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Basics of Qt

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- Widgets, Layouts and Styles
- Meta-Objects and Memory Management

Signals and Slots

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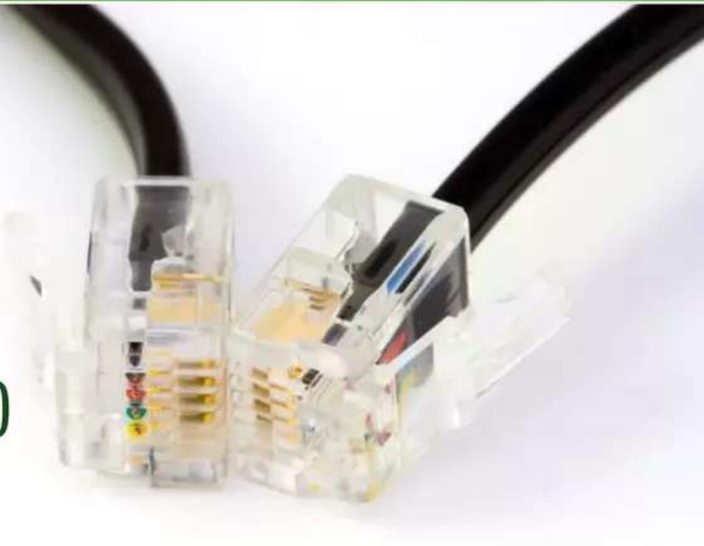
Callbacks?

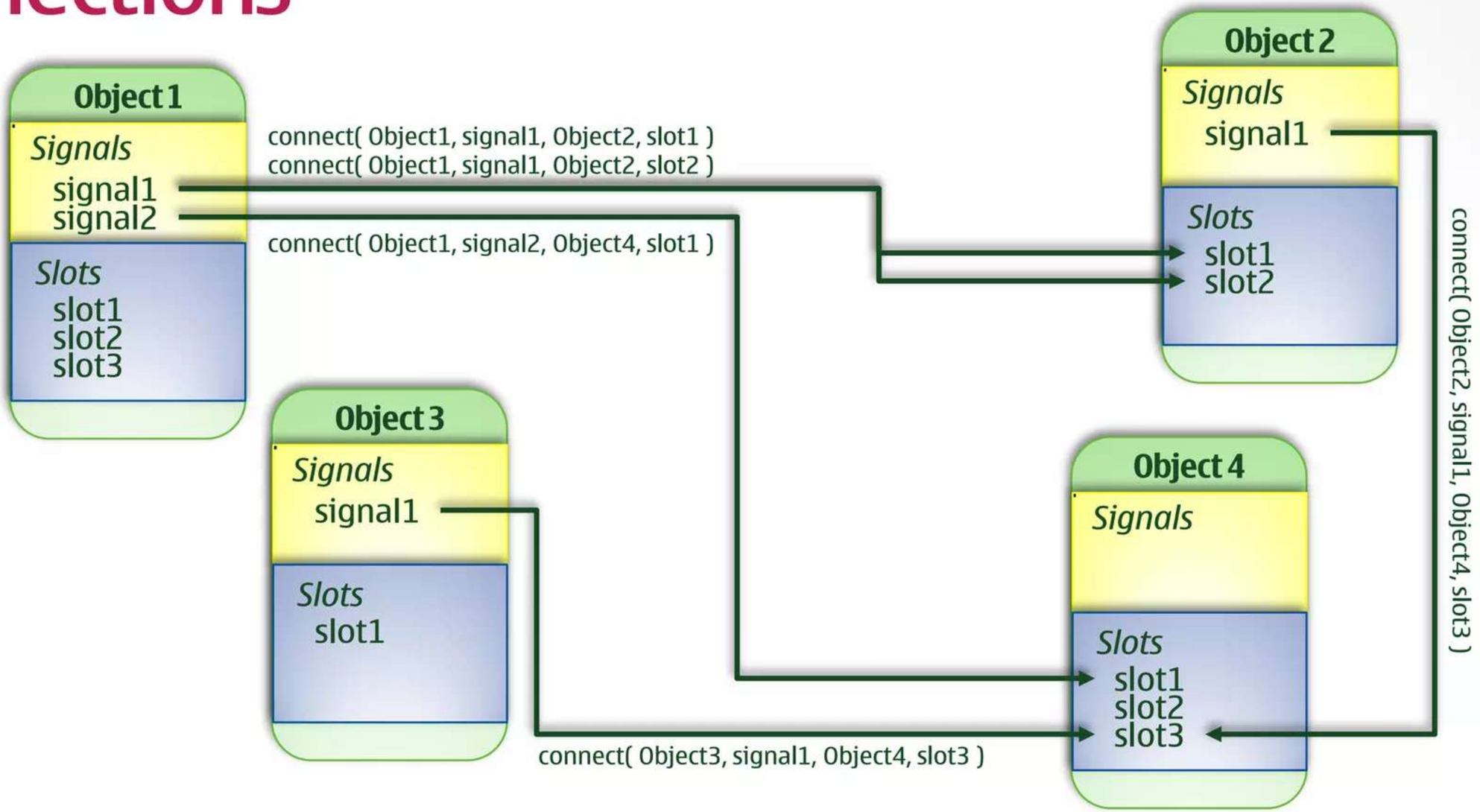
- **Traditional callbacks**
  - Callback is pointer to a function
  - Called when appropriate (event notification, ...)
- **Problems**
  - **Not type-safe:** does the caller use the correct arguments?
  - **Less generic:** callback strongly coupled to processing function. Processing function must know which callback to call.

