

Public-Service Announcement

"Computer Science Mentors (CSM) will be running small group sections this semester! CSM is a student organization that aims to create a stronger feeling of community in classes like CS61B. We'll be offering sections that you regularly attend to review the past week's 61B material. These hour-long sections will be about 3 students large, each led by a trained mentor.

- Sign-ups for section times will open Wednesday (9/7) at 5pm via the CSM Scheduler at <http://csmscheduler.herokuapp.com>.
- After signing up, join the CSM 61B Piazza, where all further communication with CSM will take place.
- First sections start the week of 9/12 (next week).
- We allow up to two unexcused absences.
- Students can receive one P/NP unit for regularly attending section. CCNs along with further details will be available on the CSM 61B Piazza."

Recreation

What is the sum of the coefficients of

$$(1 - 3x + 3x^2)^{743}(1 + 3x - 3x^2)^{744}$$

after expanding and collecting terms?

CS61B Lecture #6: Arrays

- An array is a structured container whose components are
 - **length**, a fixed integer.
 - a sequence of **length** simple containers of the same type, numbered from 0.
 - (.length field usually implicit in diagrams.)
- Arrays are anonymous, like other structured containers.
- Always referred to with pointers.
- For array pointed to by A ,
 - Length is $A.length$
 - Numbered component i is $A[i]$ (i is the *index*)
 - Important feature: index can be *any integer expression*.

