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CS61C : Machine Structures

Lecture 5 – Introduction to C (pt 3) C Memory Management

2008-02-01

Hello to Scott Sloan from Superior, WI!

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Sci-Fi Realities ⇒

…the predictions of the Sci-Fi analysts feel will become reality and when: Biometric Security – voice, iris, retinal scans [2010], Space Tourism [2013], Holodeck [2016], Self-Aware Computers [2019], Domestic Robots [2020]. Get in line!

www.pcworld.com/article/id,141682-page,1-c,desktoppcs/article.html

Review

- Pointers and arrays are virtually same
- C knows how to increment pointers
- C is an efficient language, with little protection
  - Array bounds not checked
  - Variables not automatically initialized
- (Beware) The cost of efficiency is more overhead for the programmer.
  - "C gives you a lot of extra rope but be careful not to hang yourself with it!"

Pointers (1/4)

...review...

- Sometimes you want to have a procedure increment a variable?
- What gets printed?

```
void AddOne(int  x)
{      x =  x + 1;    }

int y = 5;
AddOne( y);
printf(“y = %d\n”, y);
```

y = 5

Pointers (2/4)

…review…

- Solved by passing in a pointer to our subroutine.
- Now what gets printed?

```
void AddOne(int *p)
{      *p = *p + 1;     }

int y = 5;
AddOne(&y);
printf("y = %d\n", y);
```

```
y = 6
```

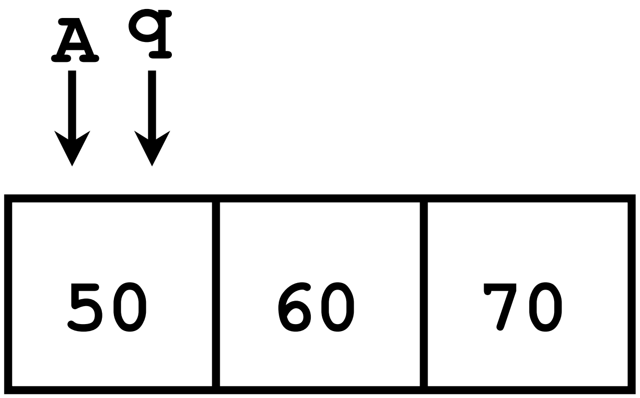
Pointers (3/4)

- But what if what you want changed is a pointer?
- What gets printed?

```
void IncrementPtr(int  *p)
{    p =  p + 1;    }

int A[3] = {50, 60, 70};
int *q = A;
IncrementPtr( q);
printf("*q = %d\n", *q);
```

*q = 50



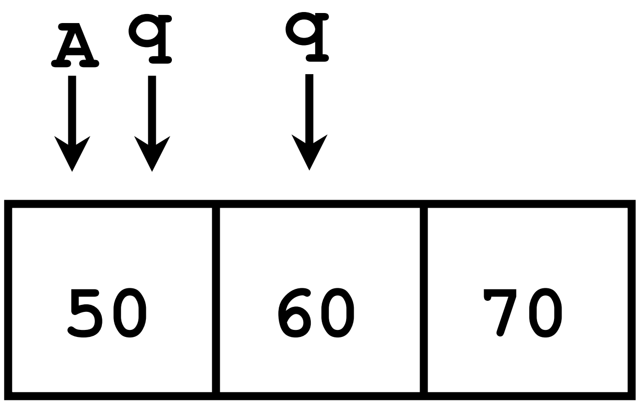
Pointers (4/4)

- Solution! Pass a pointer to a pointer, declared as `**h`
- Now what gets printed?

```
void IncrementPtr(int **h)
{    *h = *h + 1;    }

int A[3] = {50, 60, 70};
int *q = A;
IncrementPtr(&q);
printf("*q = %d\n", *q);
```

`*q = 60`



Dynamic Memory Allocation (1/4)

- C has operator `sizeof()` which gives size in bytes (of type or variable)
- Assume size of objects can be misleading and is bad style, so use `sizeof(type)`
  - Many years ago an `int` was 16 bits, and programs were written with this assumption.
  - What is the size of integers now?
- "`sizeof`" knows the size of arrays:

```
int ar[3]; // Or:   int ar[] = {54, 47, 99}
sizeof(ar) ⇒ 12
```

  - ...as well for arrays whose size is determined at run-time:

```
int n = 3;
int ar[n]; // Or: int ar[fun_that_returns_3()];
sizeof(ar) ⇒ 12
```

Dynamic Memory Allocation (2/4)

- To allocate room for something new to point to, use `malloc()` (with the help of a typecast and `sizeof`):

```
ptr = (int *) malloc (sizeof(int));
```

  - Now, `ptr` points to a space somewhere in memory of size `(sizeof(int))` in bytes.
  - `(int *)` simply tells the compiler what will go into that space (called a typecast).

