Principles of

Software Design

Software Engineering

Alessio Gambi • Saarland University

The Challenge

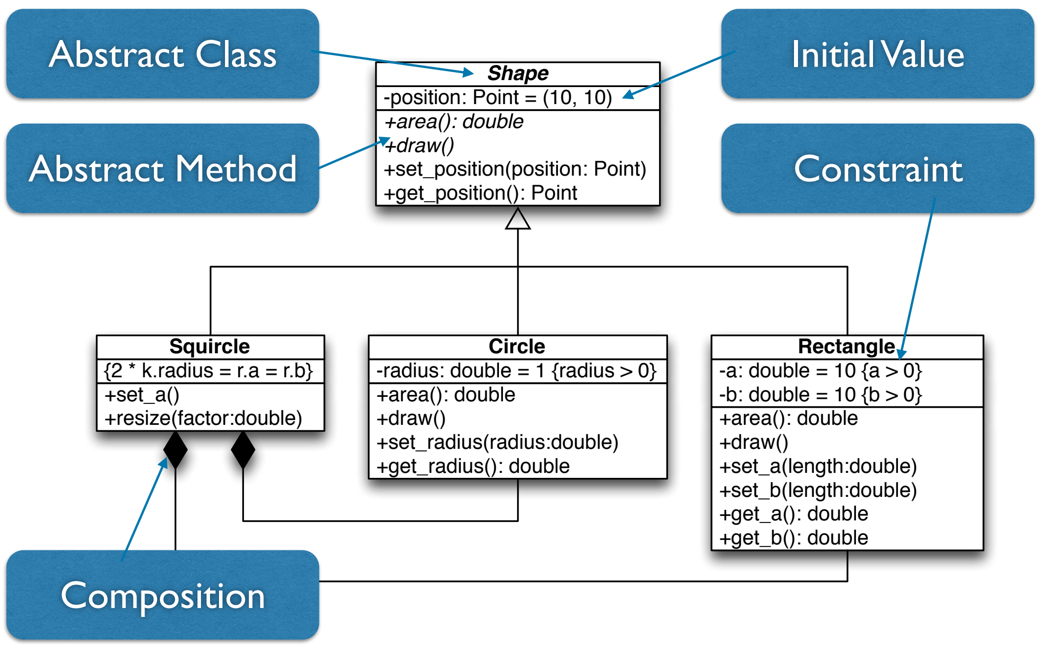
- Software may live much longer than expected
- Software must be continuously adapted to a changing environment and requirements
- Maintenance takes 50–80% of the cost
- Goal: Make software *maintainable* and *reusable* – at little or no cost

UML Recap

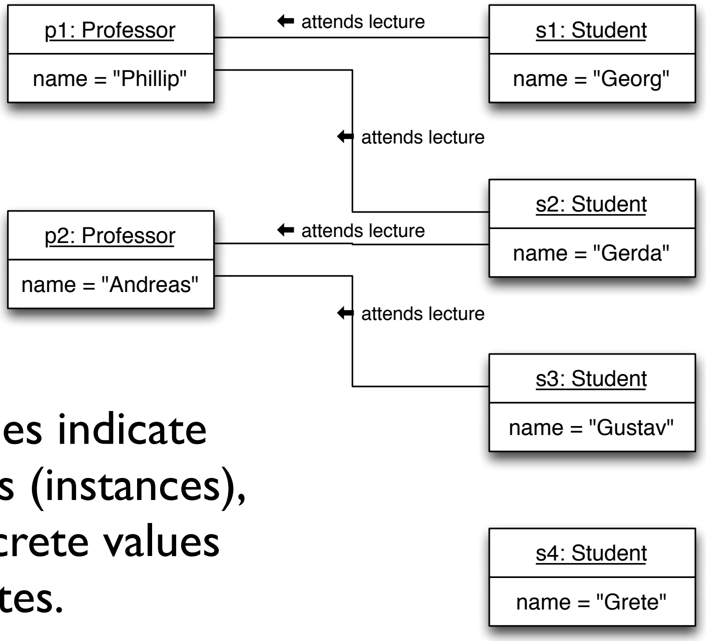
- Want a *notation* to express OO designs
- UML = *Unified Modeling Language*
- a standardized (ISO/IEC 19501:2005), *general-purpose modeling language*
- includes a set of *graphic notation techniques* to create visual models of *object-oriented* software-intensive systems