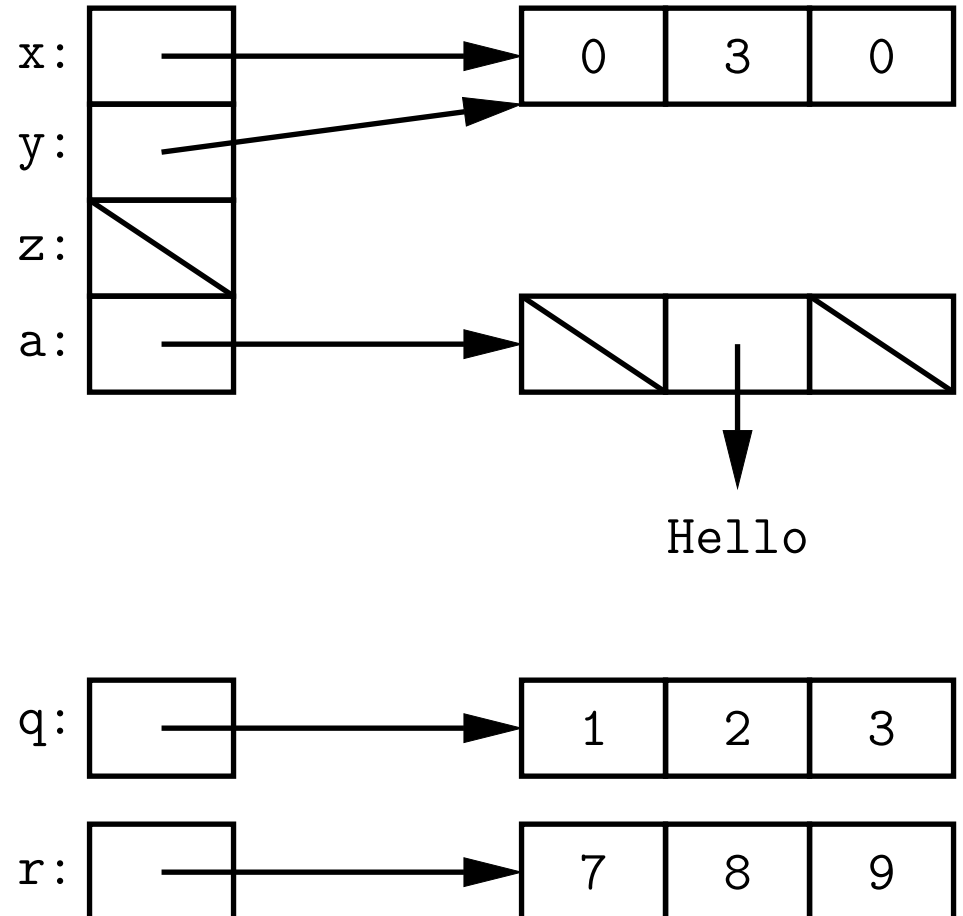
A Few Samples

Java

```
int[] x, y, z;  
String[] a;  
x = new int[3];  
y = x;  
a = new String[3];  
x[1] = 2;  
y[1] = 3;  
a[1] = "Hello";
```

```
int[] q;  
q = new int[] { 1, 2, 3 };  
// Short form for declarations:  
int[] r = { 7, 8, 9 };
```

Results



Example: Accumulate Values

Problem: Sum up the elements of array A.

```
static int sum(int[] A) {  
    int N;  
    N = 0;  
    for (int i = 0; i < A.length; i += 1)  
        N += A[i];  
    return N;  
}
```

```
// New (1.5) syntax  
for (int x : A)  
    N += x;
```

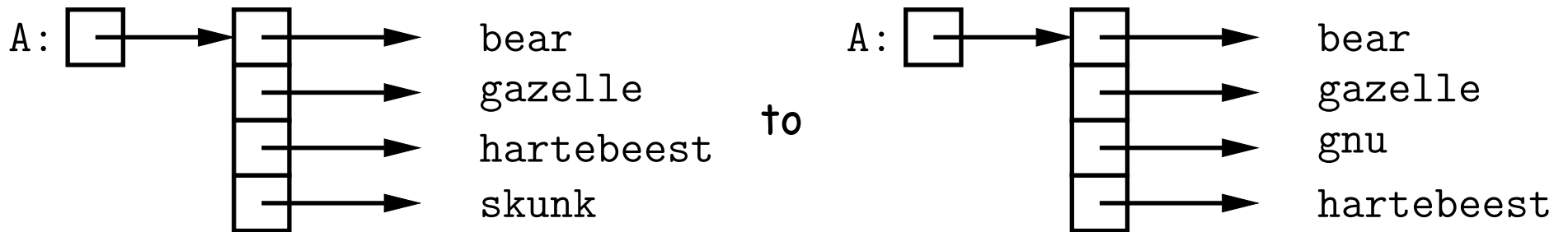
// For the hard-core: could have written

```
int N, i;  
for (i=0, N=0; i<A.length; N += A[i], i += 1)  
    { } // or just ;
```

// But please don't: it's obscure.

Example: Insert into an Array

Problem: Want a call like `insert(A, 2, "gnu")` to convert (destructively)



```
/** Insert X at location K in ARR, moving items K, K+1, ... to locations
 * K+1, K+2, .... The last item in ARR is lost. */
static void insert (String[] arr, int k, String x) {
    for (int i = arr.length-1; i > k; i -= 1) // Why backwards?
        arr[i] = arr[i-1];
    /* Alternative to this loop:
       System.arraycopy(arr, k, arr, k+1, arr.length-k-1);*/
    arr[k] = x;
}
```

(Aside) Java Shortcut

- **Useful tip:** Can write just `'arraycopy'` by including at the top of the source file:

```
import static java.lang.System.arraycopy;
```

- This means “define the simple name `arraycopy` to be the equivalent of `java.lang.System.arraycopy` in the current source file.”
- Can do the same for `out` so that you can write

```
out.println(...);
```

