Coding Techniques

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Today's Specials

- KISS—Keep It Simple, Stupid
- Fail Safe and Fail Secure
- Locking Memory
- Sanitizing Memory
- Handles

Software Insecurity: Size

Software is *big*. Most interesting software systems consist of tens of thousands, hundreds of thousands or even millions of lines of code.

It is very difficult to make even small systems secure

Unforseen interactions between parts of the system can open you to security problems

Tenex Password Hack (1)

- Tenex was an operating system for the DEC-10
- password checking on files
- passwords were stored unencrypted
- password check only through (un-debuggable) system call

Tenex Password Hack (2)

- Tenex also had paged memory
- when a process accessed a page that was currently paged out to disk, a *page fault* occured
- feature that could notify a process whenever a page fault occured

Tenex Password Hack (3)

Here is the routine to check for the right password:

```
extern const char* lookup_password(const char* filename);
const int password_length = 14;

int password_equal(const char* a, const char* b) {
  int i;

  for (i = 0; i < 14; i++)
    if (a[i] != b[i])
      return 0;
  return 1;
}

int check (const char* filename, const char *given_password) {
  const char *actual_password = lookup_password(filename);
  return password_equal(actual_password, given_password);
}
```

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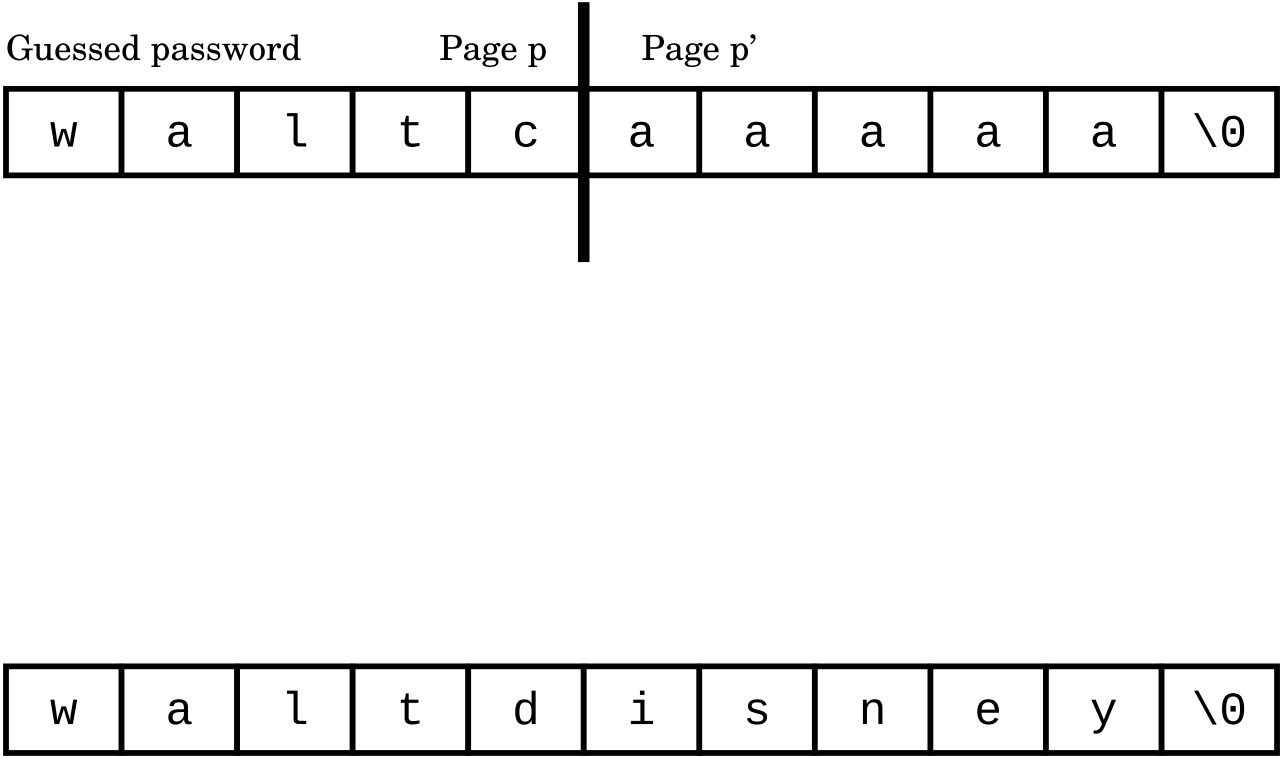
3. Force p' to be paged out.
4. Ask the operating system to open f with the password.
5. If a positive answer comes back, you’re done. If a negative answer comes back, check if a page fault has occurred. If one has not occurred, increase the $i+1$-st character of the password by 1 and try again at step 3. If a page fault has occurred, increase i by 1 and try again at step 2.

Stealing Tenex Passwords



Guessed password

Page p | Page p’

