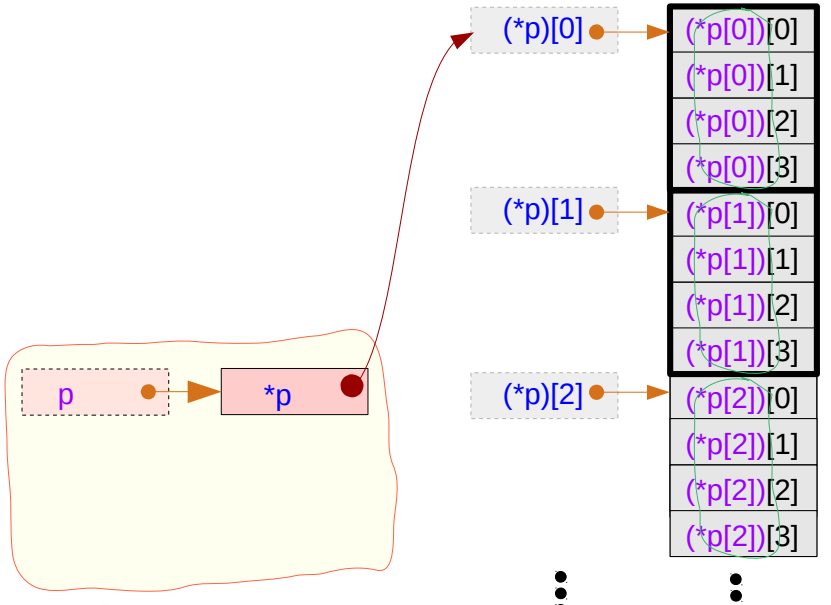
assignment	equivalence
p[0]=&x[0]	*p[0]=x[0]
p[1]=&x[1]	*p[1]=x[1]
p[2]=&x[2]	*p[2]=x[2]
p[3]=&x[3]	*p[3]=x[3]

int (*p)[4][4];

assignment	equivalence
p=&x	(*p)[0]=x[0]
	(*p)[1]=x[1]
	(*p)[2]=x[2]
	(*p)[3]=x[3]



An array of **1-d** array pointers



A **2-d** array pointer

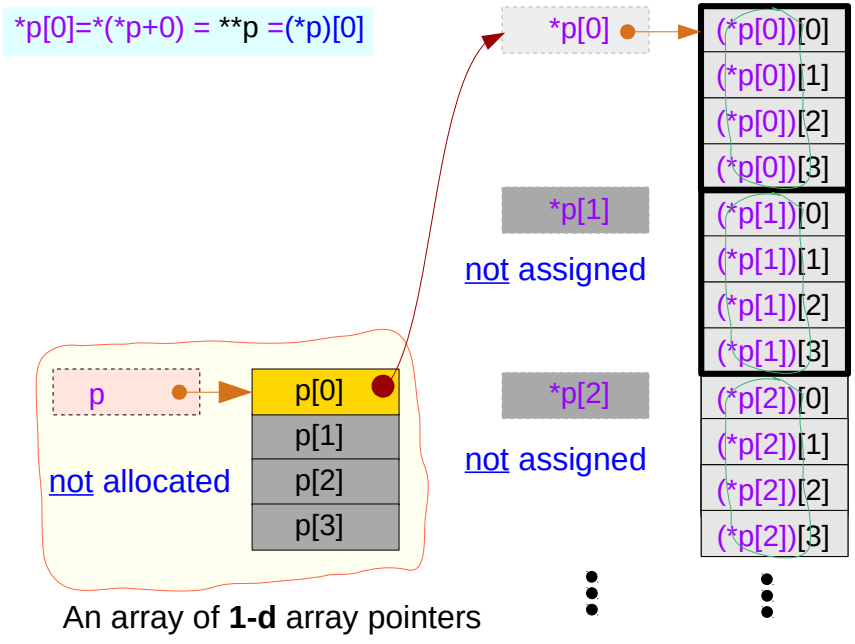
int (*p)[4][4] and (*p[i])[j] : not OK

int (*p[4])[4];

