Public-Service Announcement I

"Are you an engineer, designer, or entrepreneur? Come check out Mobile Developers of Berkeley. We create end-to-end solutions with a diverse breath of skills. Our members hone their skills in frontend, backend, design, and engineering while developing an understanding of topics such as software architecture, databases, operating systems, and networking. We build apps targeting a wide range of industries while leveraging the latest technologies in IOT, AI, fintech, ML, AR, and more. Join us for our showcase tonight, Wednesday 9/6. Our members will show you our apps and what it took to make them. Free food, fidget spinners & swag will also be there.

See https://www.mobiledevsberkeley.org/ for further information."

Public-Service Announcement II

"Introducing Political Computer Science @ Berkeley! PCS harnesses students' intellectual capabilities and potential in CS and Government affairs to address current issues within the United States legal and political systems.

We already have an Amazon Alexa Skill called Political Pundit that is about to be published; it is able to give responses to inquiries about politics/government.

To view the many other projects that we have in the works (pertaining to gerrymandering, campaign finance, Alexa, and more), visit our website: pcsberkeley.wixsite.com/pcsberkeley

We're now accepting applications for the 2017-2018 school year (it only takes 5 minutes to complete)! Apply on our website!"

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*.

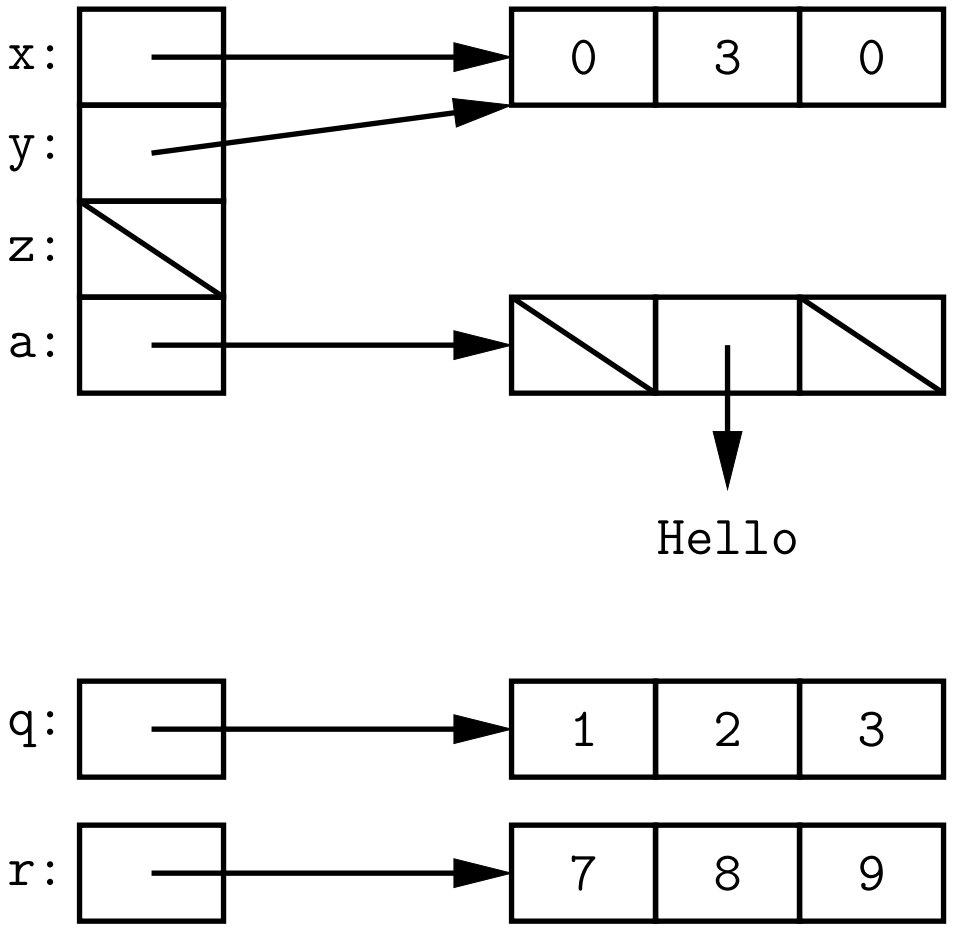
A Few Samples

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;
```

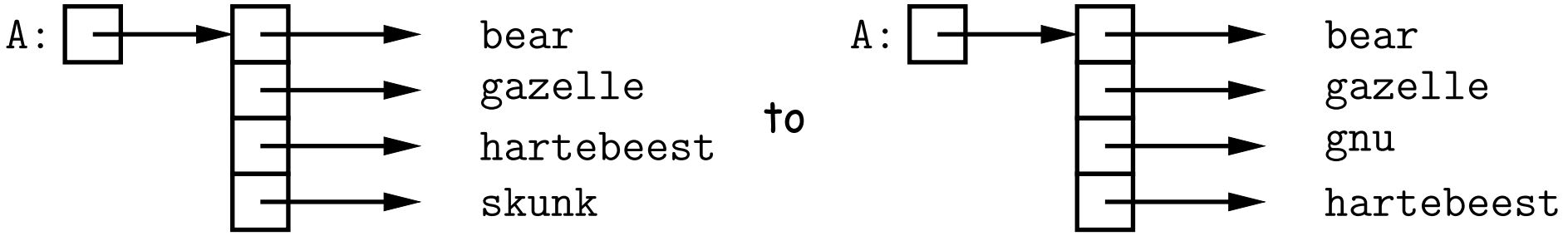
```
// For the hard-core: could have written