UML in a Nutshell

Object Model

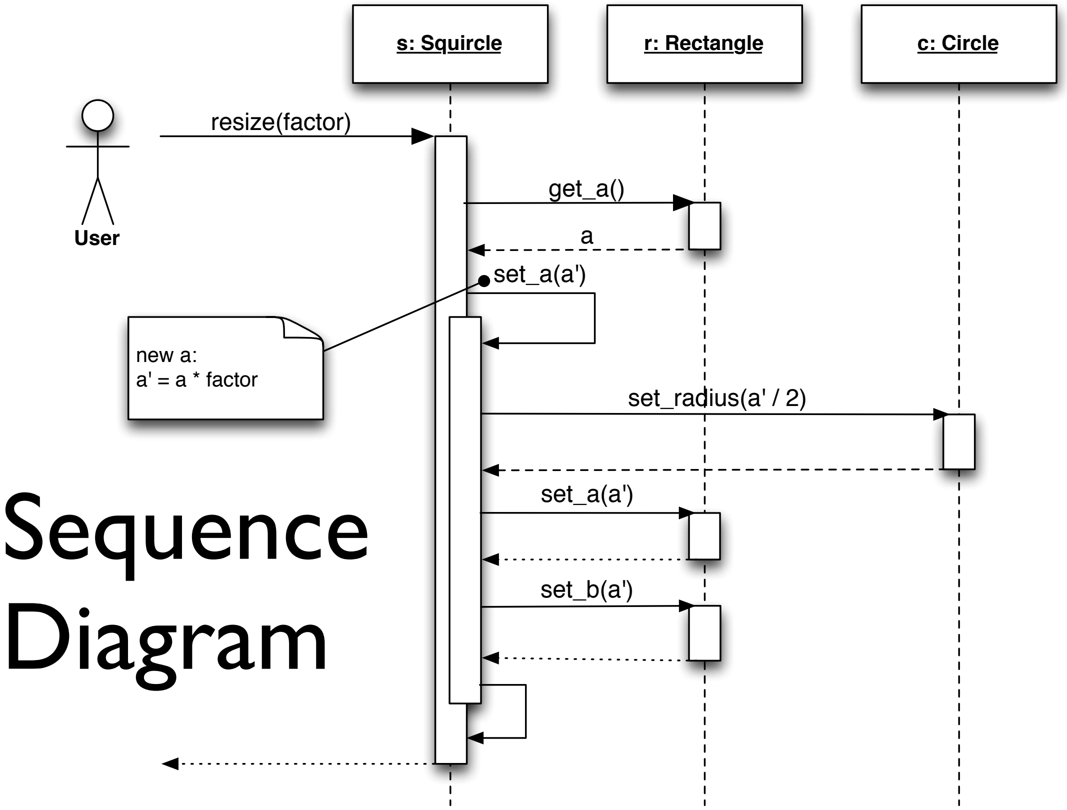


Associations between Objects

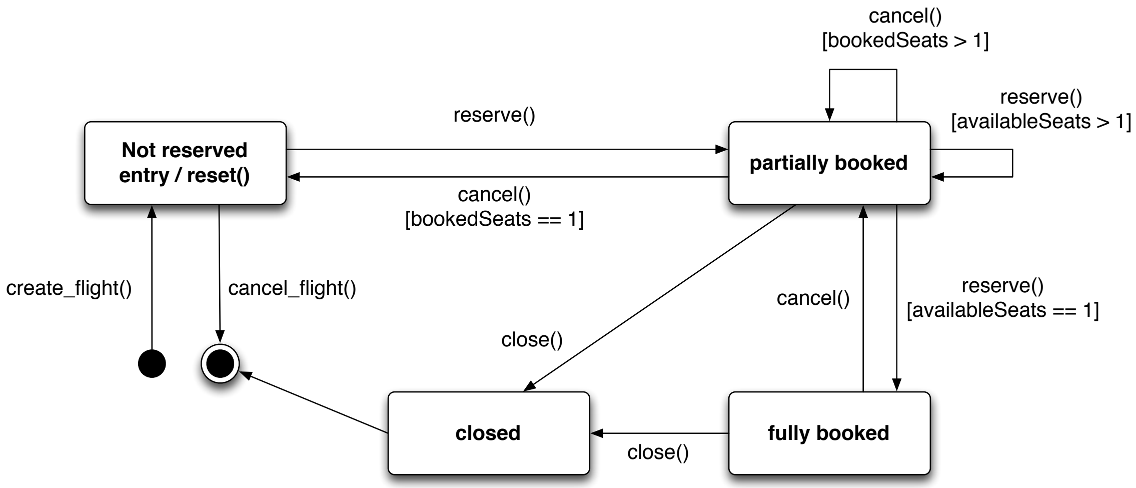


Underlined names indicate concrete objects (instances), which have concrete values for their attributes.

Sequence Diagram



State Diagram



Principles

of object-oriented design

Goal: *Maintainability* and *Reusability*

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- Abstraction

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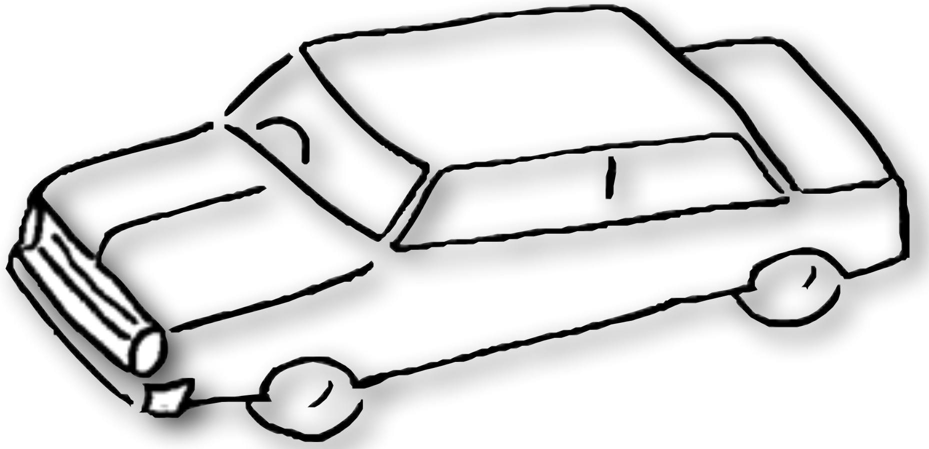
Abstraction

Abstraction

Concrete Object

Abstraction

Concrete Object



General Principle

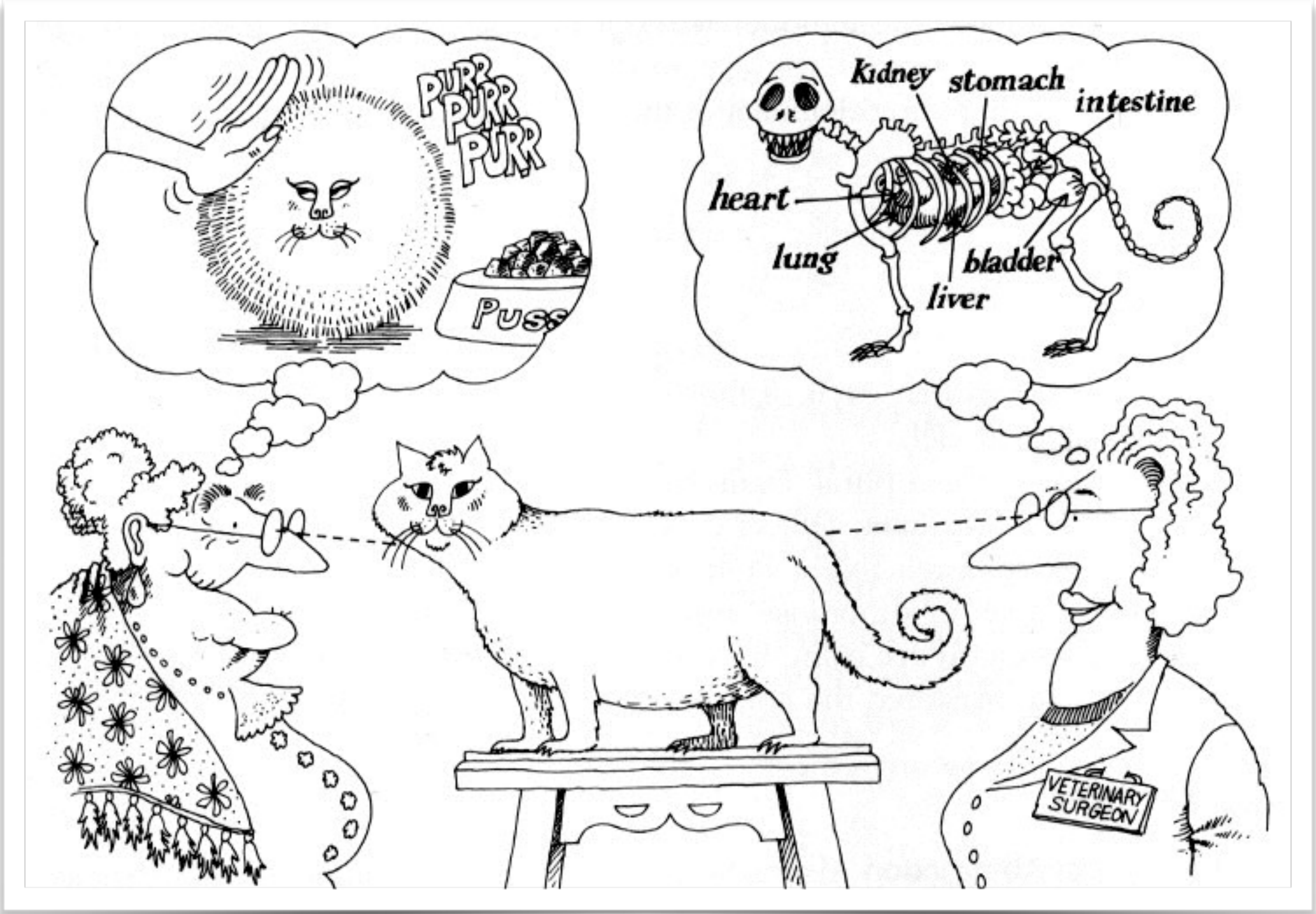
Abstraction…

- Highlights *common properties* of objects
- Distinguishes *important* and *unimportant* properties
- Must be understood even without a concrete object