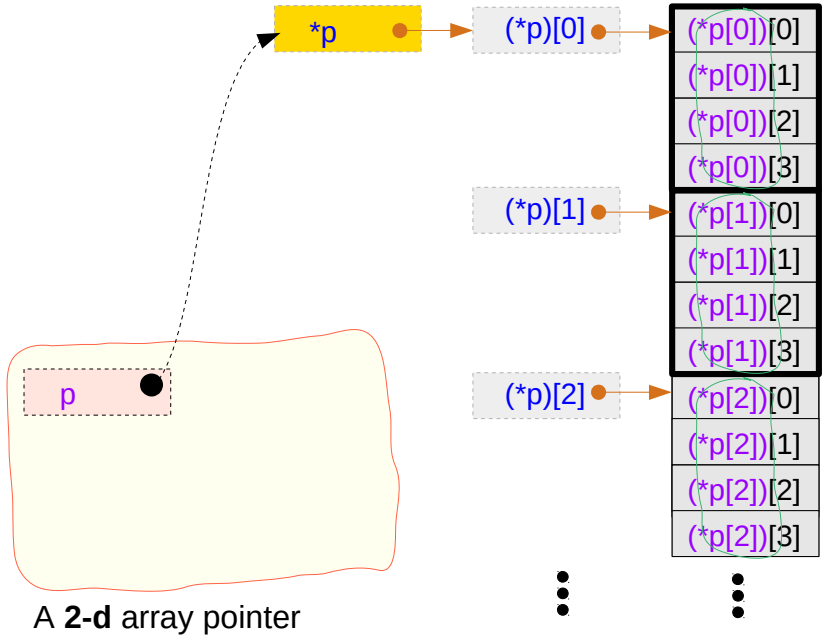
assignment	equivalence
p[0]=&x[0]	*p[0]=x[0]
p[1]=&x[1]	*p[1]=x[1]
p[2]=&x[2]	*p[2]=x[2]
p[3]=&x[3]	*p[3]=x[3]

int (*p)[4][4];

assignment	equivalence
p=&x	(*p)[0]=x[0]
	(*p)[1]=x[1]
	(*p)[2]=x[2]
	(*p)[3]=x[3]



An array of **1-d** array pointers

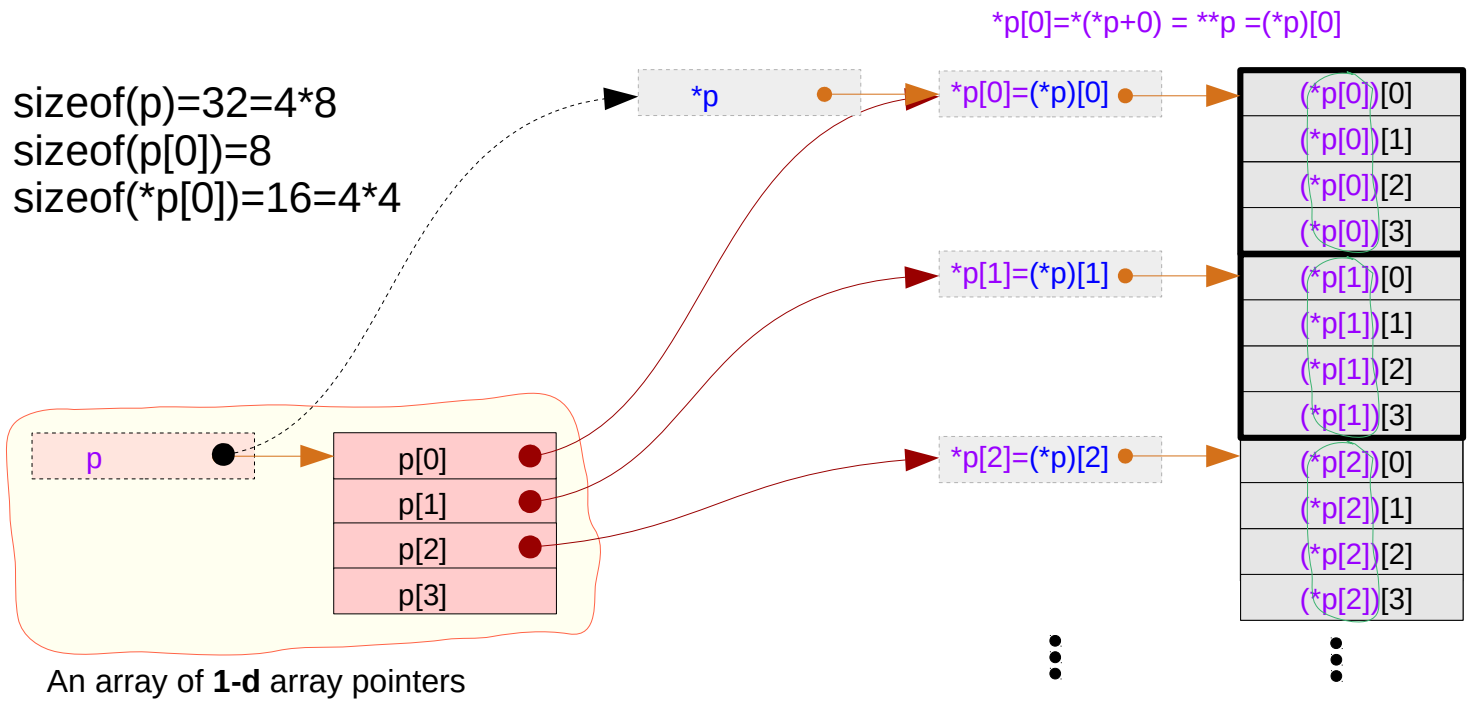


A **2-d** array pointer

int (*p[4])[4] and accessing a 2-d array

int (*p[4])[4]; == int (*(p[4]))[4];