in place of

```
System.out.println(...);
```

- Finally, a declaration like

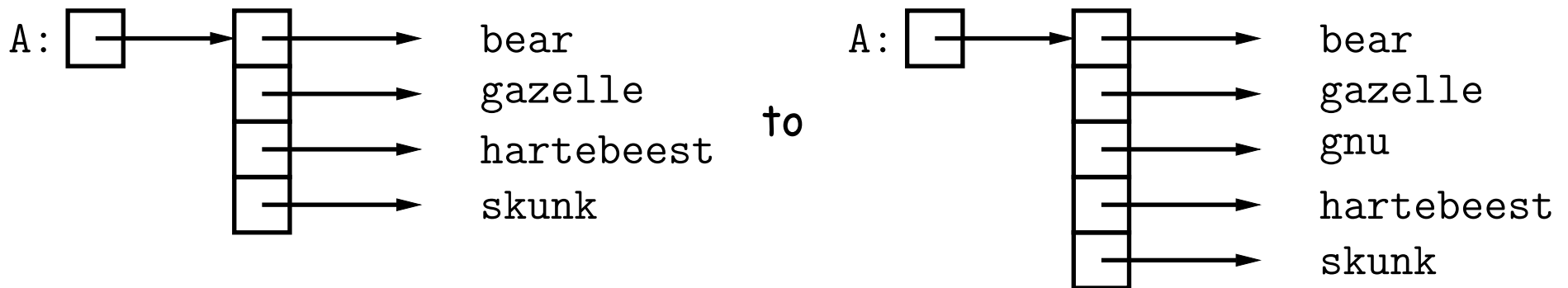
```
import static java.lang.Math.*;
```

means “take all the (public) static definitions in `java.lang.Math` and make them available in this source file by their simple names (the name after the last dot).”

- Useful for functions like `sin`, `sqrt`, etc.

Growing an Array

Problem: Suppose that we want to change the description above, so that `A = insert2 (A, 2, "gnu")` does *not* shove "skunk" off the end, but instead "grows" the array.

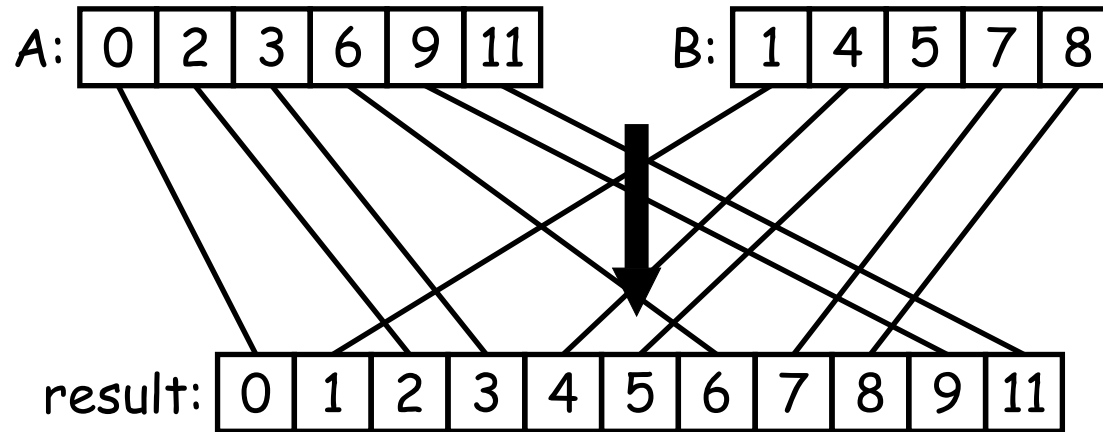


```
/** Return array, r, where r.length = ARR.length+1; r[0..K-1]
 * the same as ARR[0..K-1], r[k] = x, r[K+1..] same as ARR[K..]. */
static String[] insert2(String[] arr, int k, String x) {
    String[] result = new String[arr.length + 1];
    arraycopy(arr, 0, result, 0, k);
    arraycopy(arr, k, result, k+1, arr.length-k);
    result[k] = x;
    return result;
}
```

Why do we need a different return type from `insert2`??

Example: Merging

Problem: Given two sorted arrays of ints, A and B, produce their *merge*: a sorted array containing all items from A and B.



Example: Merging Program

Problem: Given two sorted arrays of ints, A and B, produce their *merge*: a sorted array containing all from A and B.