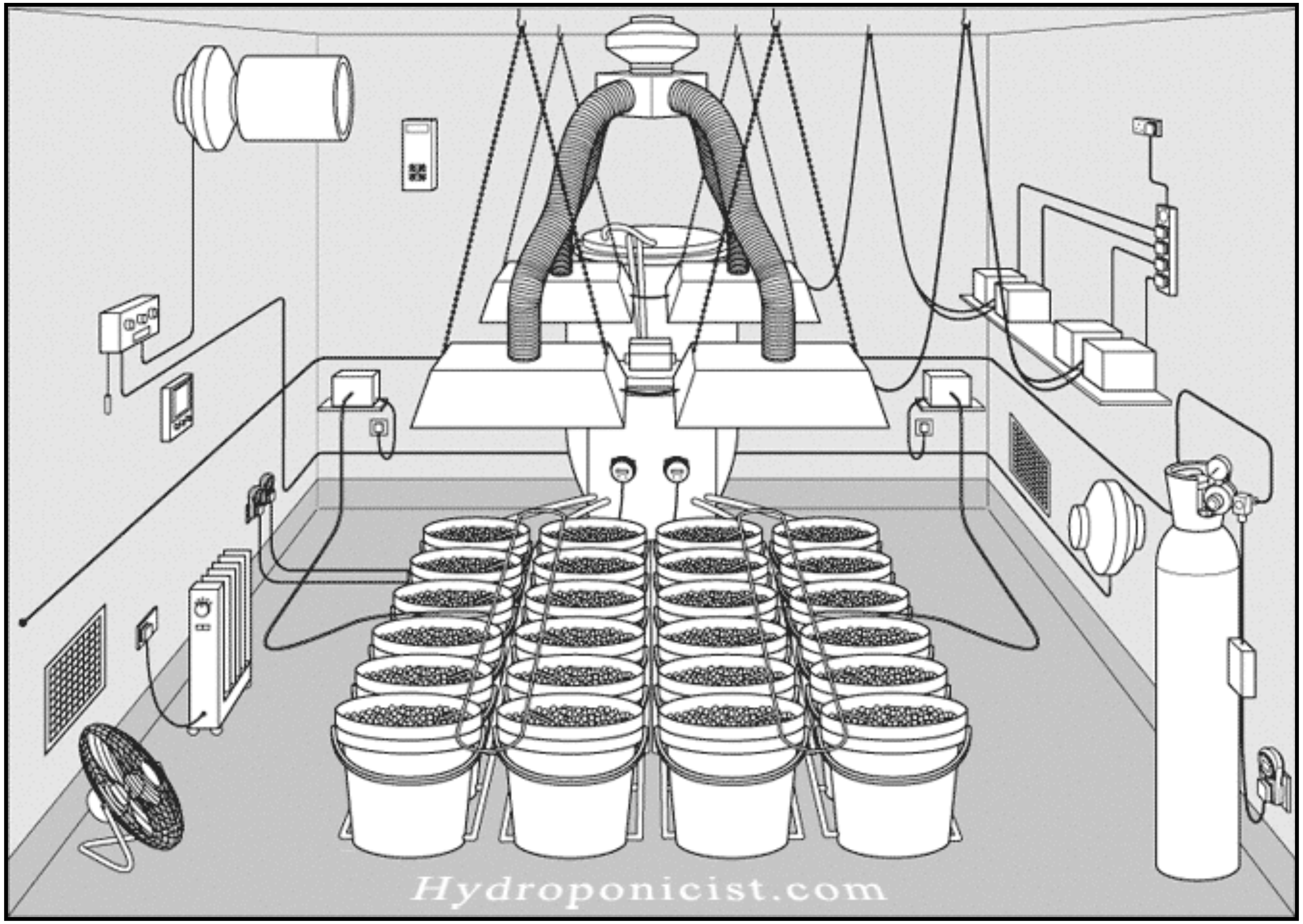
Abstraction

“An abstraction denotes the essential characteristics of an object that distinguish it from all other kinds of objects and thus provide crisply defined conceptual boundaries, relative to the perspective of the viewer”

Perspectives



Example: Sensors



An Engineer’s Solution

```
void check_temperature() {
    // see specs AEG sensor type 700, pp. 53
    short *sensor = 0x80004000;
    short *low    = sensor[0x20];
    short *high   = sensor[0x21];
    int temp_celsius = low + high * 256;
    if (temp_celsius > 50) {
        turn_heating_off()
    }
}
```

Abstract Solution

```
typedef float Temperature;
typedef int Location;

class TemperatureSensor {
public:
    TemperatureSensor(Location);
    ~TemperatureSensor();

    void calibrate(Temperature actual);
    Temperature currentTemperature() const;
    Location location() const;

private: …
}
```

Abstract Solution

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typedef float Temperature;
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private: …
}
```

All implementation details are *hidden*

More Abstraction

Ceci n'est pas une pipe.

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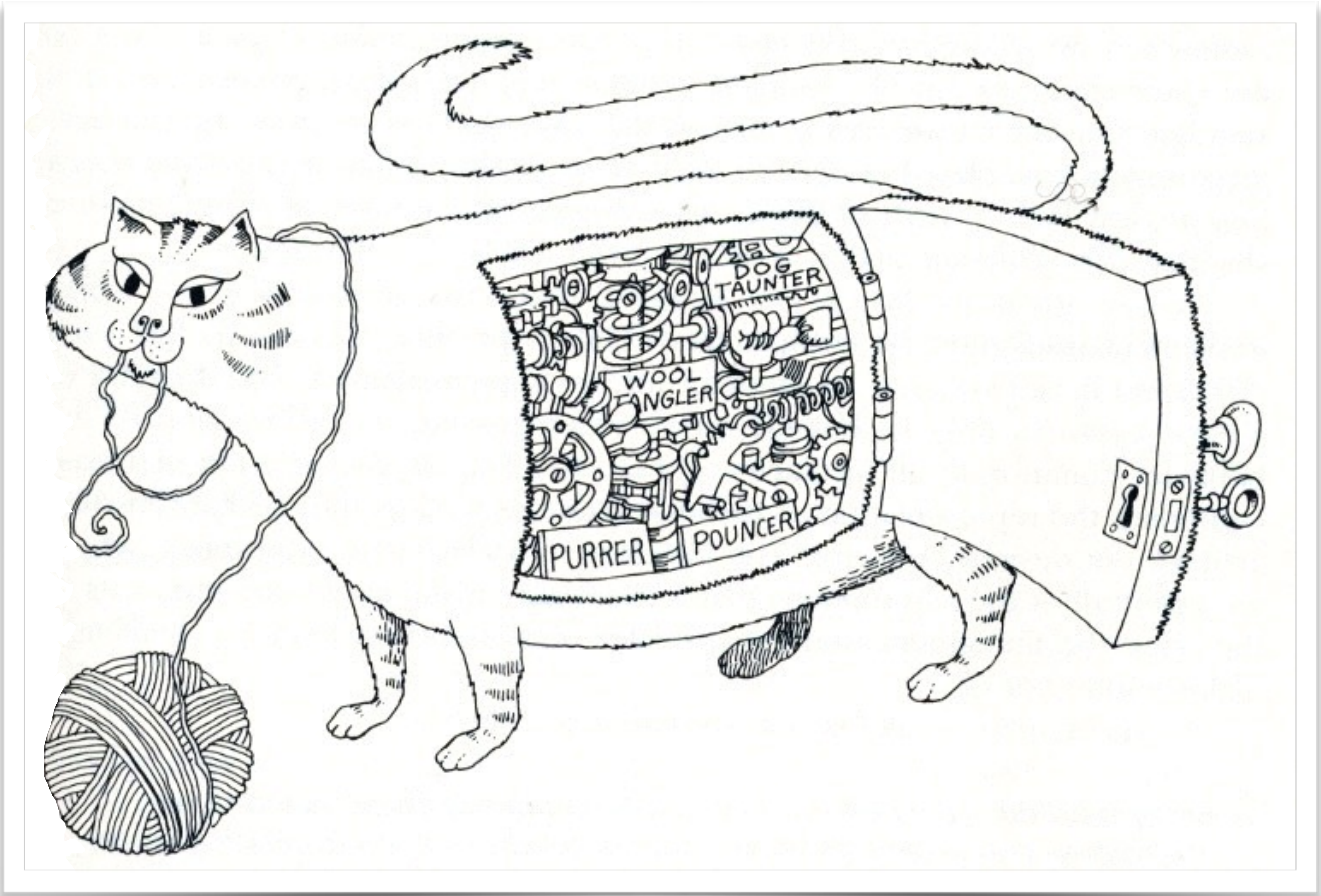
Encapsulation

- No part of a complex system should depend on internal details of another
- Goal: keep software changes *local*
- *Information hiding*: Internal details (state, structure, behavior) become the object's *secret*

Encapsulation

“Encapsulation is the process of compartmentalizing the elements of an abstraction that constitute its structure and its behavior; encapsulation serves to separate the contractual interface of an abstraction and its implementation.”

Encapsulation



An active Sensor