w	a	l	t	c	a	a	a	a	a	\0

w	a	l	t	d	i	s	n	e	y	\0

Real password

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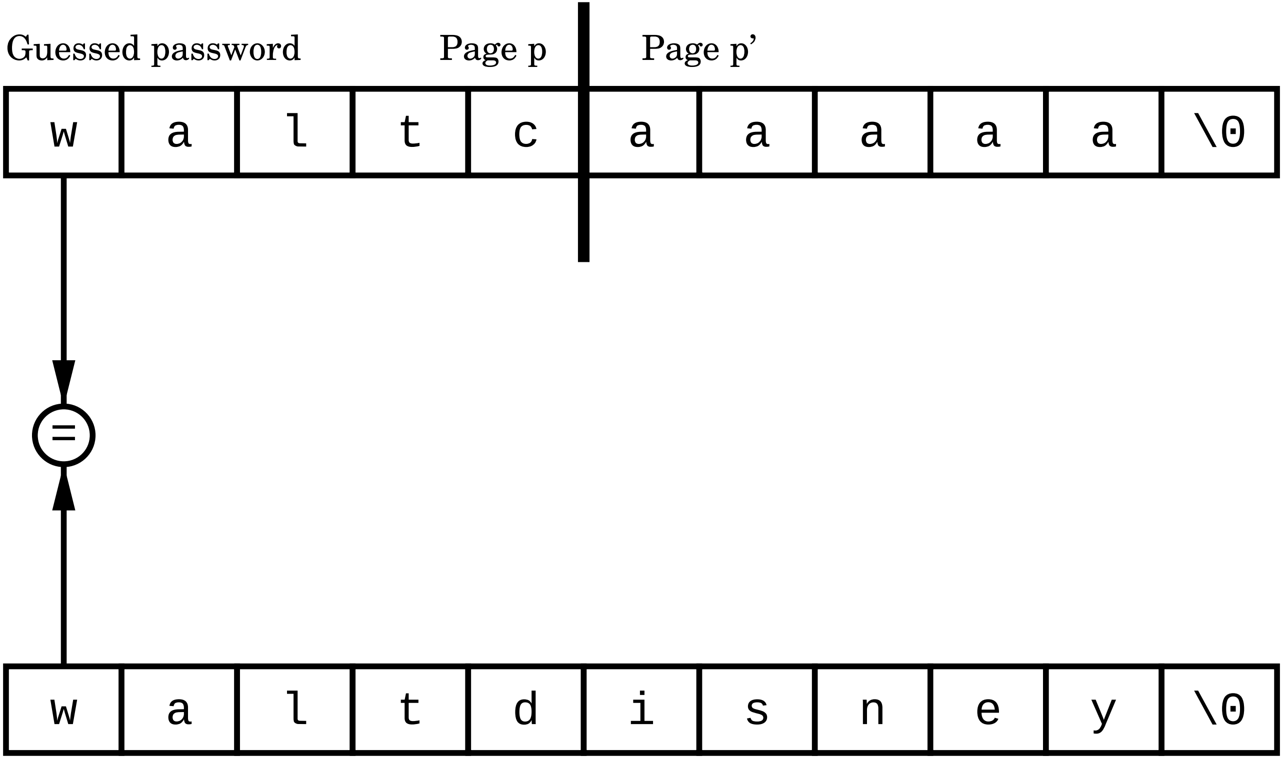

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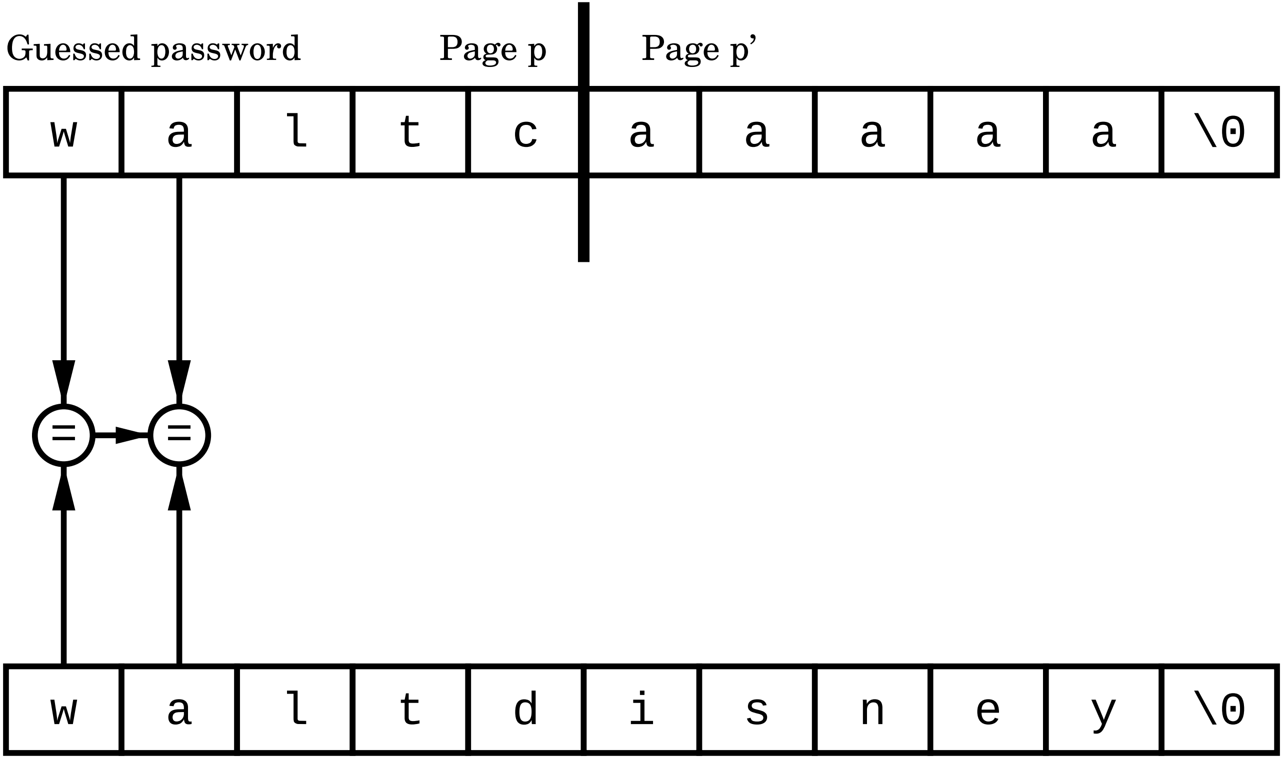