(*p[i])[j]; == (*(p[i]))[j]; == ((*p)[i])[j];



assignment

*(p[0])=x[0]
*(p[1])=x[1]
*(p[2])=x[2]
*(p[3])=x[3]

equivalence

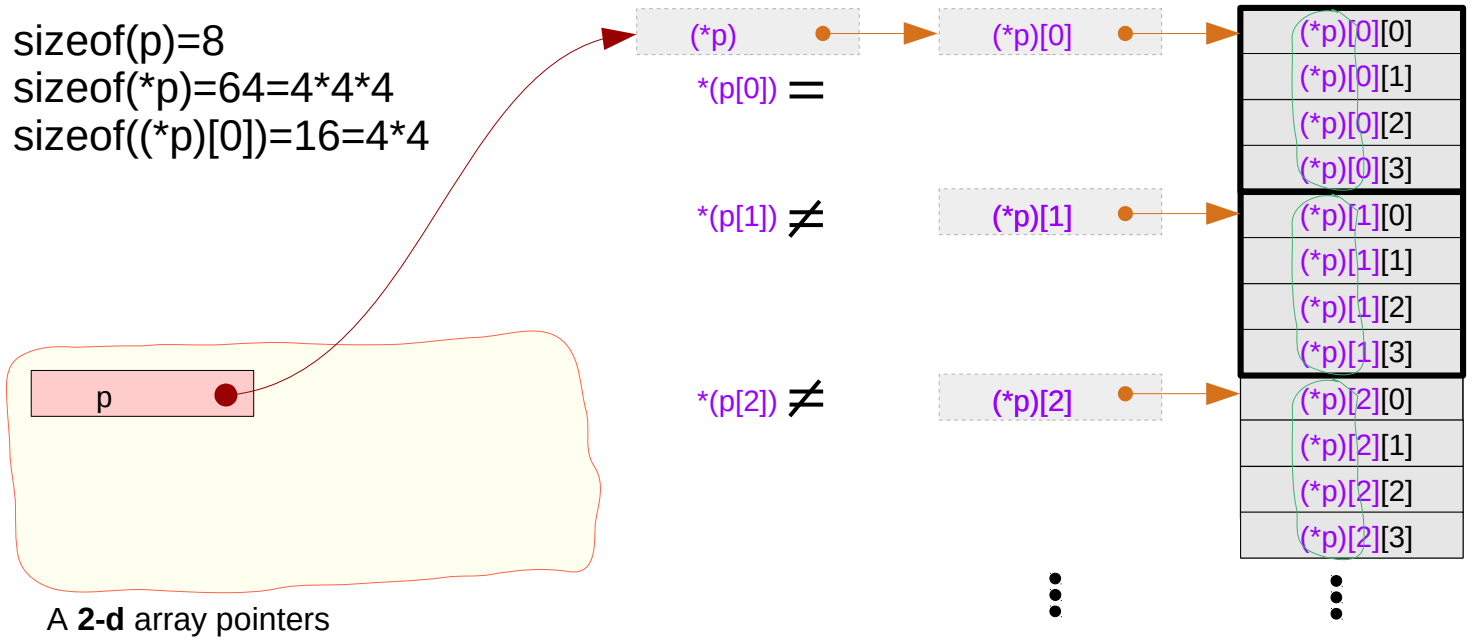
*(p[0])=(*p)[0]
*(p[1])=(*p)[1]
*(p[2])=(*p)[2]
*(p[3])=(*p)[3]

int (*p)[4][4] and accessing a 2-d array

int (*p)[4][4]; = int ((*p)[4])[4];

(*p)[i][j]; = ((*p)[i])[j]; ≠ (*(p[i]))[j];

sizeof(p)=8
sizeof(*p)=64=4*4*4
sizeof((*p)[0])=16=4*4



A **2-d** array pointers

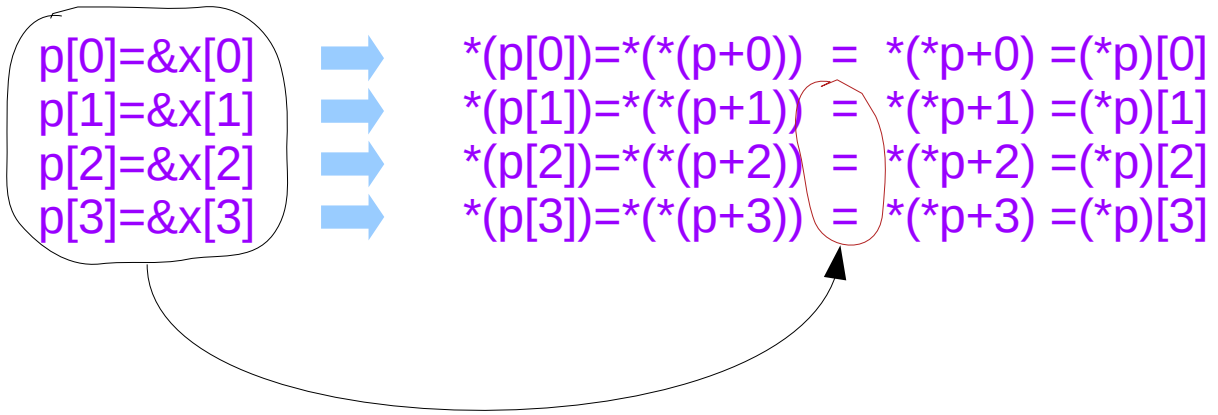
int (*p[4])[4] and equivalence relations