Remark: In order to solve this recursively, it is useful to *generalize* the original function to allow merging *portions* of the arrays.

```
/** Assuming A and B are sorted, returns their merge. */
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0);
}
```

```
/** The merge of A[L0..] and B[L1..] assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1) {
    int N = A.length - L0 + B.length - L1; int[] C = new int[N];
    if (L0 >= A.length) arraycopy(B, L1, C, 0, N);
    else if (L1 >= B.length) arraycopy(A, L0, C, 0, N);
    else if (A[L0] <= B[L1]) {
        C[0] = A[L0]; arraycopy(merge(A, L0+1, B, L1), 0, C, 1, N-1);
    } else {
        C[0] = B[L1]; arraycopy(merge(A, L0, B, L1+1), 0, C, 1, N-1);
    }
    return C;
}
```

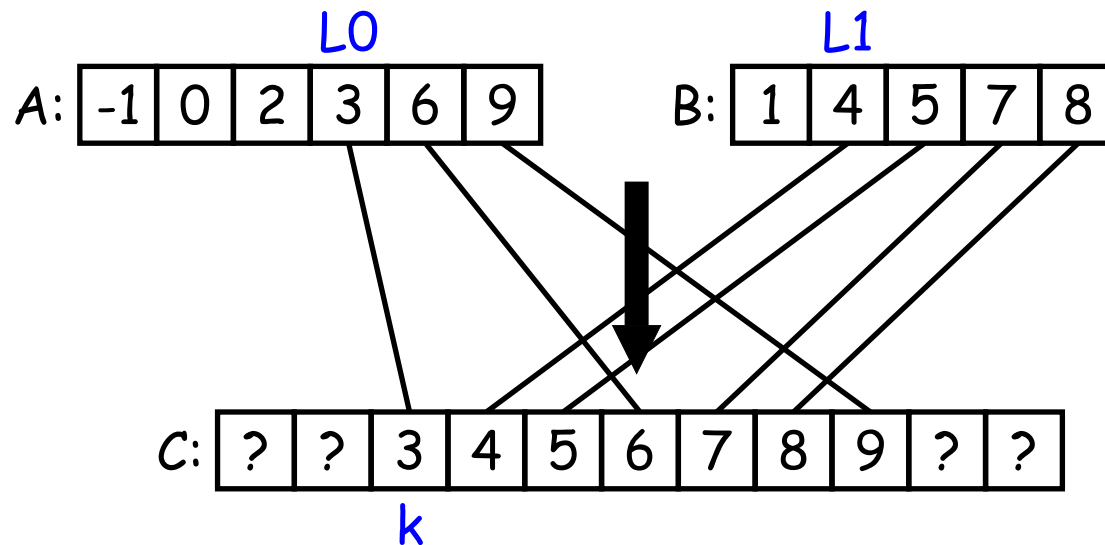
What is wrong with this implementation?

A Tail-Recursive Strategy

```
public static int[] merge(int[] A, int[] B) {  
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);  
}
```

```
/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */  
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){  
    ...  
}
```

This last method merges *part* of A with part of B into part of C. For example, consider a possible call `merge(A, 3, B, 1, C, 2)`



A Tail-Recursive Solution

```
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){
    if (L0 >= A.length) /* ? */
    else if (L1 >= B.length) /* ? */
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0];
        /* ? */
    } else {
        C[k] = B[L1];
        /* ? */
    }
    return C;
}
```

A Tail-Recursive Solution

```
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){
    if (L0 >= A.length) /* ? */
    else if (L1 >= B.length) /* ? */
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0];
        /* ? */
    } else {
        C[k] = B[L1];
        /* ? */
    }
    return C;
}
```

A Tail-Recursive Solution

```
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){
    if (L0 >= A.length) arraycopy(B, L1, C, k, B.length-L1);
    else if (L1 >= B.length) arraycopy(A, L0, C, k, A.length-L0);
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0];
        /* ? */
    } else {
        C[k] = B[L1];
        /* ? */
    }
    return C;
}
```