```
class ActiveSensor {
public:
    ActiveSensor(Location)
    ~ActiveSensor();

    void calibrate(Temperature actual);
    Temperature currentTemperature() const;
    Location location() const;

    void register(void (*callback)(ActiveSensor *));

private: …
}
```

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class ActiveSensor {
public:
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    void calibrate(Temperature actual);
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called when temperature changes

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```

called when temperature changes

Callback management is the sensor’s secret

Anticipating Change

Features that are anticipated to change should be *isolated* in specific components

- Number literals
- String literals
- Presentation and interaction

Number literals

```
int a[100]; for (int i = 0; i <= 99; i++) a[i] = 0;
```

Number literals

```
int a[100]; for (int i = 0; i <= 99; i++) a[i] = 0;
```

▼

```
const int SIZE = 100;
int a[SIZE]; for (int i = 0; i < SIZE; i++) a[i] = 0;
```

Number literals

```
double sales_price = net_price * 1.19;
```

Number literals

```
double sales_price = net_price * 1.19;
```

▼

```
final double VAT = 1.19;
double sales_price = net_price * VAT;
```

String literals

```
if (sensor.temperature() > 100)
    printf(“Water is boiling!”);
```

String literals

```
if (sensor.temperature() > 100)
    printf(“Water is boiling!”);
```

▼

```
if (sensor.temperature() > BOILING_POINT)
    printf(message(BOILING_WARNING,
                   “Water is boiling!”);
```

String literals

```
if (sensor.temperature() > 100)
    printf(“Water is boiling!”);
```

▼

```
if (sensor.temperature() > BOILING_POINT)
    printf(message(BOILING_WARNING,
                   “Water is boiling!”);
```

```
if (sensor.temperature() > BOILING_POINT)
    alarm.handle_boiling();
```

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Modularity

- Basic idea: Partition a system such that parts can be designed and revised independently (“divide and conquer”)
- System is partitioned into *modules* that each fulfil a specific task
- Modules should be changeable and reuseable independent of other modules

Modularity

ASSEMBLY INSTRUCTIONS
TICKER
STICK-ON STRIPES
DO-IT-YOURSELF CAT KIT
LEG-REAR OFFSIDE
PURRER
MIAOWER

Modularity

“Modularity is the property of a system that has been decomposed into a set of cohesive and loosely coupled modules.”

Module Balance

- Goal 1: Modules should *hide information* – and expose as little as possible
- Goal 2: Modules should *cooperate* – and therefore must exchange information
- These goals are in conflict with each other

Principles of Modularity

- High cohesion – Modules should contain functions that logically belong together
- Weak coupling – Changes to modules should not affect other modules
- Law of Demeter – talk only to friends

High cohesion

- Modules should contain functions that logically belong together
- Achieved by grouping functions that work on the same data
- “natural” grouping in object oriented design

Weak coupling

- Changes in modules should not impact other modules
- Achieved via
  - Information hiding
  - Depending on as few modules as possible

Law of Demeter

or Principle of Least Knowledge

- Basic idea: Assume as little as possible about other modules
- Approach: Restrict method calls to *friends*

Call your Friends

A method M of an object O should only call methods of

1. O itself
2. M's parameters
3. any objects created in M
4. O's direct component objects

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"single dot rule"

Demeter: Example

```
class Uni {
    Prof boring = new Prof();
    public Prof getProf() { return boring; }
    public Prof getNewProf() { return new Prof(); }

}

class Test {
    Uni uds = new Uni();
    public void one() { uds.getProf().fired(); }
    public void two() { uds.getNewProf().hired(); }
}
```

Demeter: Example

```
class Uni {
    Prof boring = new Prof();
    public Prof getProf() { return boring; }
    public Prof getNewProf() { return new Prof(); }
    public void fireProf(...) { ... }
}

class BetterTest {
    Uni uds = new Uni();
    public void betterOne() { uds.fireProf(...); }