- `malloc` is almost never used for 1 var

```
ptr = (int *) malloc (n*sizeof(int));
```

  - This allocates an array of `n` integers.

Dynamic Memory Allocation (3/4)

- Once `malloc()` is called, the memory location contains garbage, so don't use it until you've set its value.
- After dynamically allocating space, we must dynamically free it:

```
free(ptr);
```

- Use this command to clean up.
  - Even though the program `frees` all memory on `exit` (or when `main` returns), don't be lazy!
  - You never know when your `main` will get transformed into a subroutine!

Dynamic Memory Allocation (4/4)

- The following two things will cause your program to crash or behave strangely later on, and cause VERY VERY hard to figure out bugs:
  - `free()`ing the same piece of memory twice
  - calling `free()` on something you didn't get back from `malloc()`
- The runtime does not check for these mistakes
  - Memory allocation is so performance-critical that there just isn't time to do this
  - The usual result is that you corrupt the memory allocator's internal structure
  - You won't find out until much later on, in a totally unrelated part of your code!

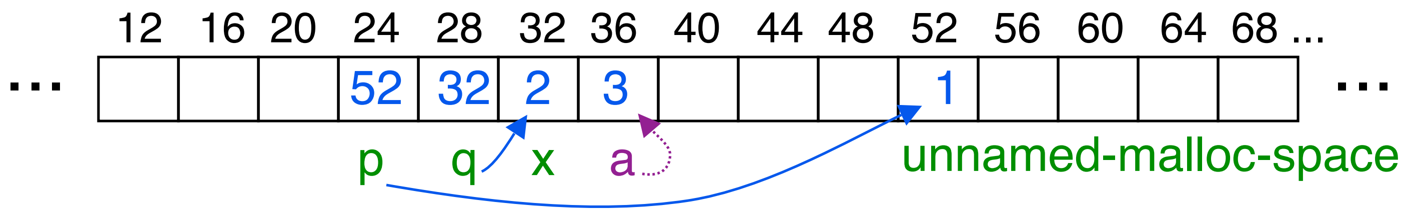
Arrays not implemented as you’d think

```
void foo() {
 int *p, *q, x, a[1]; // a[] = {3} also works here
 p = (int *) malloc (sizeof(int));
 q = &x;

 *p = 1; // p[0] would also work here
 *q = 2; // q[0] would also work here
 *a = 3; // a[0] would also work here

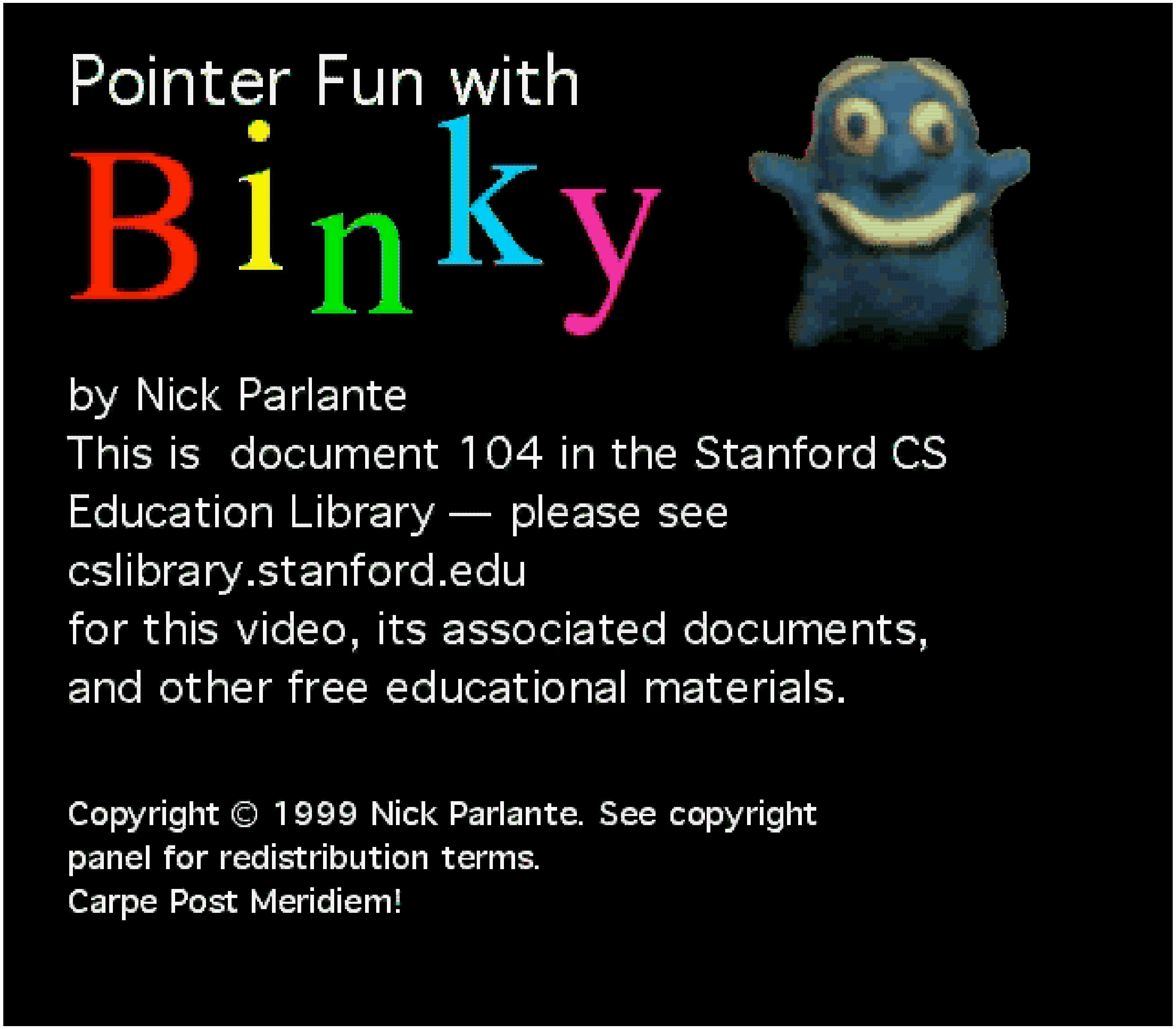
 printf("*p:%u, p:%u, &p:%u\n", *p, p, &p);
 printf("*q:%u, q:%u, &q:%u\n", *q, q, &q);
 printf("*a:%u, a:%u, &a:%u\n", *a, a, &a);

}
```



```
*p:1, p:52, &p:24
*q:2, q:32, &q:28
*a:3, a:36, &a:36
```