int (*p[4])[4];

assignment	equivalence
p[0]=&x[0]	*(p[0])=x[0]
p[1]=&x[1]	*(p[1])=x[1]
p[2]=&x[2]	*(p[2])=x[2]
p[3]=&x[3]	*(p[3])=x[3]

int (*p)[4][4];

assignment	equivalence
p=&x	(*p)[0]=x[0]
	(*p)[1]=x[1]
	(*p)[2]=x[2]
	(*p)[3]=x[3]



these assignments make these equivalences

int (*p)[4][4] and equivalence relation

int (*p[4])[4];

assignment	equivalence
p[0]=&x[0]	*(p[0])=x[0]
p[1]=&x[1]	*(p[1])=x[1]
p[2]=&x[2]	*(p[2])=x[2]
p[3]=&x[3]	*(p[3])=x[3]

int (*p)[4][4];

assignment	equivalence
p=&x	(*p)[0]=x[0]
	(*p)[1]=x[1]
	(*p)[2]=x[2]
	(*p)[3]=x[3]

p=&x

(p[0])=(*(p+0)) = *(*p+0) =(*p)[0]
(p[1])=(*(p+1)) ≠ *(*p+1) =(*p)[1]
(p[2])=(*(p+2)) ≠ *(*p+2) =(*p)[2]
(p[3])=(*(p+3)) ≠ *(*p+3) =(*p)[3]

int (*p[4])[4] and int (*p)[4][4]

An array of **1-d** array pointers

int (*p[4])[4];	=	int (*(p[4]))[4];	≠	int ((*p)[4])[4];
(*p[i])[j];	=	(*(p[i]))[j];	=	((*p)[i])[j];

A **2-d** array pointers

int (*p)[4][4];	=	int ((*p)[4])[4];	≠	int (*(p[4]))[4];
(*p)[i][j];	=	((*p)[i])[j];	≠	(*(p[i]))[j];

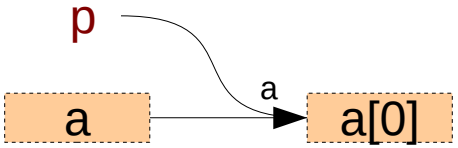
(*n-1*)-d array pointer to a *n*-d array

int a[4] ;	**1-d** array	
int (*p) ;	**0-d** array pointer	(p = a)
int b[4] [2];	**2-d** array	
int (*q) [2];	**1-d** array pointer	(q = b)
int c[4] [2][3];	**3-d** array	
int (*r) [2][3];	**2-d** array pointer	(r = c)
int d[4] [2][3][4];	**4-d** array	
int (*s) [2][3][4];	**3-d** array pointer	(s = d)

***n*-d** array name and **(*n-1*)-d** array pointer

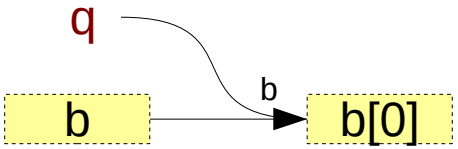
```
int a[4] ;
int (*p) ;
```

```
p = &a[0];
p = a;
```



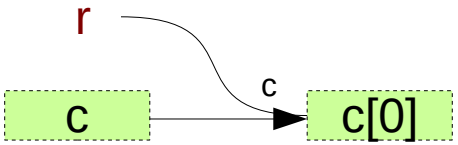

```
int b[4] [2];
int (*q) [2];
```

```
q = &b[0];
q = b;
```



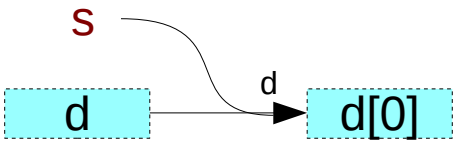

```
int c[4] [2][3];
int (*r) [2][3];
```

```
r = &c[0];
r = c;
```




```
int d[4] [2][3][4];
int (*s) [2][3][4];
```

```
s = &d[0];
s = d;
```