A Tail-Recursive Solution

```
public static int[] merge(int[] A, int[] B) {
    return merge(A, 0, B, 0, new int[A.length+B.length], 0);
}

/** Merge A[L0..] and B[L1..] into C[K..], assuming A and B sorted. */
static int[] merge(int[] A, int L0, int[] B, int L1, int[] C, int k){
    if (L0 >= A.length) arraycopy(B, L1, C, k, B.length-L1);
    else if (L1 >= B.length) arraycopy(A, L0, C, k, A.length-L0);
    else if (A[L0] <= B[L1]) {
        C[k] = A[L0];
        merge(A, L0+1, B, L1, C, k+1);
    } else {
        C[k] = B[L1];
        merge(A, L0, B, L1+1, C, k+1);
    }
    return C;
}
```

Iterative Solution

In general, we don't use either of the previous approaches in languages like C and Java. Array manipulation is most often iterative:

```
public static int[] merge(int[] A, int[] B) {  
    int[] C = new int[A.length + B.length];
```

```
}
```


Iterative Solution II

```
public static int[] merge(int[] A, int[] B) {  
    int[] C = new int[A.length + B.length];  
    int L0, L1;  
    L0 = L1 = 0;  
    for (int k = 0; k < C.length; k += 1) {  
        if (L0 >= A.length) {  
            C[k] = B[L1]; L1 += 1;  
        } else if (L1 >= B.length) {  
            C[k] = A[L0]; L0 += 1;  
        } else if (A[L0] <= B[L1]) {  
            C[k] = A[L0]; L0 += 1;  
        } else {  
            C[k] = B[L1]; L1 += 1;  
        }  
    }  
    return C;  
}
```

Alternative Solution: Removing k

Claim: An invariant of the loop is that $k=L_0+L_1$.

```
public static int[] merge(int[] A, int[] B) {
    int[] C = new int[A.length + B.length];
    int L0, L1;
    L0 = L1 = 0;
    while (L0 + L1 < C.length) {
        if (L0 >= A.length) {
            C[L0 + L1] = B[L1]; L1 += 1;
        } else if (L1 >= B.length) {
            C[L0 + L1] = A[L0]; L0 += 1;
        } else if (A[L0] <= B[L1]) {
            C[L0 + L1] = A[L0]; L0 += 1;
        } else {
            C[L0 + L1] = B[L1]; L1 += 1;
        }
    }
    return C;
}
```

Multidimensional Arrays

What about two- or higher-dimensional layouts, such as

$$A =$$

2	3	4	5
4	9	16	25
8	27	64	125

?

Multidimensional Arrays in Java

These are not primitive in Java, but we can build them as **arrays of arrays**:

```
int[] [] A = new int[3] [];  
A[0] = new int[] {2, 3, 4, 5};  
A[1] = new int[] {4, 9, 16, 25};  
A[2] = new int[] {8, 27, 64, 125};
```

// or

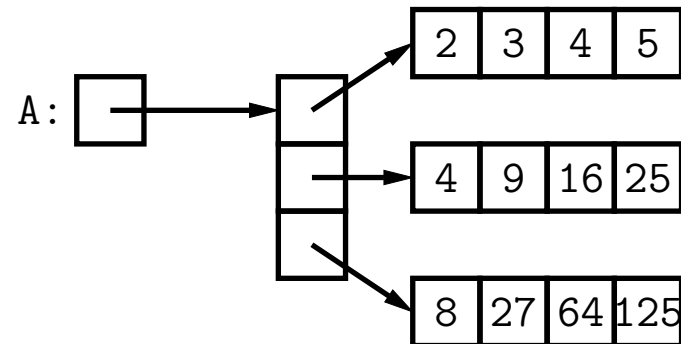
```
int[] [] A;  
A = new int[] [] { {2, 3, 4, 5},  
                  {4, 9, 16, 25},  
                  {8, 27, 64, 125} };
```