Binky Pointer Video (thanks to NP @ SU)



Pointer Fun with

Binky

by Nick Parlante
This is document 104 in the Stanford CS
Education Library — please see
cslibrary.stanford.edu
for this video, its associated documents,
and other free educational materials.

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panel for redistribution terms.
Carpe Post Meridiem!

Kilo, Mega, Giga, Tera, Peta, Exa, Zetta, Yotta

1. Kid meets giant Texas people exercising zen-like yoga. – Rolf O
2. Kind men give ten percent extra, zestfully, youthfully. – Hava E
3. Kissing Mentors Gives Testy Persistent Extremists Zealous Youthfulness. – Gary M
4. Kindness means giving, teaching, permeating excess zeal yourself. – Hava E
5. Killing messengers gives terrible people exactly zero, yo
6. Kindergarten means giving teachers perfect examples (of) zeal (&) youth
7. Kissing mediocre girls/guys teaches people (to) expect zero (from) you
8. Kinky Mean Girls Teach Penis-Extending Zen Yoga
9. Kissing Mel Gibson, Teddy Pendergrass exclaimed: “Zesty, yo!” – Dan G
10. Kissing me gives ten percent extra zeal & youth! – Dan G (borrowing parts)

Peer Instruction

Which are guaranteed to print out 5?

```
I:   main() {
       int *a-ptr; *a-ptr = 5; printf(“%d”, *a-ptr); }

II:  main() {
       int *p, a = 5;
       p = &a; ...
       /* code; a & p NEVER on LHS of = */
       printf(“%d”, a); }

III: main() {
       int *ptr;
       ptr = (int *) malloc (sizeof(int));
       *ptr = 5;
       printf(“%d”, *ptr); }
```

	I	II	III
0:	-	-	-
1:	-	-	YES
2:	-	YES	-
3:	-	YES	YES
4:	YES	-	-
5:	YES	-	YES
6:	YES	YES	-
7:	YES	YES	YES

"And in Conclusion…"

- Use handles to change pointers
- Create abstractions with structures
- Dynamically allocated heap memory must be manually deallocated in C.
  - Use malloc() and free() to allocate and deallocate memory from heap.