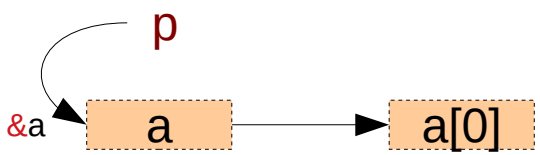
***n*-d** array pointer to a ***n*-d** array

```
int  a  [4] ;          1-d array
int (*p) [4];          1-d array pointer      (p = &a)

int  b  [4][2];        2-d array
int (*q) [4][2];       2-d array pointer      (q = &b)

int  c  [4][2][3];     3-d array
int (*r) [4][2][3];    3-d array pointer      (r = &c)

int  d  [4][2][3][4];  4-d array
int (*s) [4][2][3][4]; 4-d array pointer      (s = &d)
```

***n*-d** array name and ***n*-d** array pointer

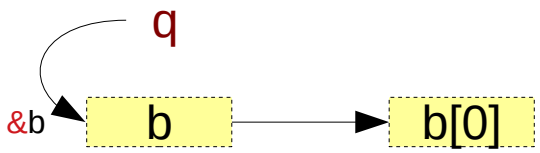
```
int  a  [4] ;
int (*p) [4];
```

p = &a;




```
int  b  [4][2];
int (*q) [4][2];
```

q = &b;



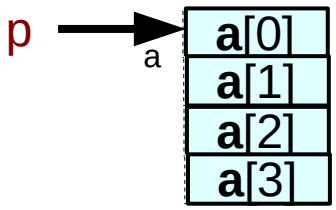

```
int  c  [4][2][3];
int (*r) [4][2][3];
```

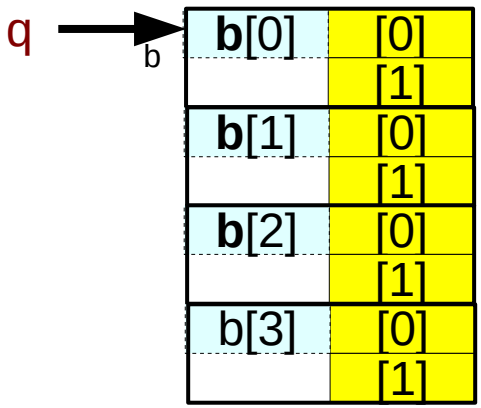
r = &c;

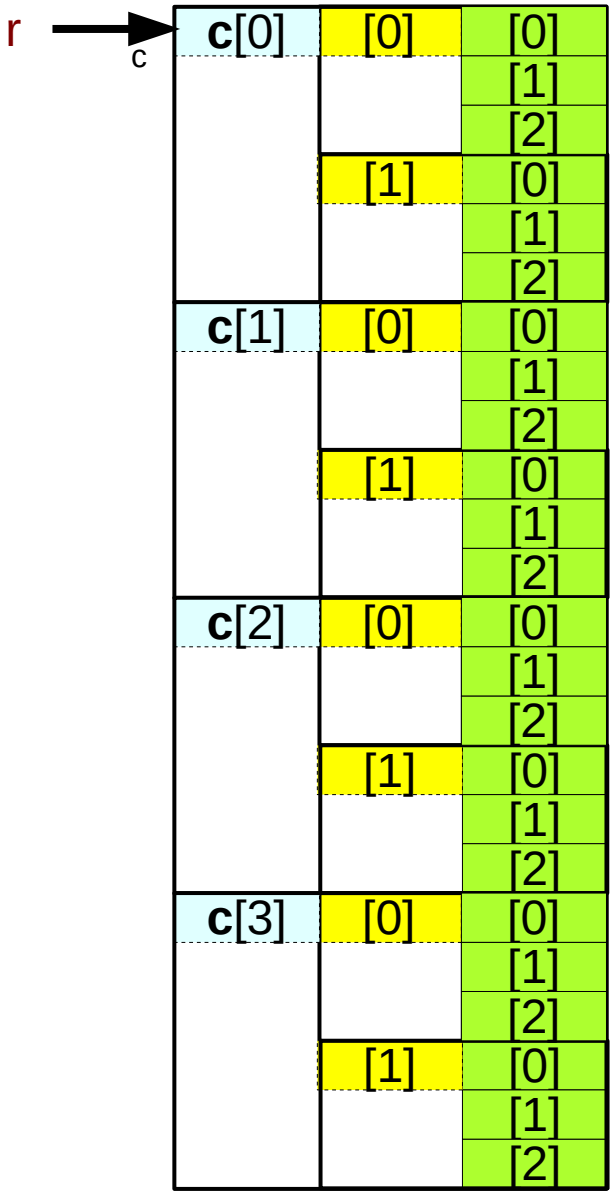

```
int  d  [4][2][3][4];
int (*s) [4][2][3][4];
```

s = &d;

multi-dimensional array pointers

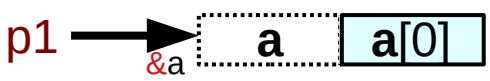




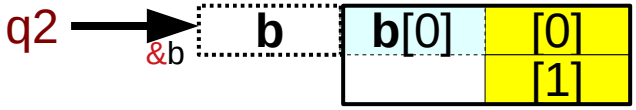



```
int a[4] ;          1-d array
int (*p) ;          0-d array pointer

int b[4]   [2];     2-d array
int (*q)   [2];     1-d array pointer

int c[4]   [2][3];  3-d array
int (*r)   [2][3];  2-d array pointer

int d[4]   [2][3][4];  4-d array
int (*s)   [2][3][4];  3-d array pointer
```