Guessed password

Page p

Page p’

w a l t c a a a a a \0

w a l t d i s n e y \0

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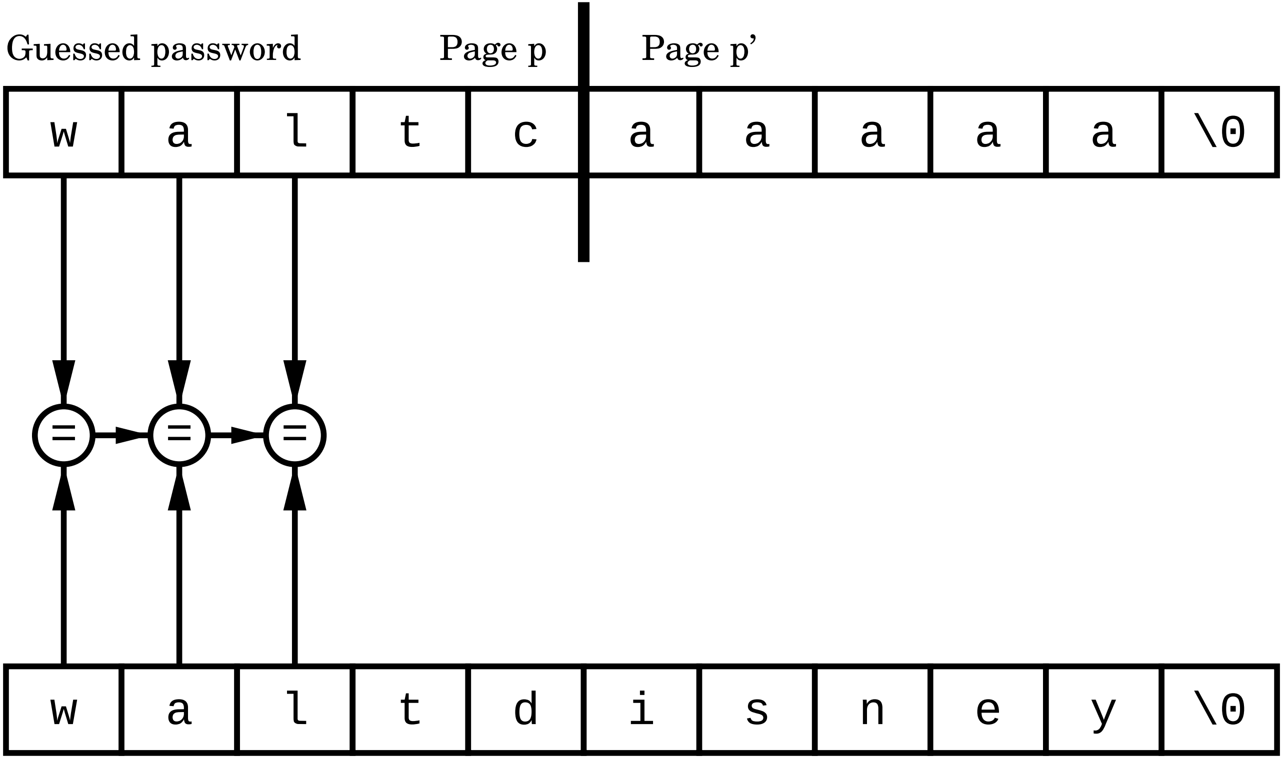

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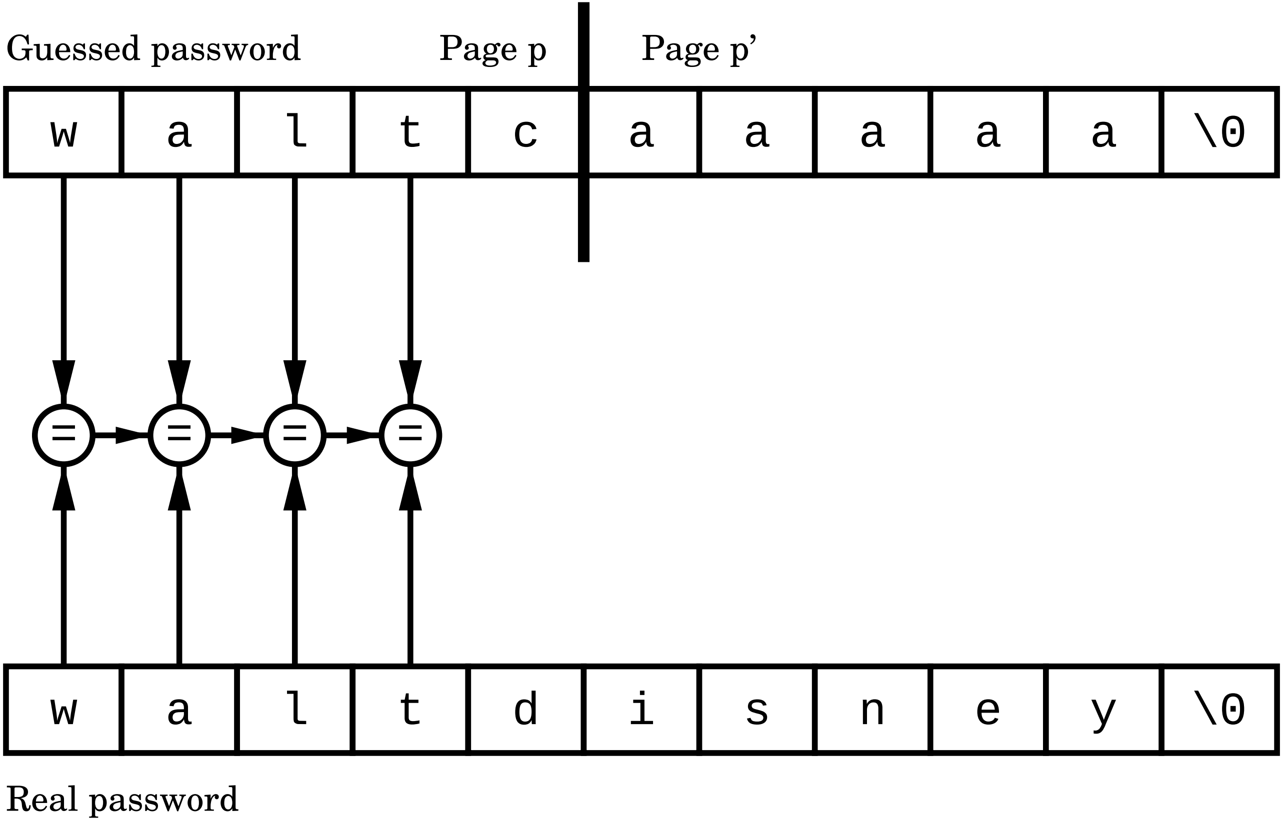