// or

```
int[] [] A = { {2, 3, 4, 5},  
              {4, 9, 16, 25},  
              {8, 27, 64, 125} };
```

// or

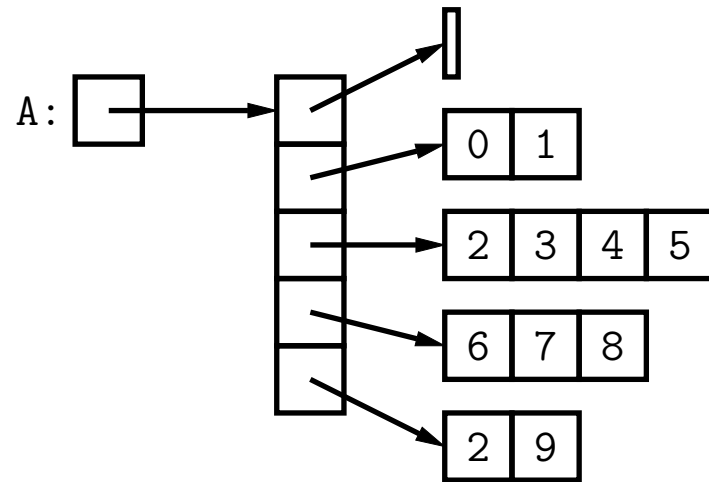
```
int[] [] A = new A[3][4];  
for (int i = 0; i < 3; i += 1)  
    for (int j = 0; j < 4; j += 1)  
        A[i][j] = (int) Math.pow(j + 2, i + 1);
```



Exotic Multidimensional Arrays

- Since every element of an array is independent, there is no single “width” in general:

```
int[] [] A = new int[5] [] ;  
A[0] = new int[] {};  
A[1] = new int[] {0, 1};  
A[2] = new int[] {2, 3, 4, 5};  
A[3] = new int[] {6, 7, 8};  
A[4] = new int[] {9};
```



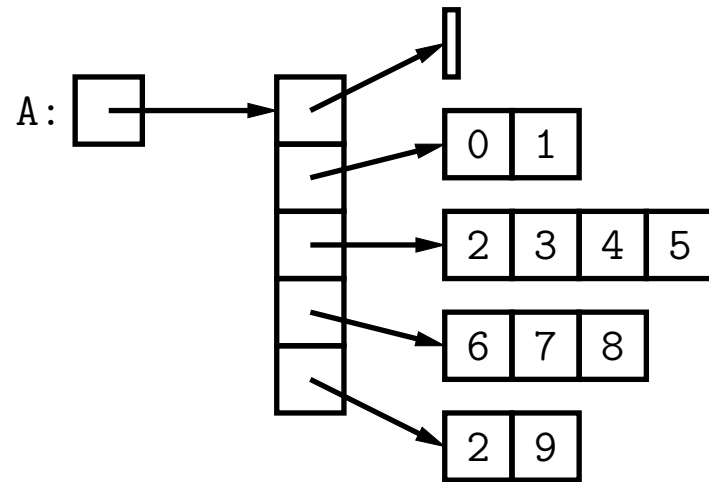
- What does this print?

```
int[] [] ZERO = new int[3] [] ;  
ZERO[0] = ZERO[1] = ZERO[2] =  
    new int[] {0, 0, 0};  
ZERO[0][1] = 1;  
System.out.println(ZERO[2][1]);
```

Exotic Multidimensional Arrays

- Since every element of an array is independent, there is no single “width” in general:

```
int[] [] A = new int[5] [] ;  
A[0] = new int[] {};  
A[1] = new int[] {0, 1};  
A[2] = new int[] {2, 3, 4, 5};  
A[3] = new int[] {6, 7, 8};  
A[4] = new int[] {9};
```



- What does this print?

```
int[] [] ZERO = new int[3] [] ;  
ZERO[0] = ZERO[1] = ZERO[2] =  
    new int[] {0, 0, 0};  
ZERO[0][1] = 1;  
System.out.println(ZERO[2][1]);
```