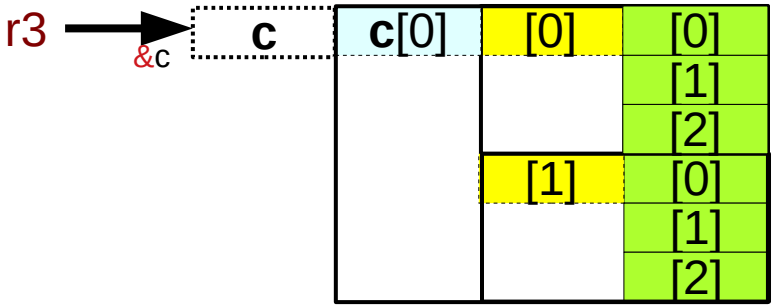
Initializing ***n-d*** array pointers



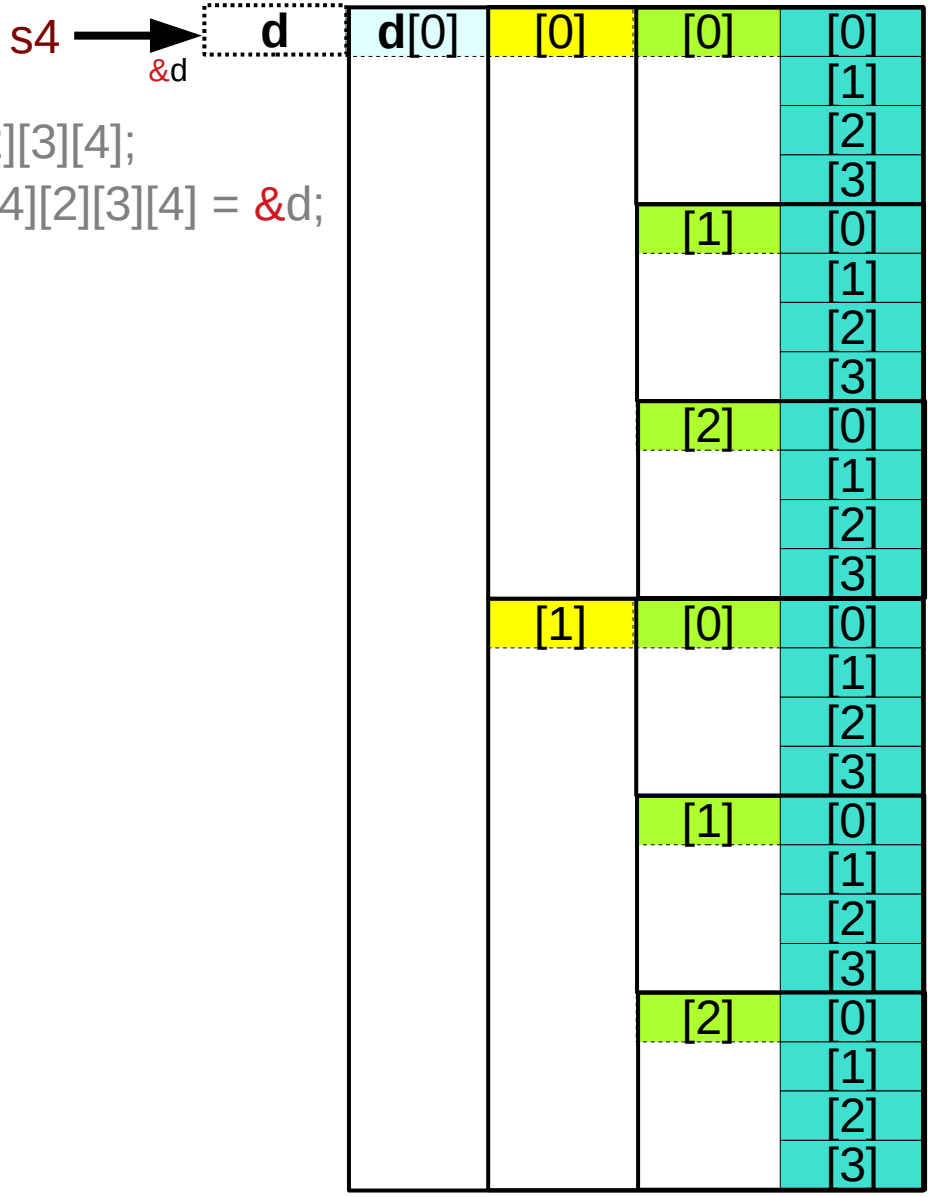

```
int a[4] ;
int (*p1)[4] = &a ;
```




```
int b[4][2];
int (*q2)[4][2] = &b;
```