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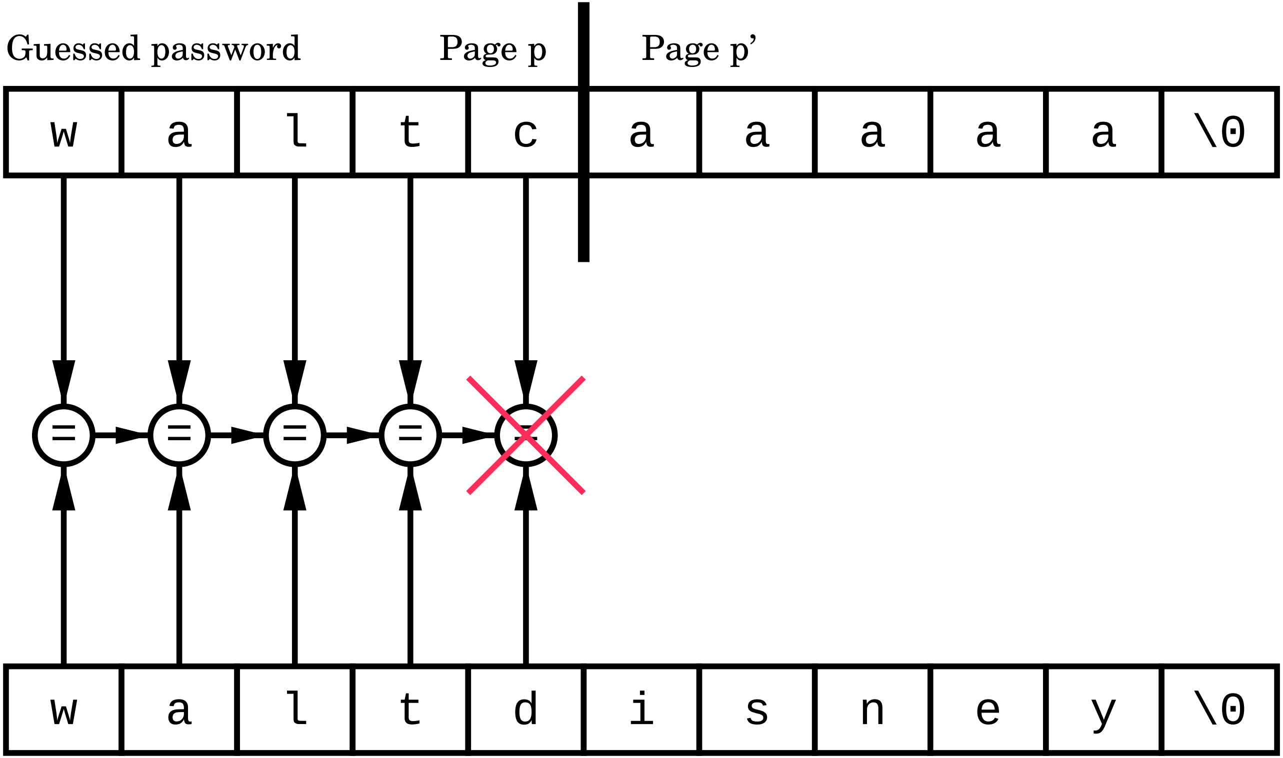

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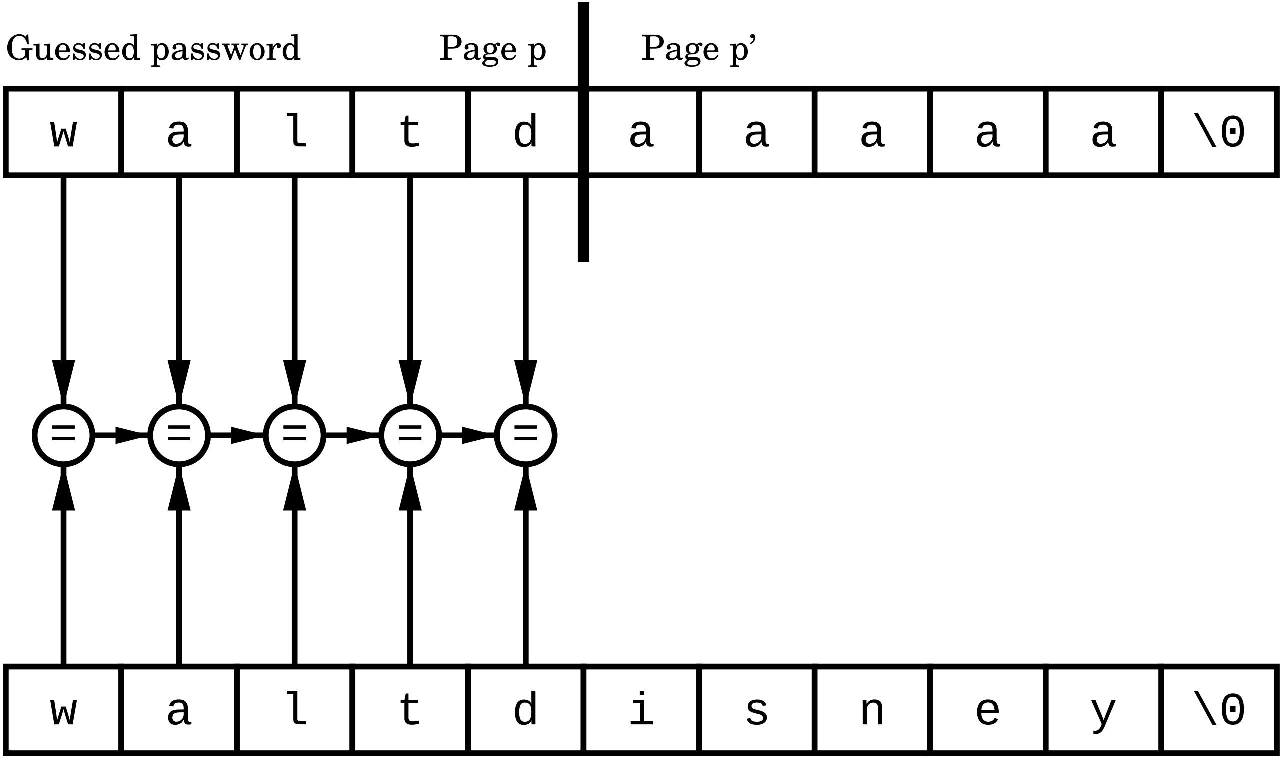