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);*/
                        from      to       # to copy
  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(...);
  ```

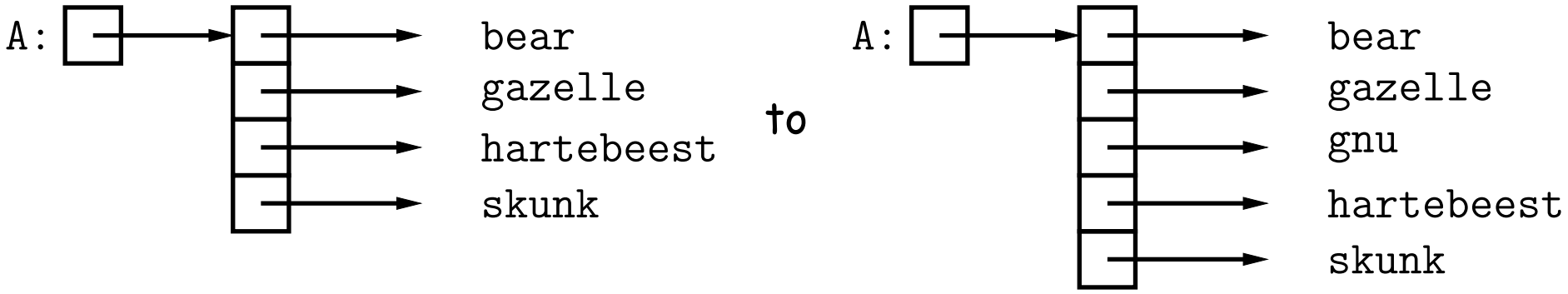
- Finally, a declaration like

  ```
  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.

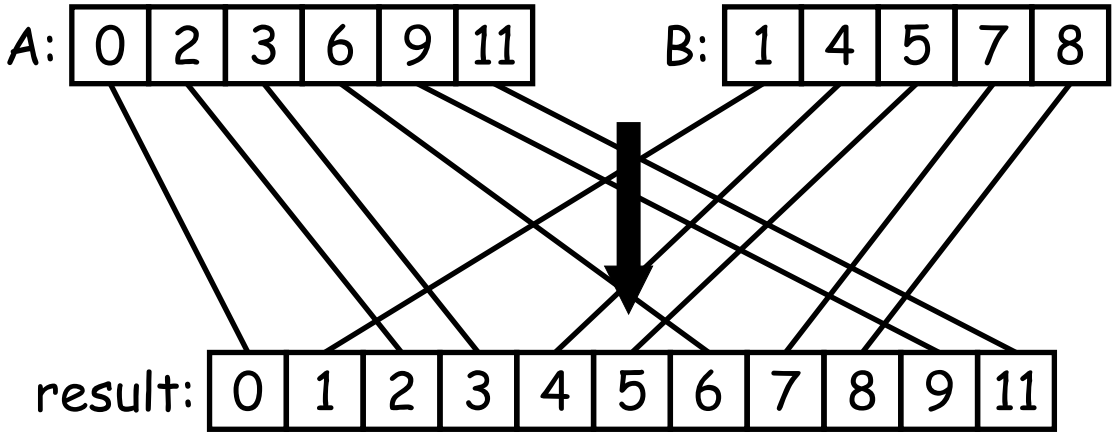



```
/** Return array, r, where r.length = ARR.length+1; r[0..K-1]
 *  the same as ARR[0..K-1], r[k] = x, r[K+1..] same as ARR[K..]. */
static String[] insert2(String[] arr, int k, String x) {
  String[] result = new String[arr.length + 1];
  arraycopy(arr, 0, result, 0, k);
  arraycopy(arr, k, result,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

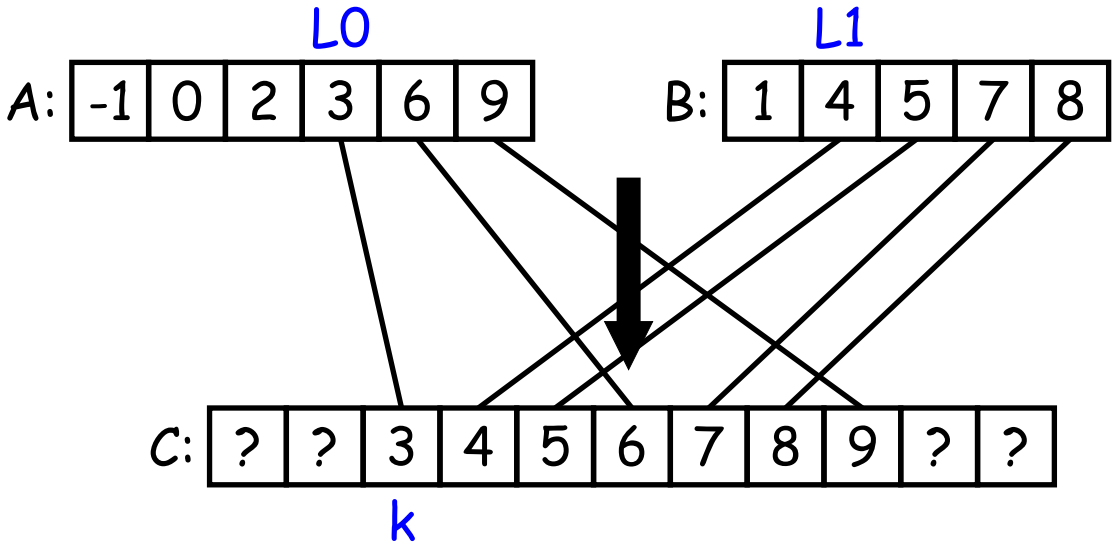
What is wrong with this implementation?

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=L0+L1`.