Reference slides

You ARE responsible for the material on these slides (they're just taken from the reading anyway) ; we've moved them to the end and off-stage to give more breathing room to lecture!

C structures : Overview

- A `struct` is a data structure composed from simpler data types.
  - Like a class in Java/C++ but without methods or inheritance.

```
struct point {  /* type definition */
    int x;
    int y;
};

void PrintPoint(struct point p)
{  As always in C, the argument is passed by “value” – a copy is made.
    printf(“(%d,%d)”, p.x, p.y);
}

struct point p1 = {0,10}; /* x=0, y=10 */

PrintPoint(p1);
```

C structures: Pointers to them

- Usually, more efficient to pass a pointer to the struct.
- The C arrow operator (`->`) dereferences and extracts a structure field with a single operator.
- The following are equivalent:

```
struct point *p;
 /* code to assign to pointer */
printf("x is %d\n", (*p).x);
printf("x is %d\n", p->x);
```

How big are structs?

- Recall C operator `sizeof()` which gives size in bytes (of type or variable)
- How big is `sizeof(p)`?

```
struct p {
    char x;
    int y;
};
```

  - 5 bytes? 8 bytes?
  - Compiler may word align integer `y`

Linked List Example

- Let’s look at an example of using structures, pointers, `malloc()`, and `free()` to implement a linked list of strings.

```
/* node structure for linked list */
struct Node {
     char *value;
     struct Node *next;
};
```

Recursive definition!

`typedef` simplifies the code

```
struct Node {
    char *value;
    struct Node *next;
 };
```

```
String value;
```

```
/* "typedef" means define a new type */
typedef struct Node NodeStruct;
```

… OR …

```
typedef struct Node {
    char *value;
    struct Node *next;
 } NodeStruct;
```

… THEN

```
 typedef NodeStruct *List;
 typedef char *String;
```

```
/* Note similarity!  */
/* To define 2 nodes */

struct Node {
    char *value;
    struct Node *next;
} node1, node2;
```

Linked List Example

```
/* Add a string to an existing list */
List cons(String s, List list)
{
  List node = (List) malloc(sizeof(NodeStruct));

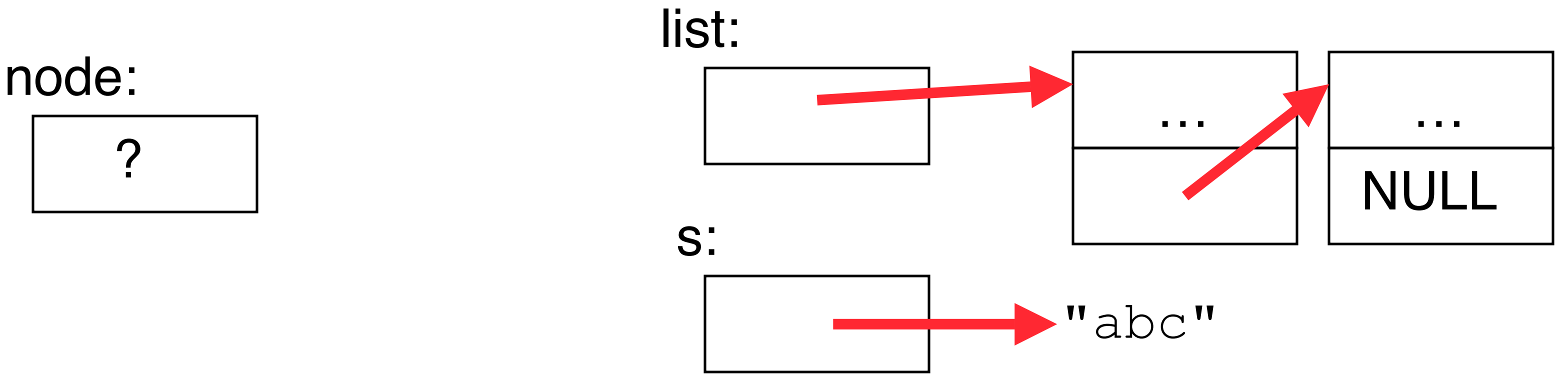
  node->value = (String) malloc (strlen(s) + 1);
  strcpy(node->value, s);
  node->next = list;
  return node;
}

{
   String s1 = "abc", s2 = "cde";
   List theList = NULL;
   theList = cons(s2, theList);
   theList = cons(s1, theList);
/* or, just like (cons s1 (cons s2 nil)) */
   theList = cons(s1, cons(s2, NULL));
```