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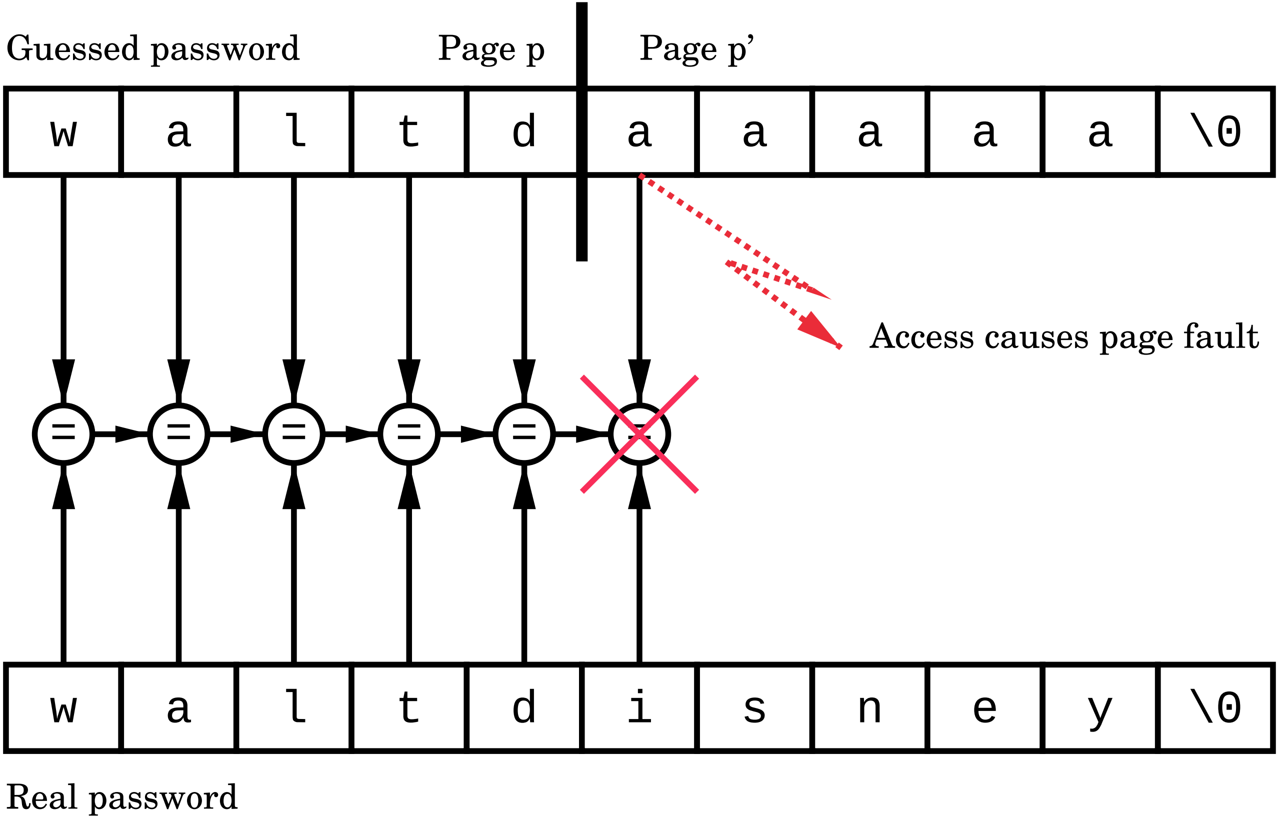

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The knight to slay this dragon of complexity was sendmail. Sendmail was configurable to handle all these addresses through a generalized string rewriting framweork.

The downside of it was that no-one wanted to write or debug sendmail configuration files, because they were so complex.

Sendmail Example

```
S98
R$* < $m . >       $# local $@ $1      deliver mail to our domain
R$* < $m >         $# error $@ 4.5.1   can’t resolve domain?
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```
# Towers of Hanoi
S49
RHANOI:$+       $:1 2 3$1
R$-$-$-$*[$+]   $:$1$2$3$4
R$-$-$-         $@$1$2$3
R$-$-$-@$*      $:$>49 $1$3$2$4
R$-$-$-$*       $:$>49 $2$3$1$4[Move Top Disk Of Peg $1 To Peg $3]
R$-$-$-$*       $:$3$2$1@$4
```

It’s Turing-complete, but it’s not nice! (Same holds for Intercal.)