}
```

Demeter effects

- Reduces coupling between modules
- Disallow direct access to parts
- Limit the number of accessible classes
- Reduce dependencies
- Results in several new wrapper methods ("Demeter transmogrifiers")

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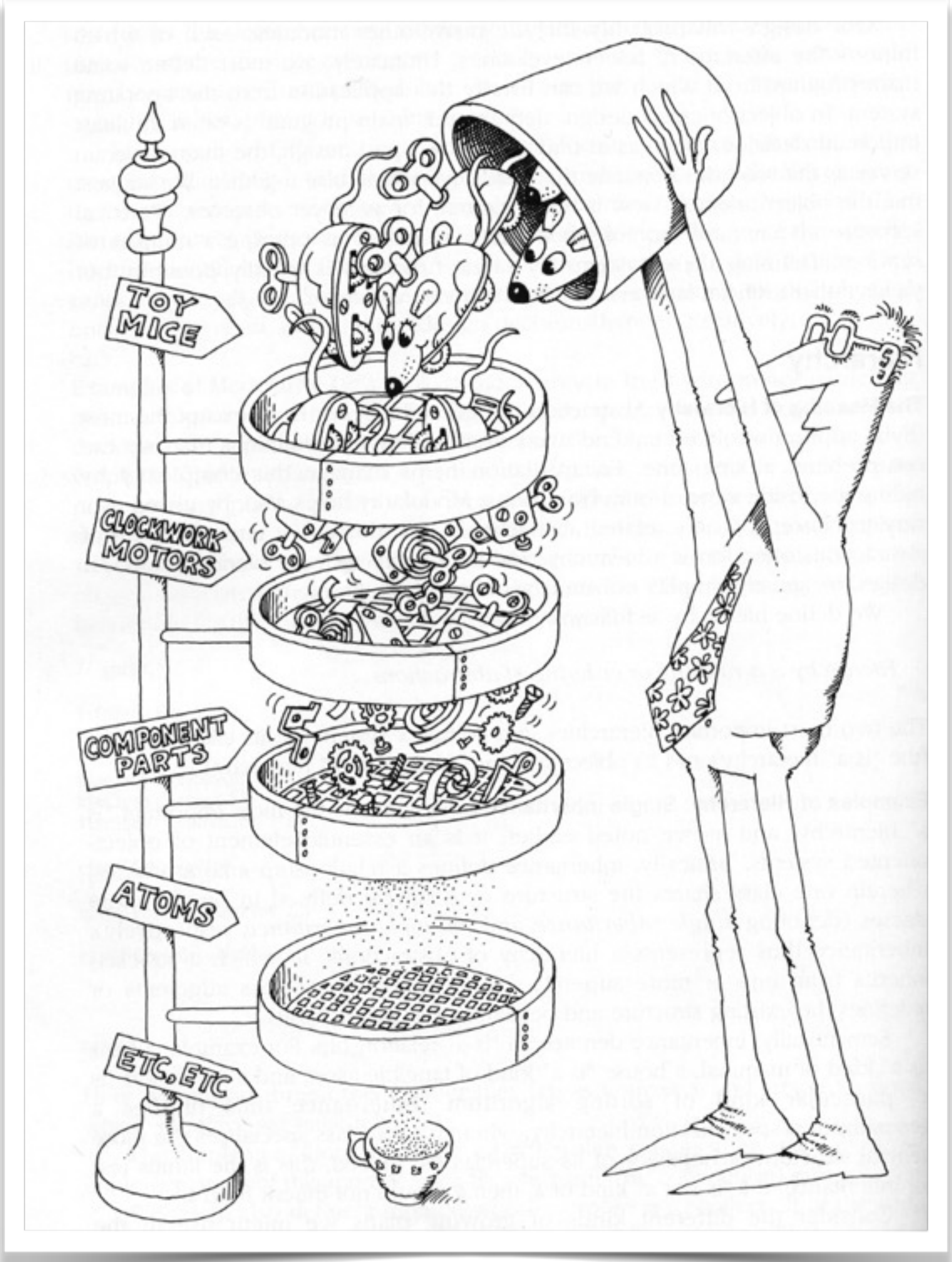
Hierarchy

“Hierarchy is a ranking or ordering of abstractions.”



Central Hierarchies

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- “has-a” hierarchy – *Aggregation* of abstractions
  - A *car* has three to four *wheels*

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- “has-a” hierarchy –
  Aggregation of abstractions
  - A *car* has three to four *wheels*
- “is-a” hierarchy –
  Generalization across abstractions
  - A *turning wheel* is a *wheel*
  - A *sport car* is a *car*

Hierarchy principles

- Open/Close principle – Classes should be open for extensions
- Liskov principle – Subclasses should not require more, and not deliver less
- Dependency principle – Classes should only depend on abstractions

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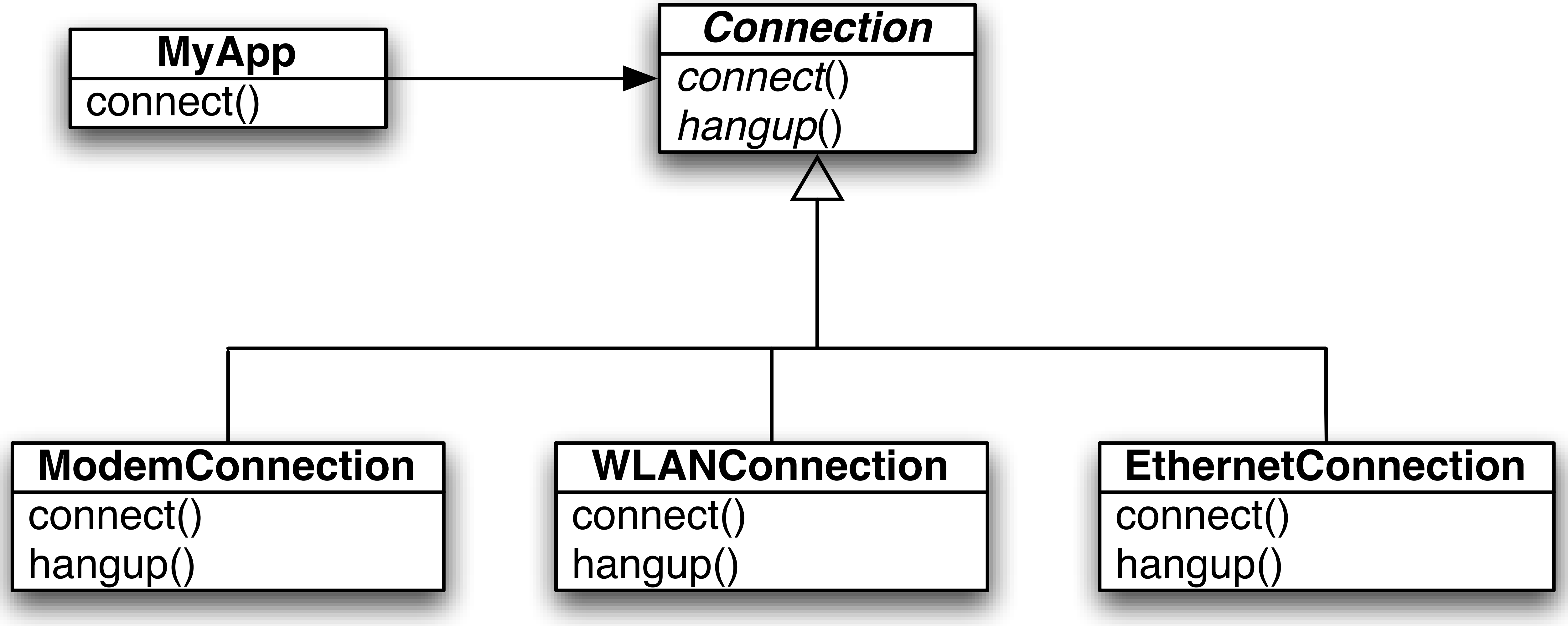
Open/Close principle

- A class should be *open* for extension, but *closed* for changes
- Achieved via *inheritance* and *dynamic binding*

An Internet Connection

```
void connect() {
    if (connection_type == MODEM_56K)
    {
          Modem modem = new Modem();
          modem.connect();
      }
      else if (connection_type == ETHERNET) …
      else if (connection_type == WLAN) …
      else if (connection_type == UMTS) …
}
```

Solution with Hierarchies



MyApp
connect()

Connection
connect()
hangup()

ModemConnection
connect()
hangup()

WLANConnection
connect()
hangup()

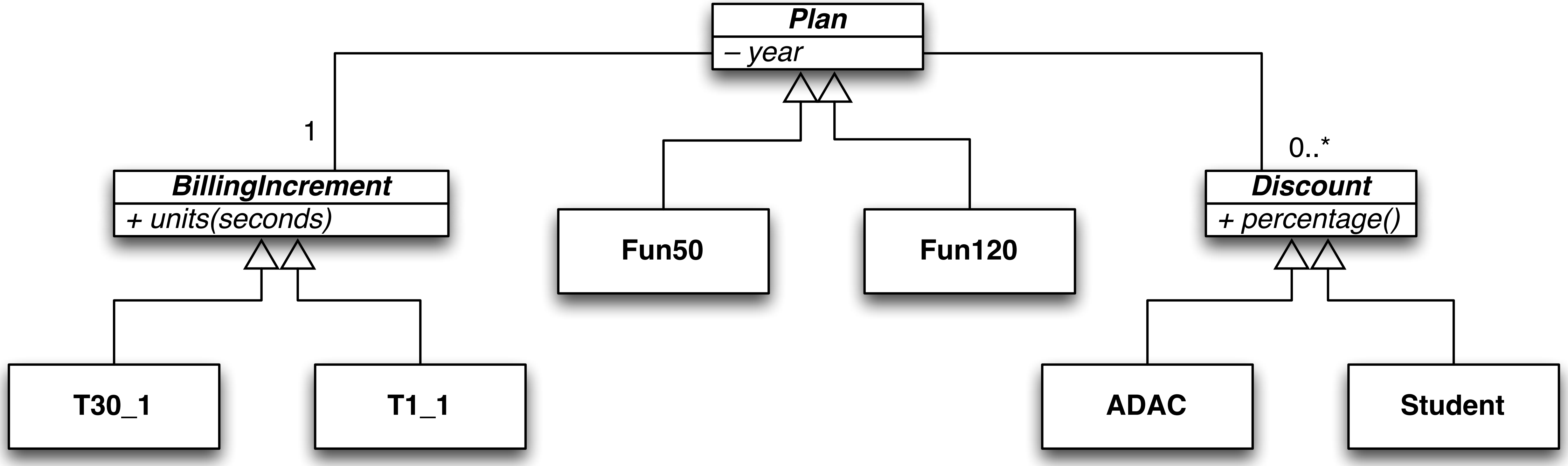
EthernetConnection
connect()
hangup()