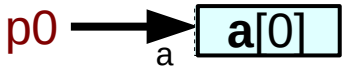



```
int c[4][2][3];
int (*r3)[4][2][3] = &c;
```

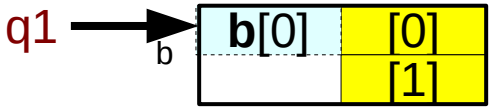



```
int d[4][2][3][4];
int (*s4)[4][2][3][4] = &d;
```

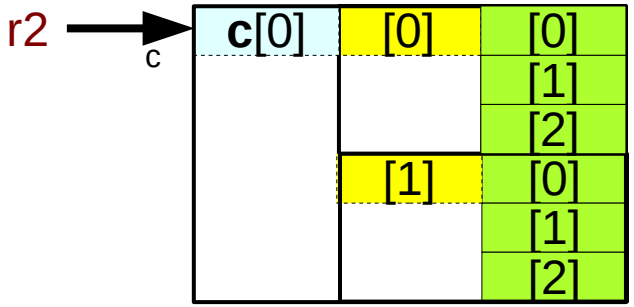
Initializing *(n-1)-d* array pointers



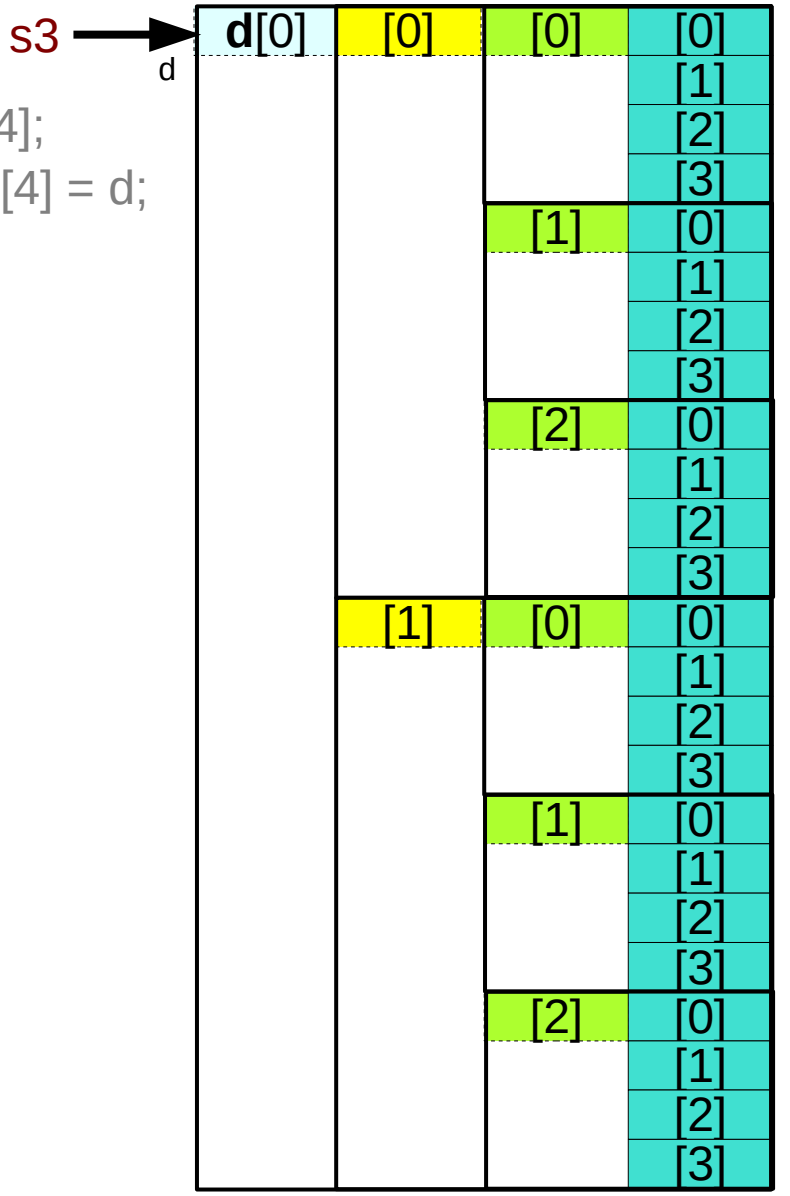

```
int a[4] ;
int (*p0) = a ;
```




```
int b[4][2];
int (*q1)[2] = b;
```




```
int c[4][2][3];
int (*r2)[2][3] = c;
```




```
int d[4][2][3][4];
int (*s3)[2][3][4] = d;
```