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Designed for security: `qmail` offers "qmail security guarantee": First person to detect a security flaw in qmail gets \$500. Offer open since March 1997, still no takers as of today; no `postfix` holes ever published.

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- (The configuration needs of a software can change over time.)

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- Make sure that you still can make a controlled exit if an error occurs: remember important variables etc.
- Always *explicitly* free all resources (memory, files, . . .) on termination; don’t rely on the operating system to do it for you.

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- Offer secure defaults (probably the most overlooked recommendation of them all).
- Don’t report success if success isn’t certain.

Reporting Success (1)

```
typedef enum { no_error, write_failed } write_error_t;

/* Writes a critical file. If this function returns with 0, the file
   has been written and committed to stable storage. Returns -1 on
   error. */
write_error_t write_critical_file() {
  FILE *fp = fopen("file", "w");
  const char* message = "This is a message";

  if (fwrite(message, strlen(message) + 1, 1, fp) != strlen(message) + 1) {
    error("Write failed"); return write_failed;
  }

  fclose(fp);
  return no_error;
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If the *fclose*(3) call fails, the file might not be on the disk!

Reporting Success (2)

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File might be in kernel buffers even if *fclose*(3) succeeds.

Reporting Success (3)

```
typedef enum { no_error, write_failed, close_failed, sync_failed } write_error_t;

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  if (fclose(fp) != 0) { error("Close failed"); return close_failed; }

  if (fsync(fileno(fp)) != 0) { error("Sync failed"); return sync_failed; }

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Problem: invent a good strategy what to do if *fclose*(3) or *fsync*(3) fail. (Just reporting an error is often no good.)

A Little Puzzle

Check the following code:

```
unsigned char*
encrypt_file(const char* file_name, const char* user) {
  key_t* secret_key = lookup_secret_key(user);
  unsigned char* plaintext = read_file(file_name);
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Well, what *could* be wrong with it?

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- Encrypt it before storing it

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- Someone with access to the disk can get the secret (and that's *not* an academic threat!)
- Even if the data is officially erased (by overwriting it), it can still be restored (the phenomenon is called "remanence")
- It's *very difficult* to erase data from a disk

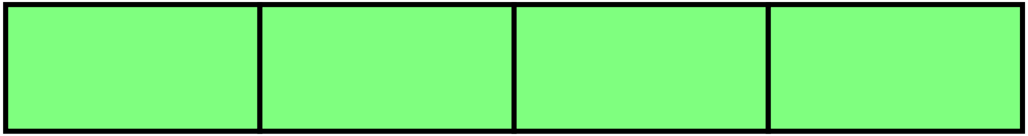
Keeping Data in Memory

```
#include <sys/mman.h>

/* Warning! mlock calls don’t stack! */
key_t* lookup_secret_key(const char* user) {
  key_t* ret = (key_t*) malloc(sizeof(key_t));
  if (ret != 0) {
    /* Must be root for this to succeed */
    if (mlock(ret, sizeof(ret)) == 0) {
      /* Proceed */
    } else {
      /* Handle error */
    }
  }
  return ret;
}

int release (const void* buf, size_t len) {
  free(buf);
  /* Must be root for this to succeed */
  return munlock(buf, len);
}
```

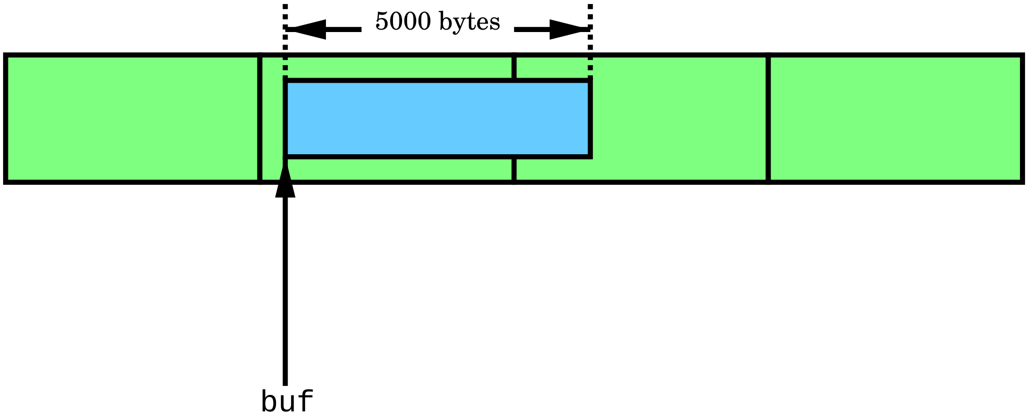
How mlock(2) works



🟩 Can be paged to disk

🟥 Locked in memory

How mlock(2) works



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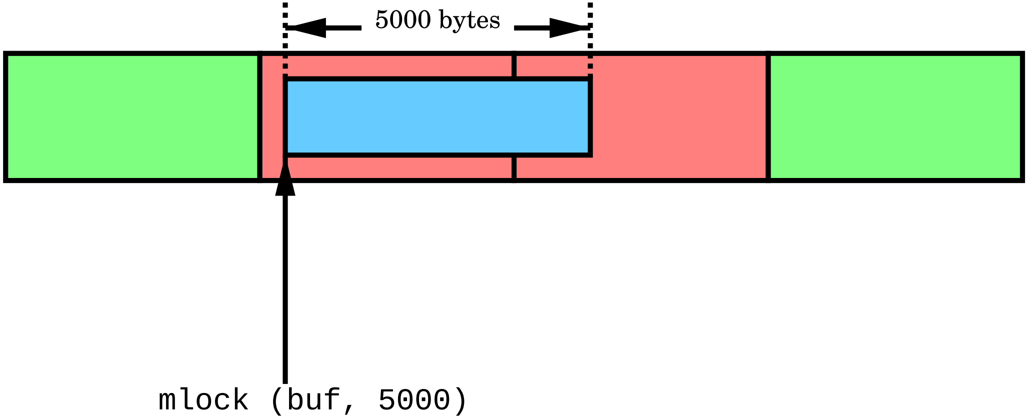