Linked List Example

```
/* Add a string to an existing list, 2nd call */
List cons(String s, List list)
{
  List node = (List) malloc(sizeof(NodeStruct));

  node->value = (String) malloc (strlen(s) + 1);
  strcpy(node->value, s);
  node->next = list;
  return node;
}
```



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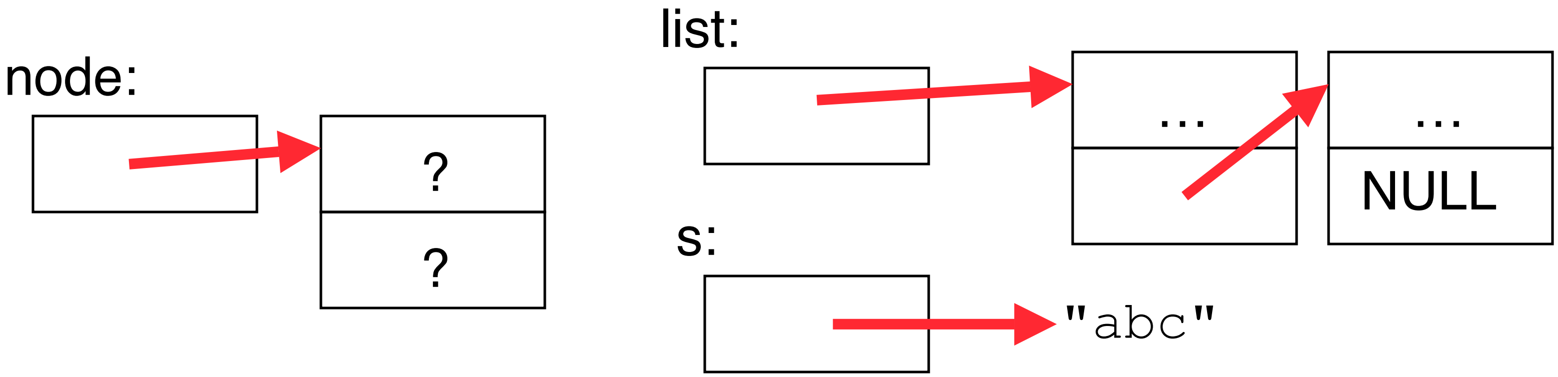