```
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

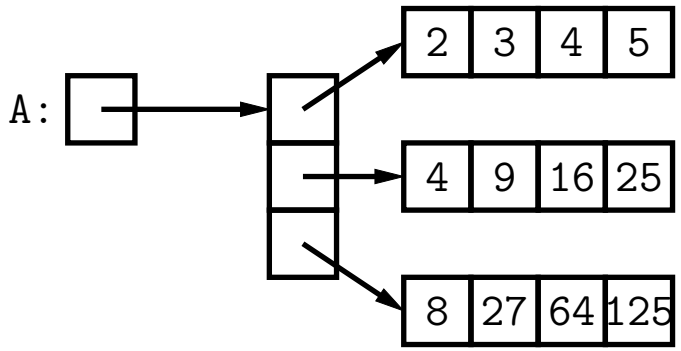
What about two- or higher-dimensional layouts, such as

$$A = \begin{array}{|r|r|r|r|}\hline 2 & 3 & 4 & 5 \\ \hline 4 & 9 & 16 & 25 \\ \hline 8 & 27 & 64 & 125 \\ \hline \end{array}$$ **?**

Multidimensional Arrays in Java

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

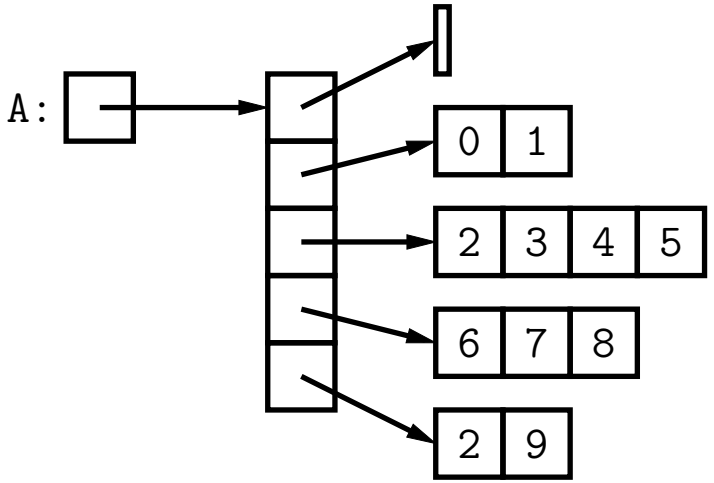
```
  int[][] A = new int[3][];
  A[0] = new int[] {2, 3, 4, 5};
  A[1] = new int[] {4, 9, 16, 25};
  A[2] = new int[] {8, 27, 64, 125};
// or
  int[][] A;
  A = new int[][] { {2, 3, 4, 5},
                    {4, 9, 16, 25},
                    { 8, 27, 64, 125} };
// or
  int[][] A = { {2, 3, 4, 5},
                {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};
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A[3] = new int[] {6, 7, 8};
A[4] = new int[] {9};
```

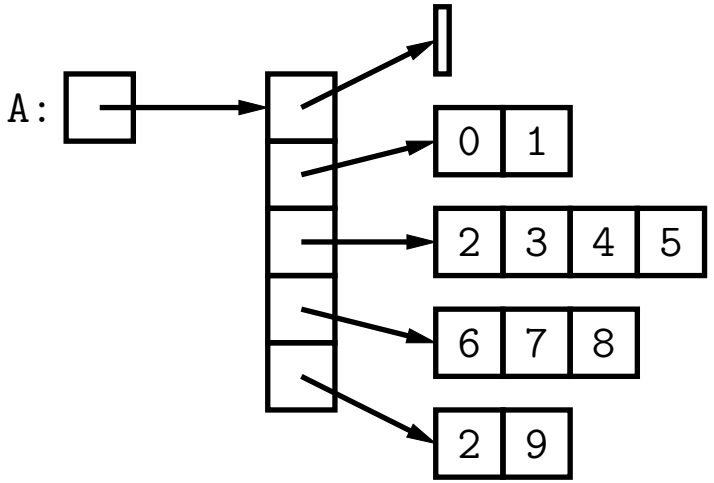

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