```
enum { FUN50, FUN120, FUN240, ... } plan;
enum { STUDENT, ADAC, ADAC_AND_STUDENT ... } special;
enum { PRIVATE, BUSINESS, ... } customer_type;
enum { T60_1, T60_60, T30_1, ... } billing_increment;

int compute_bill(int seconds)
{
    if (customer_type == BUSINESS)
        billing_increment = T1_1;
    else if (plan == FUN50 || plan == FUN120)
        billing_increment = T60_1;
    else if (plan == FUN240 && contract_year < 2011)
        billing_increment = T30_1;
    else
        billing_increment = T60_60;

    if (contract_year >= 2011 && special != ADAC)
        billing_increment = T60_60;
    // etc.etc.
```

Hierarchy Solution



- You can add a new plan at any time!

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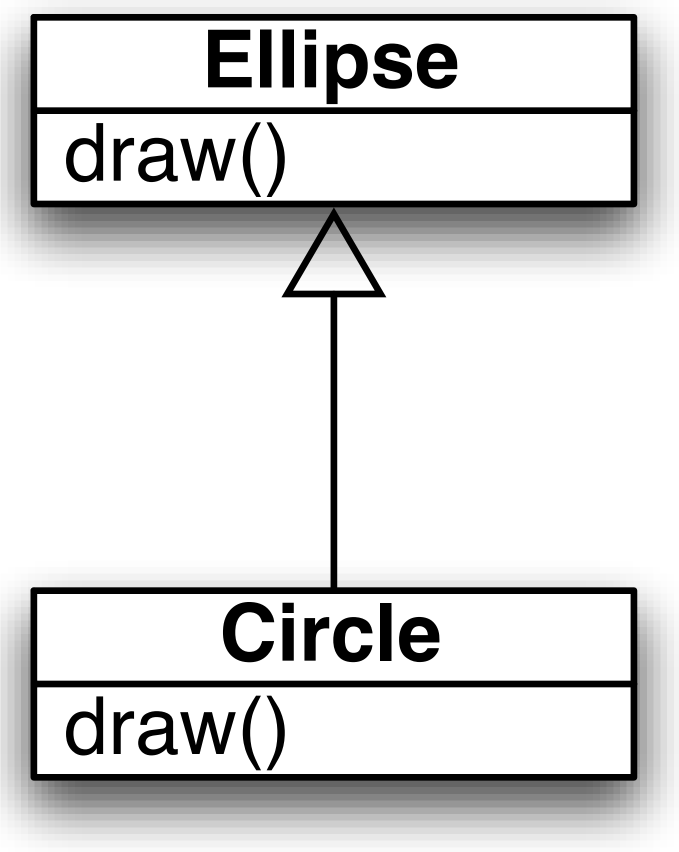
Liskov Substitution Principle

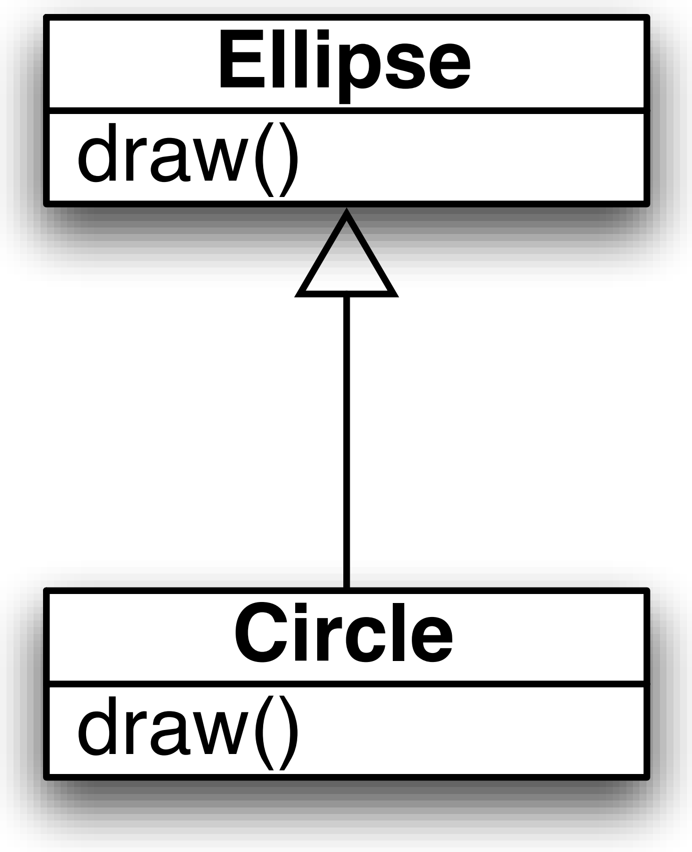
- An object of a superclass should always be substitutable by an object of a subclass:
  - Same or weaker preconditions
  - Same or stronger postconditions
- Derived methods should *not assume more or deliver less*

Circle vs Ellipse