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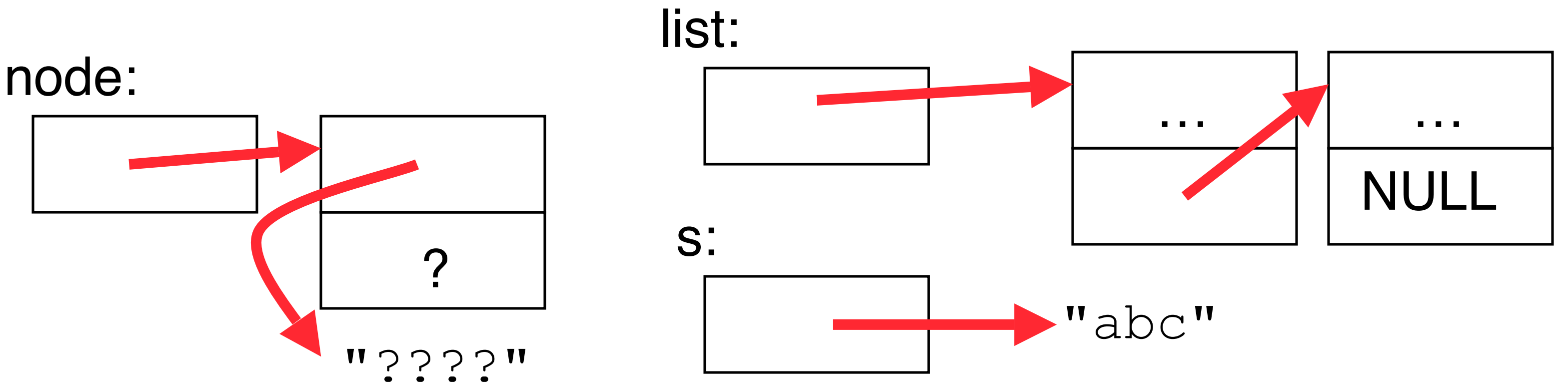
  node->next = list;
  return node;
}
```



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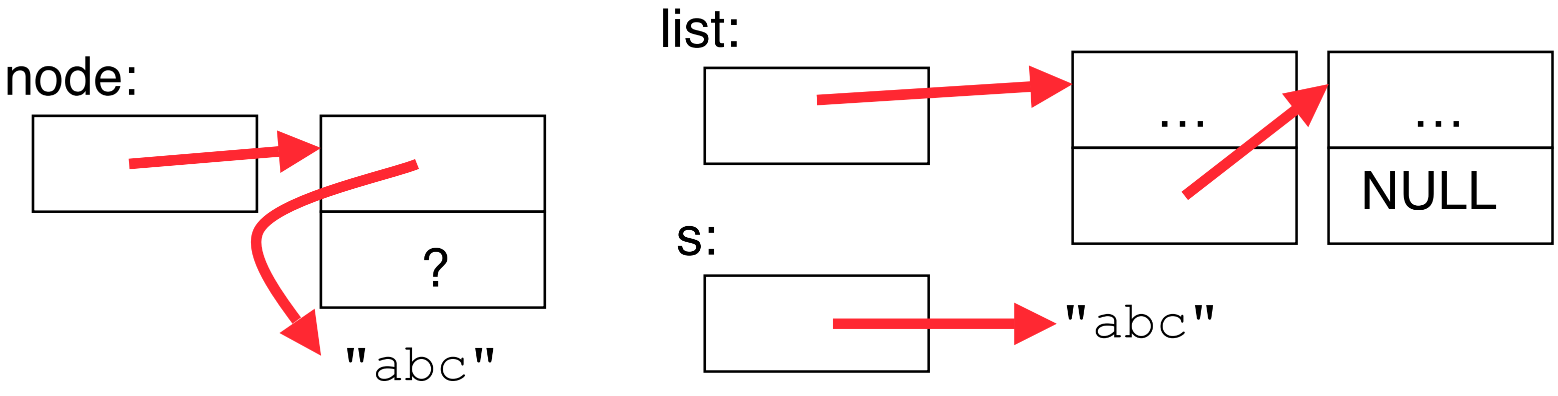

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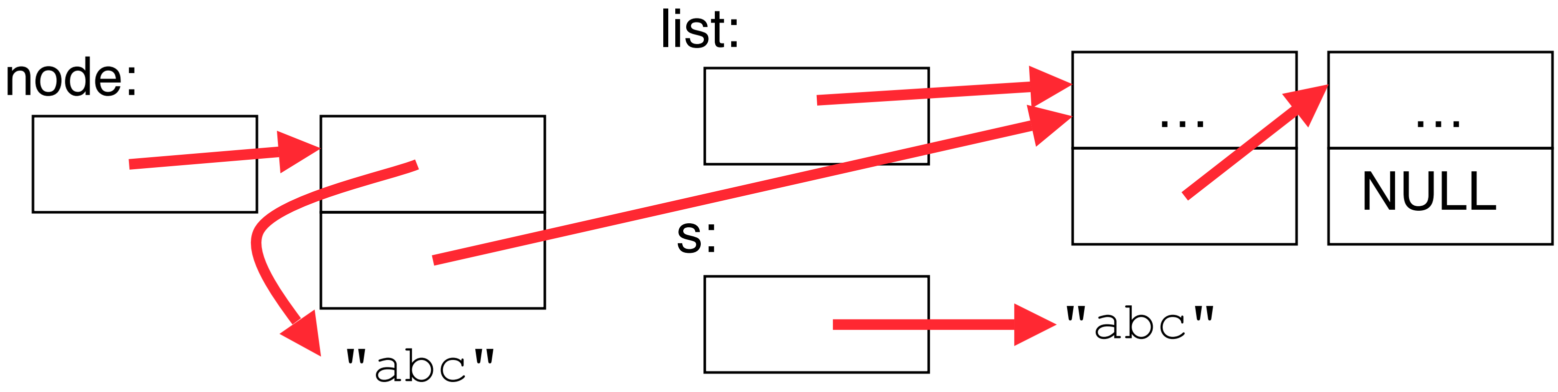

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