```
mlock (buf, 5000)
```

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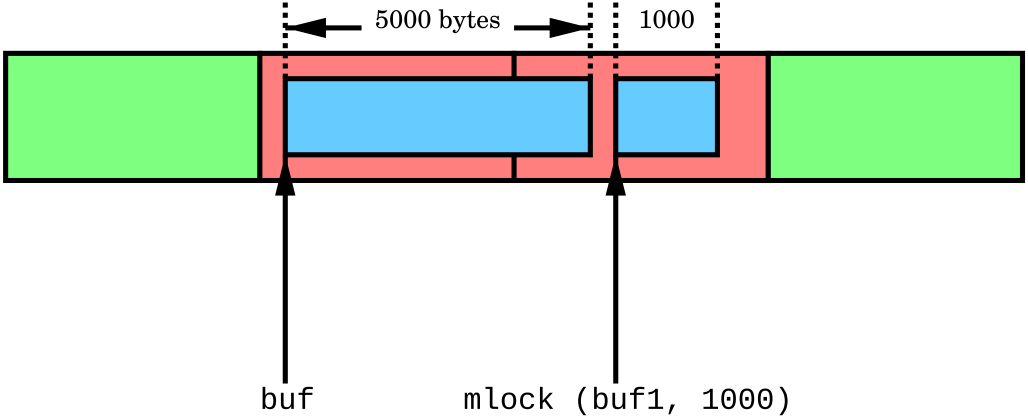
mlock(2) Calls Don’t Stack!



5000 bytes

1000

`buf`

`mlock (buf1, 1000)`

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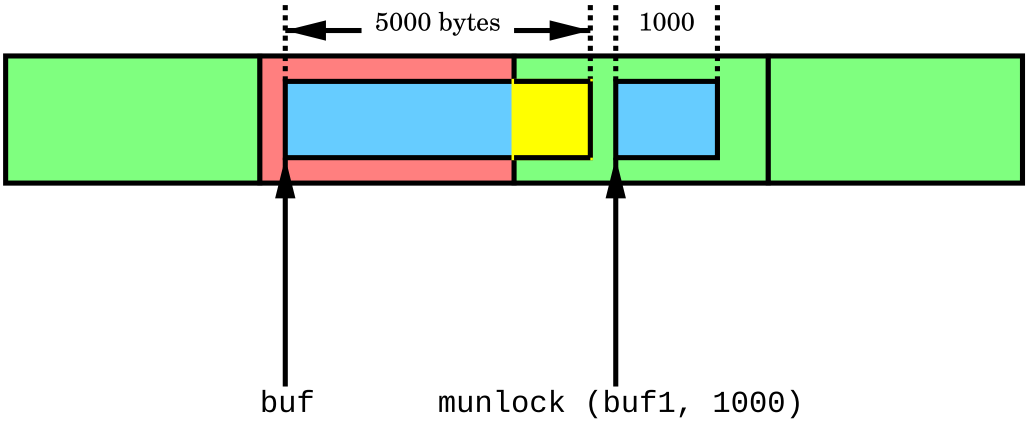

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🟨 Shouldn’t be pageable, but is

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Solution:

- For every locked page, maintain a counter that says how many buffers are in that page.

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It's probably easiest to combine that with the memory allocation functions.

Another Little Puzzle

```
unsigned char* encrypt_file(const char* file_name, const char* user) {
  key_t* secret_key = lookup_secret_key(user);     /* Uses mlock(2)! */
  unsigned char* plaintext = read_file(file_name); /* Uses mlock(2)! */
  unsigned char* ciphertext = encrypt(plaintext, secret_key);

  release(secret_key); release(plaintext);
  return ciphertext;
}

int release (const void* buf, size_t len) {
  free(buf);
  update_page_counts(buf, len);
  if (page_counts_are_zero(buf, len)) return munlock(buf, len); else return 0;
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Looks good, doesn’t it?

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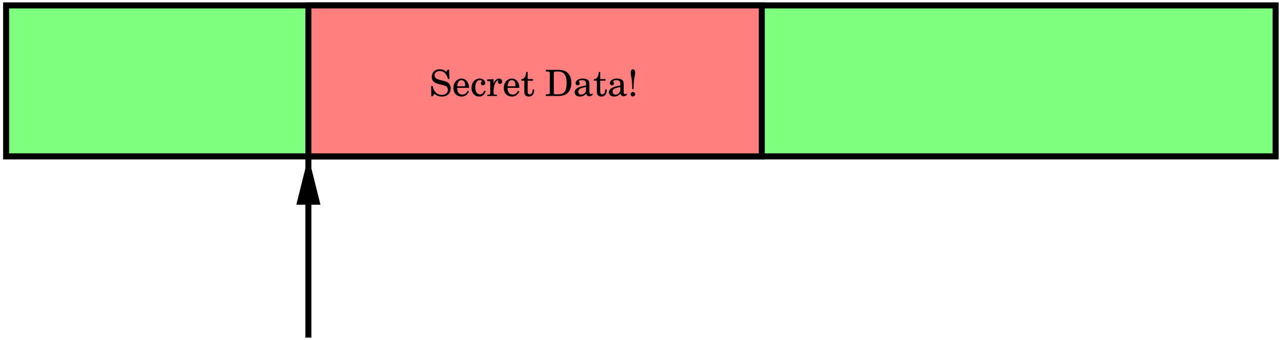

```
secret_buf = malloc(1000)
```