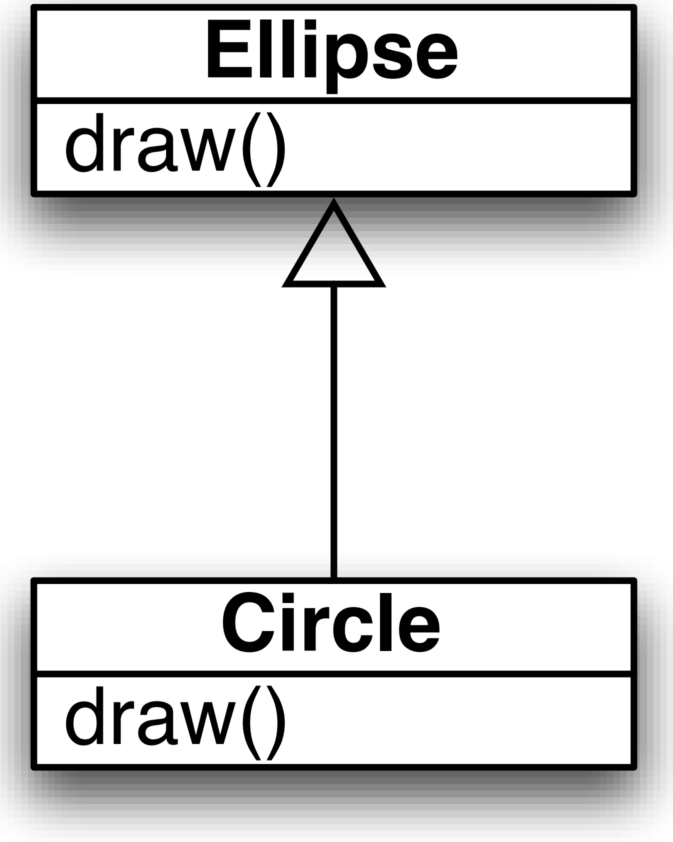
Circle vs Ellipse

- Every circle is an ellipse



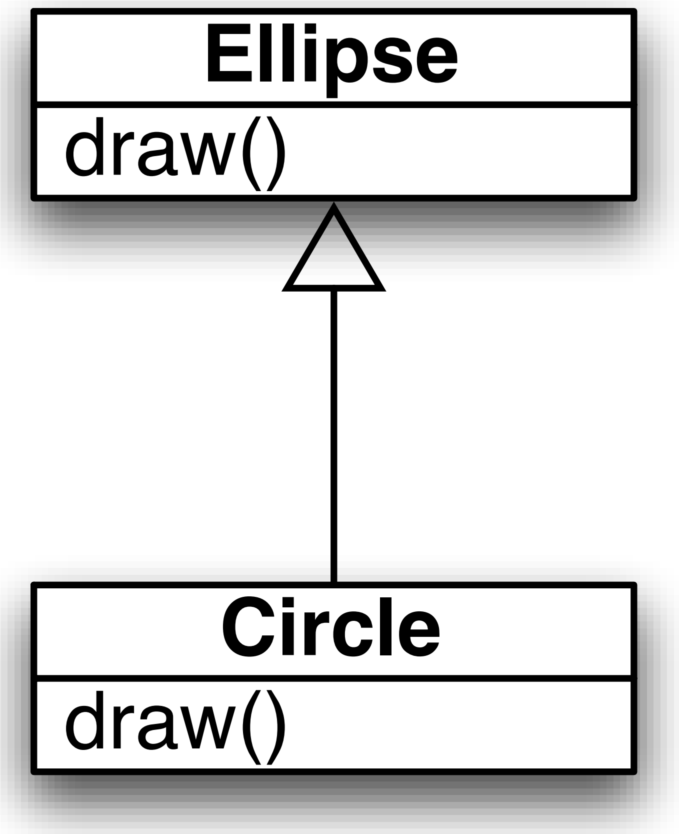
Circle vs Ellipse

- Every circle is an ellipse
- Does this hierarchy make sense?



Circle vs Ellipse

- Every circle is an ellipse
- Does this hierarchy make sense?
- No, as a circle *requires more* and *delivers less*



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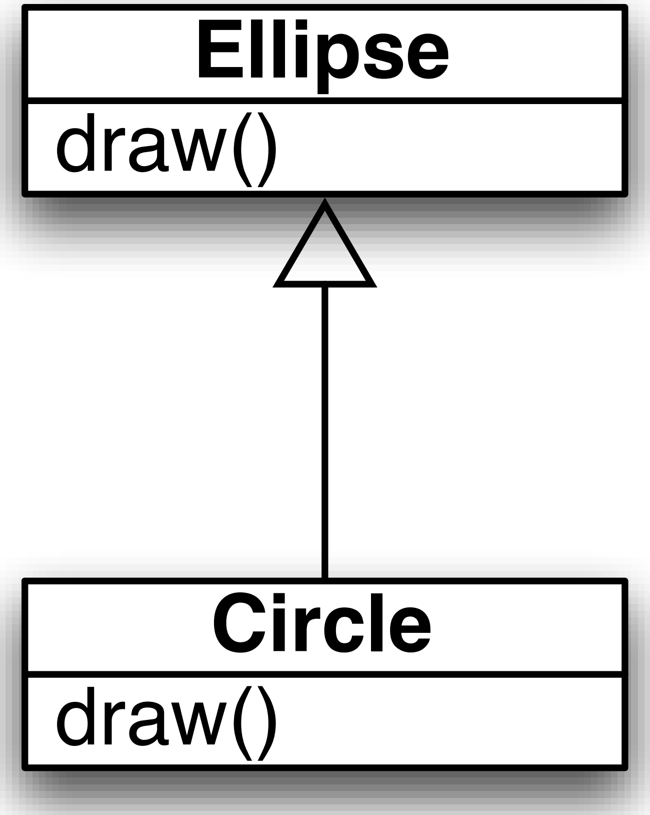

"In geometry a circle is a ellipse. In software, maybe not"

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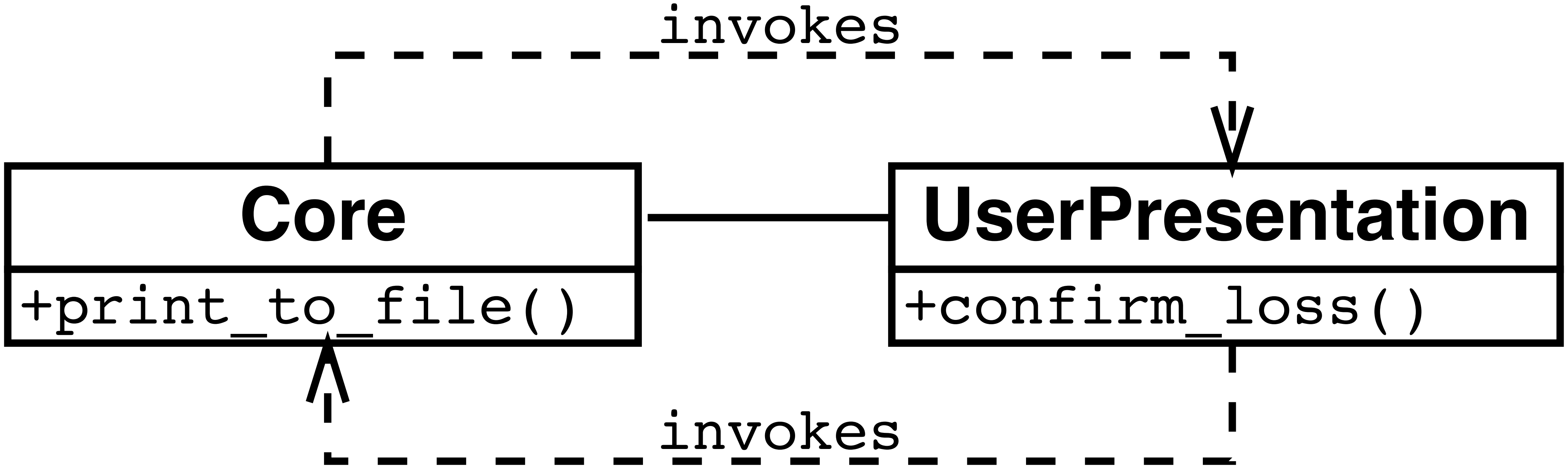
Dependency principle

- A class should only depend on *abstractions* – never on concrete subclasses *(dependency inversion principle)*
- This principle can be used to *break* dependencies

Dependency

```
// Print current Web page to FILENAME.
void print_to_file(string filename)
{
    if (path_exists(filename))
    {
        // FILENAME exists;
        // ask user to confirm overwrite
        bool confirmed = confirm_loss(filename);
        if (!confirmed)
            return;
    }