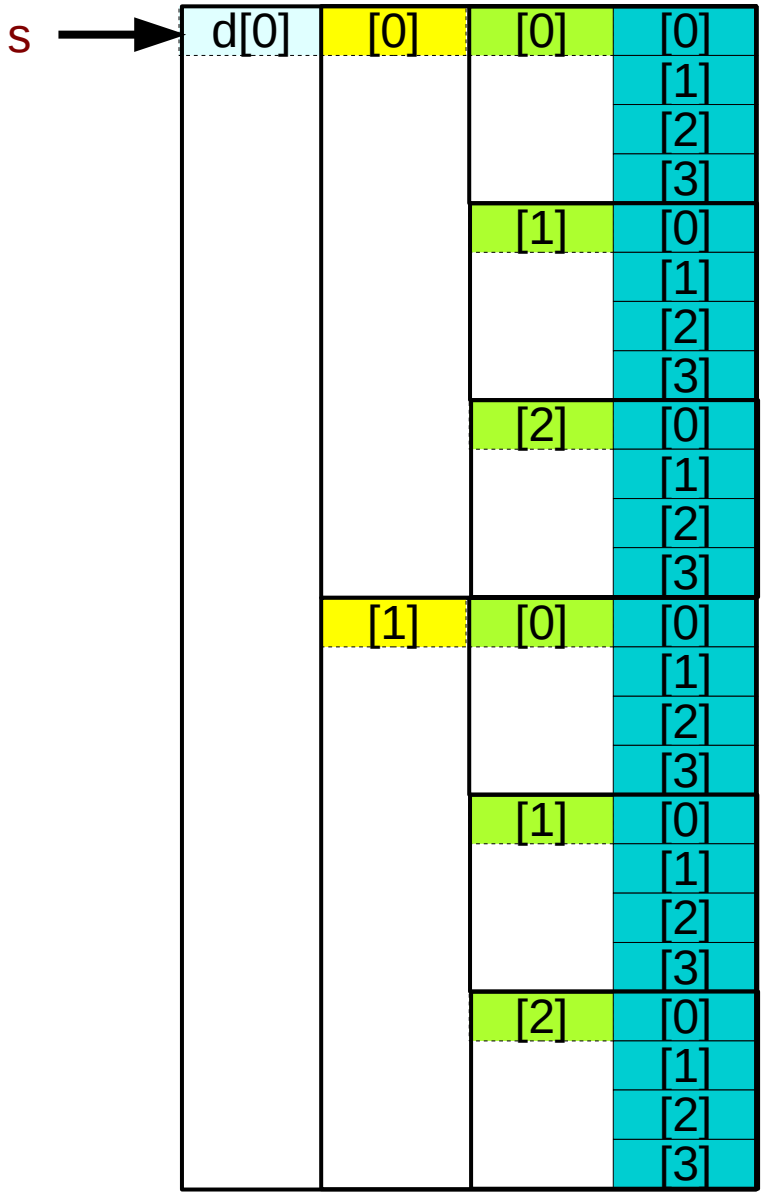
array pointers to multi-dimensional subarrays

```
int d[4][2][3][4];
int (*s)[2][3][4];
```

d	4-d array name	d[4][2][3][4]
	3-d array pointer	(*p)[2][3][4]
d[i]	3-d array name	d[i][2][3][4]
	2-d array pointer	(*q)[3][4]
d[i][j]	2-d array name	d[i][j][3][4]
	1-d array pointer	(*r)[4]
d[i][j][k]	1-d array name	d[i][j][k][4]
	0-d array pointer	(*s)

i,j,k are specific index values

i =[0..3], j = [0..1], k= [0..2]



Initializing array pointers to multi-dimensional subarrays

```
int d[4] [2][3][4];
int (*s) [2][3][4];
```

d	4-d array name	d[4][2][3][4]	p[i][j][k][l]
	3-d array pointer	(*p)[2][3][4]	int (*p)[2][3][4] = d;
d[i]	3-d array name	d[i][2][3][4]	q[j][k][l]
	2-d array pointer	(*q)[3][4]	int (*q)[3][4] = d[i];
d[i][j]	2-d array name	d[i][j][3][4]	r[k][l]
	1-d array pointer	(*r)[4]	int (*r)[4] = d[i][j];
d[i][j][k]	1-d array name	d[i][j][k][4]	s[l]
	0-d array pointer	(*s)	int (*s) = d[i][j][k];

i =[0..3], j = [0..1], k= [0..2]

Passing multidimensional array names

```
int a[4] ;
int (*p) ;
```

call

```
funa(a, …);
```

prototype

```
void funa(int (*p), …);
```

```
int b[4] [2];
int (*q) [2];
```

call

```
funb(b, …);
```

prototype

```
void funb(int (*q)[2], …);
```

```
int c[4] [2][3];
int (*r) [2][3];
```

call

```
func(c, …);
```

prototype

```
void func(int (*r)[2][3], …);
```

```
int d[4] [2][3][4];
int (*s) [2][3][4];
```

call

```
fund(d, …);
```

prototype

```
void fund(int (*s)[2][3][4], …);
```

References

[1] Essential C, Nick Parlante
[2] Efficient C Programming, Mark A. Weiss
[3] C A Reference Manual, Samuel P. Harbison & Guy L. Steele Jr.
[4] C Language Express, I. K. Chun