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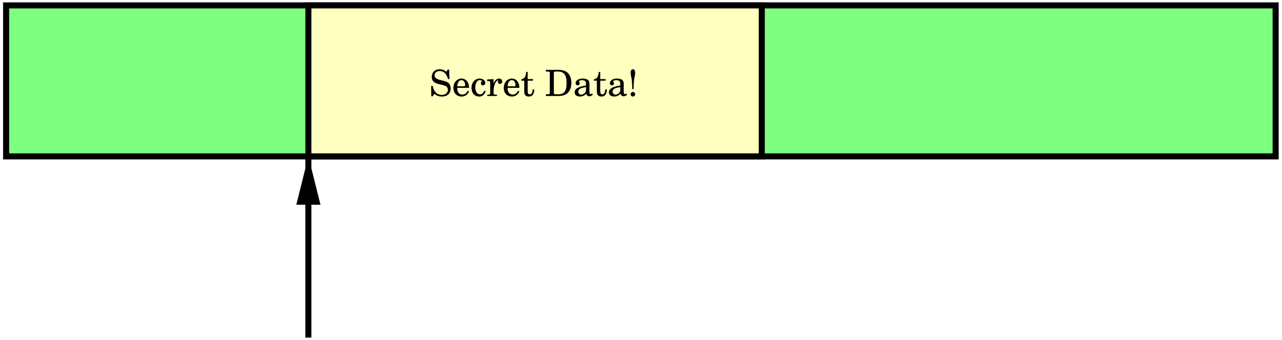

`free(secret_buf)`

Allocating Memory

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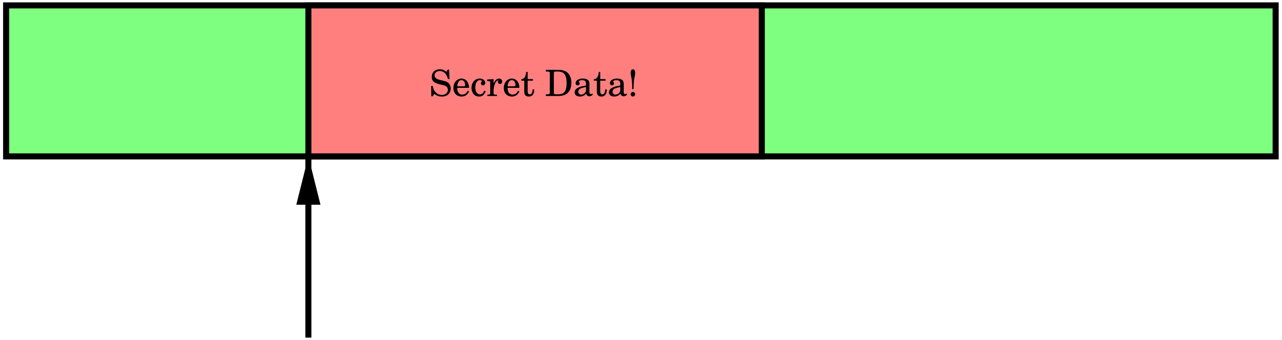

`public_buf = malloc(1000)`

Public buffer now contains secret data!

Zeroing Memory

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Better nip that problem in the bud!

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Could have been everything from Mom’s shopping list to passwords.

How to Avoid This Problem

```
#include <stdlib.h>

int release (void* buf, len_t len) {
  memset(buf, '\0', len);      /* <- Zeroize buffer before freeing */
  free(buf);

  update_page_counts(buf, len);
  if (page_counts_are_zero(buf, len))
    return munlock(buf, len);
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You must remember the size of the block you allocated. You can’t forget about that, like you can in “normal” C.

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You must remember the size of the block you allocated. You can’t forget about that, like you can in “normal” C.

You *could* zeroize each block every time before freeing it, but chances are you’ll forget one of them ⇒ do it *once* in a library routine, then call that library routine.

Handles (1)

```
typedef unsigned char key_t[256];

unsigned char* encrypt_file(const char* plaintext, const char* user) {
  key_t secret_key = lookup_key(user); /* Not a pointer! */
  unsigned char ciphertext[512];

  /* ... */

  encrypt(plaintext, secret_key, ciphertext);
  fwrite(ciphertext, 1024, 1, fp); /* Oops! Writes secret key! */

  /* ... */
}
```

By mistake, the secret key gets written to disk.

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By mistake, the secret key gets written to disk.

The mistake is easy to spot in this example, but there are enough programs where these few lines are scattered among many files.

Handles (2)

```
typedef int key_handle_t;

unsigned char* encrypt_file(const char* plaintext, const char* user) {
  key_handle_t key_handle = lookup_key(user); unsigned char ciphertext[512];

  /* ... */
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Using a handle instead of a pointer to the actual object makes it possible to check *every* use of the object.

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For *extra* paranoia, you can code identifying information into the handle. ⇒ sharing of handles difficult between subjects.

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- Handles need complete implementation, standard library has no generic support for handles
- Handles make access control easier (in many cases, it's the only way to enable access controls at all)
- Handles reduce drastically the probability of accidentally leaking secret information

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Most code that you write is difficult to test:

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- Test expected failures (decryption on modified ciphertext, signature verification on modified signature, negative values where only positive values are allowed, . . .)
- Test “impossible” conditions (bad parameters, enums outside the legal range, ‘NaN’s for floats. . .)

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#include <string.h>

void* copy_memory(const void* block, int size) {
  void* ret = malloc(size);

  if (ret != 0)
    memcpy(ret, block, size);

  return ret;
}
```

Learn From Testing (2)

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#include <string.h>

void* copy_memory(const void* block, size_t size) {
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  if (ret != 0) memcpy(ret, block, size);

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- (That's really just common sense.)

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When it becomes impossible (or even very difficult) to provide an interface with “impossible” values, then it will be even more difficult for an attacker to inject “impossible” values through official channels.

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The system has then become more secure *by design*.

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- CUnit testing framework for C at `http://cunit.sourceforge.net/`