    // Proceed printing to FILENAME
    ...
}
```

Cyclic Dependency

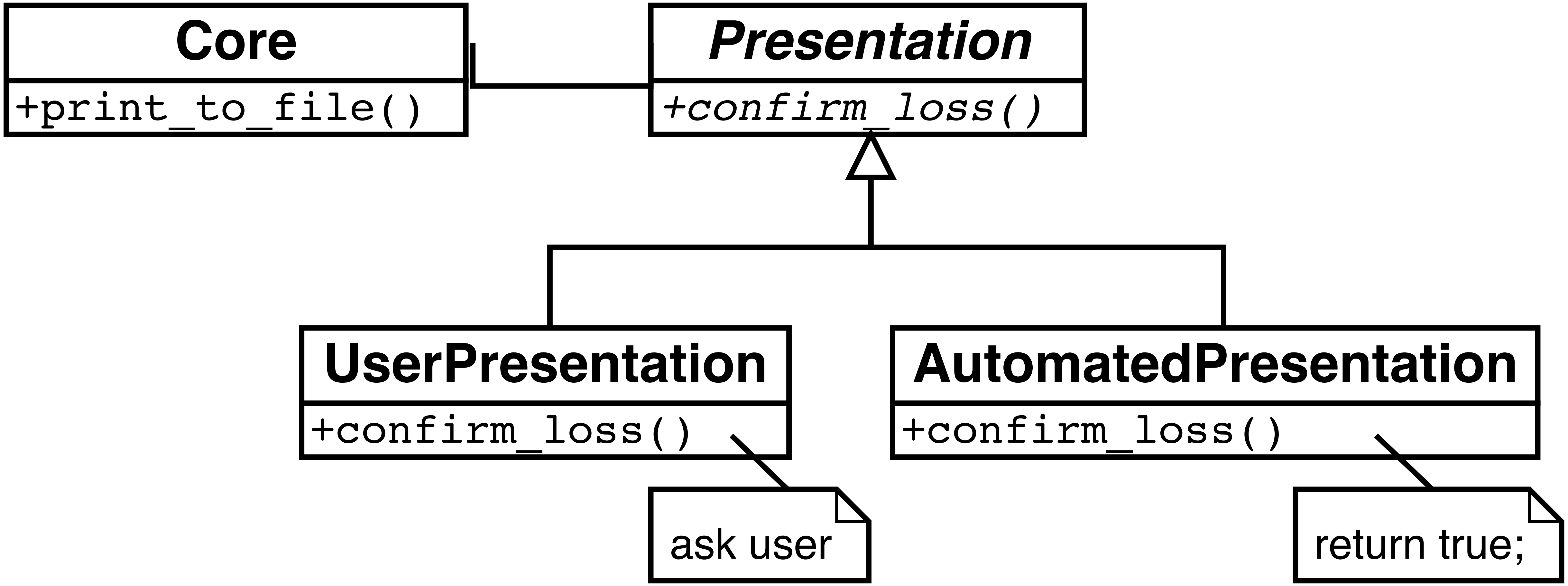


Constructing, testing, reusing *individual* modules becomes impossible!

Dependency

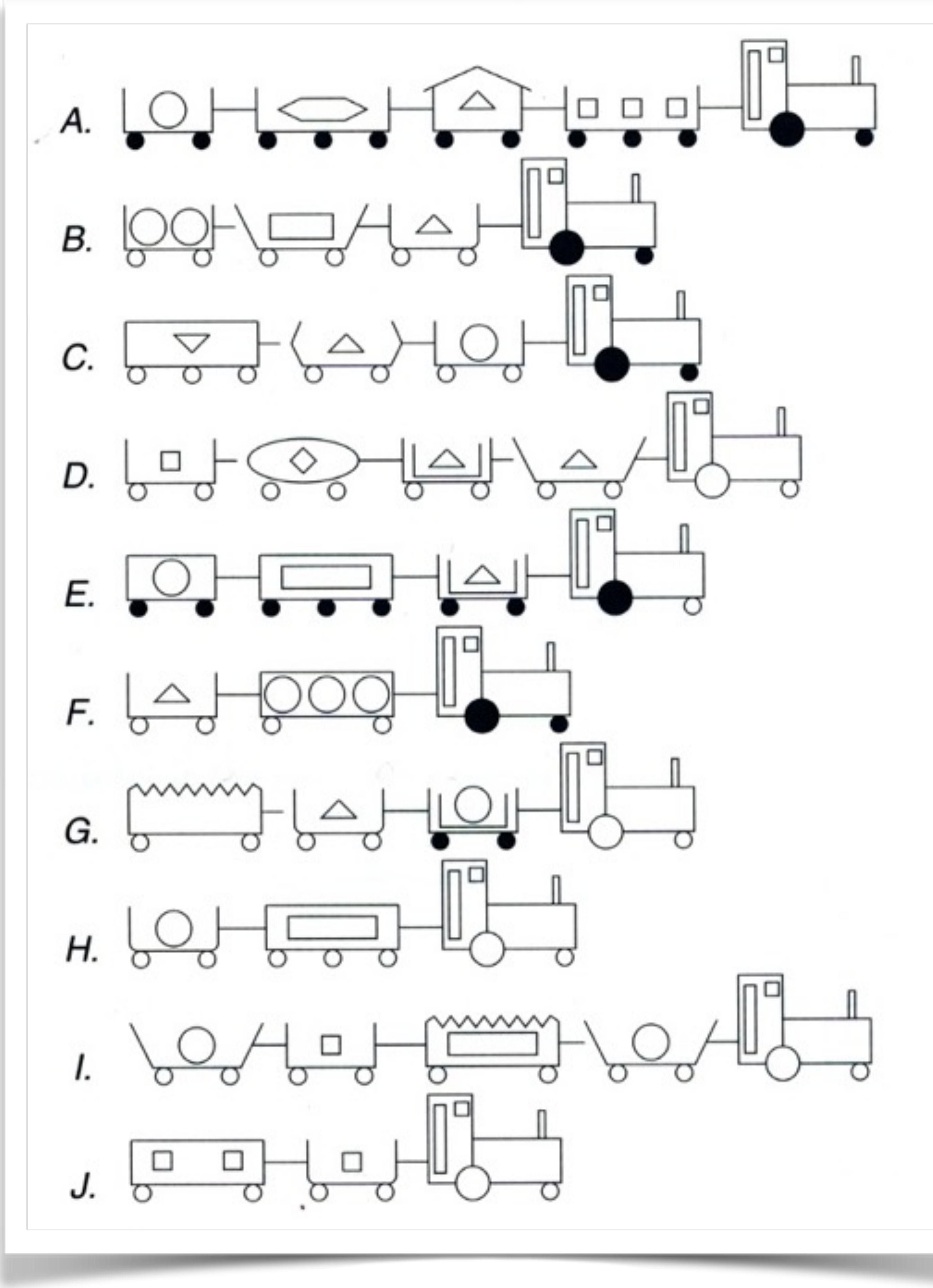
```
// Print current Web page to FILENAME.
void print_to_file(string filename, Presentation *p)
{
    if (path_exists(filename))
    {
        // FILENAME exists;
        // ask user to confirm overwrite
        bool confirmed = p->confirm_loss(filename);
        if (!confirmed)
            return;
    }

    // Proceed printing to FILENAME
    ...
}
```

Depending on Abstraction



Choosing Abstraction

- Which is the "dominant" abstraction?
- How does this choice impact the remaining system?



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