Signals & Slots



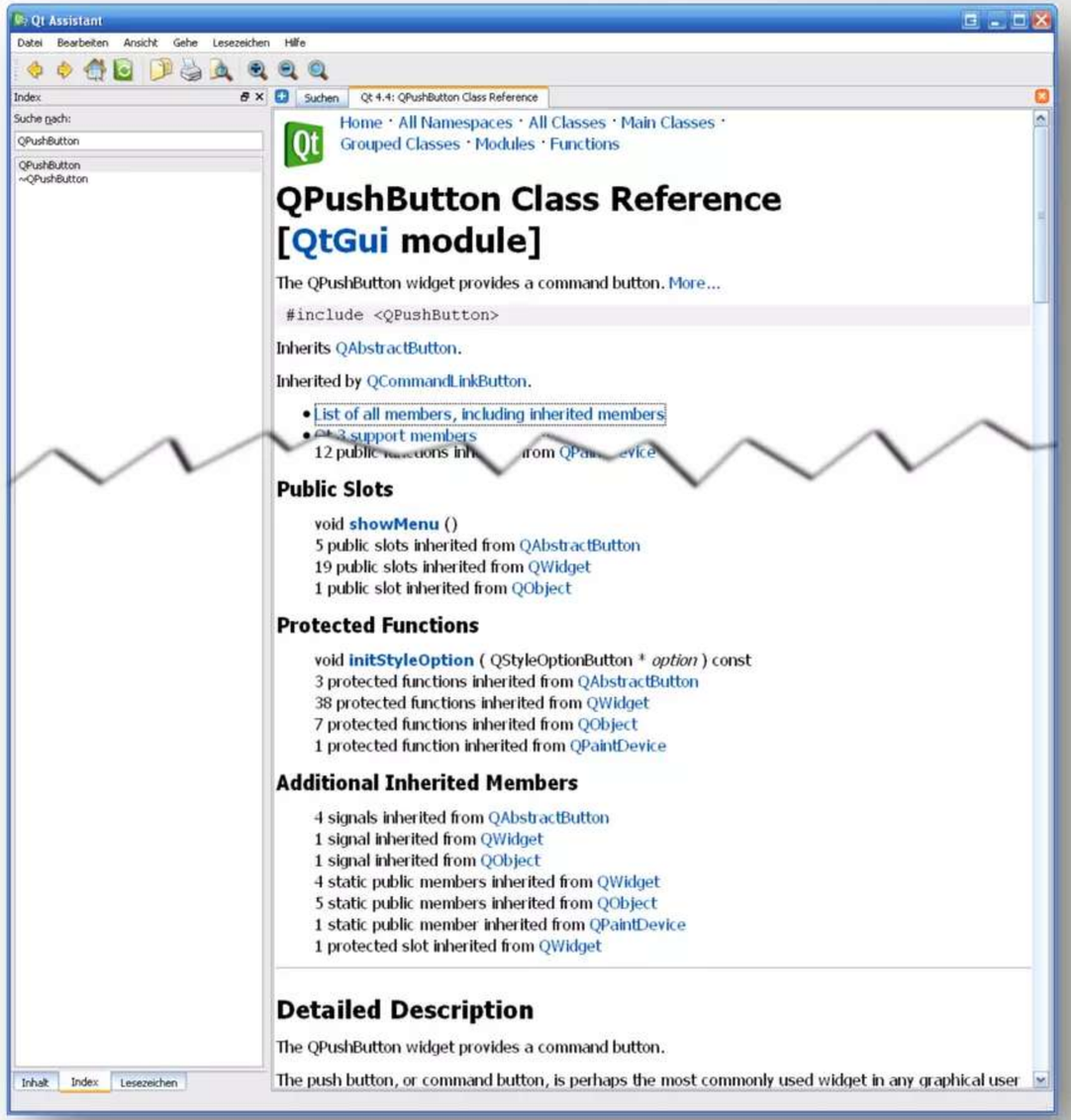
- **Signal**
  - **Emitted when a particular event occurs** (e.g., clicked())
  - Qt widgets: predefined signals
  - Also create your own signals
- **Slot**
  - **Function called in response to a signal**
  - Qt widgets: predefined slots (e.g., quit())
  - Also create your own slots
- **Connection signals ↔ slots established by developer, handled by Qt framework**

Connections

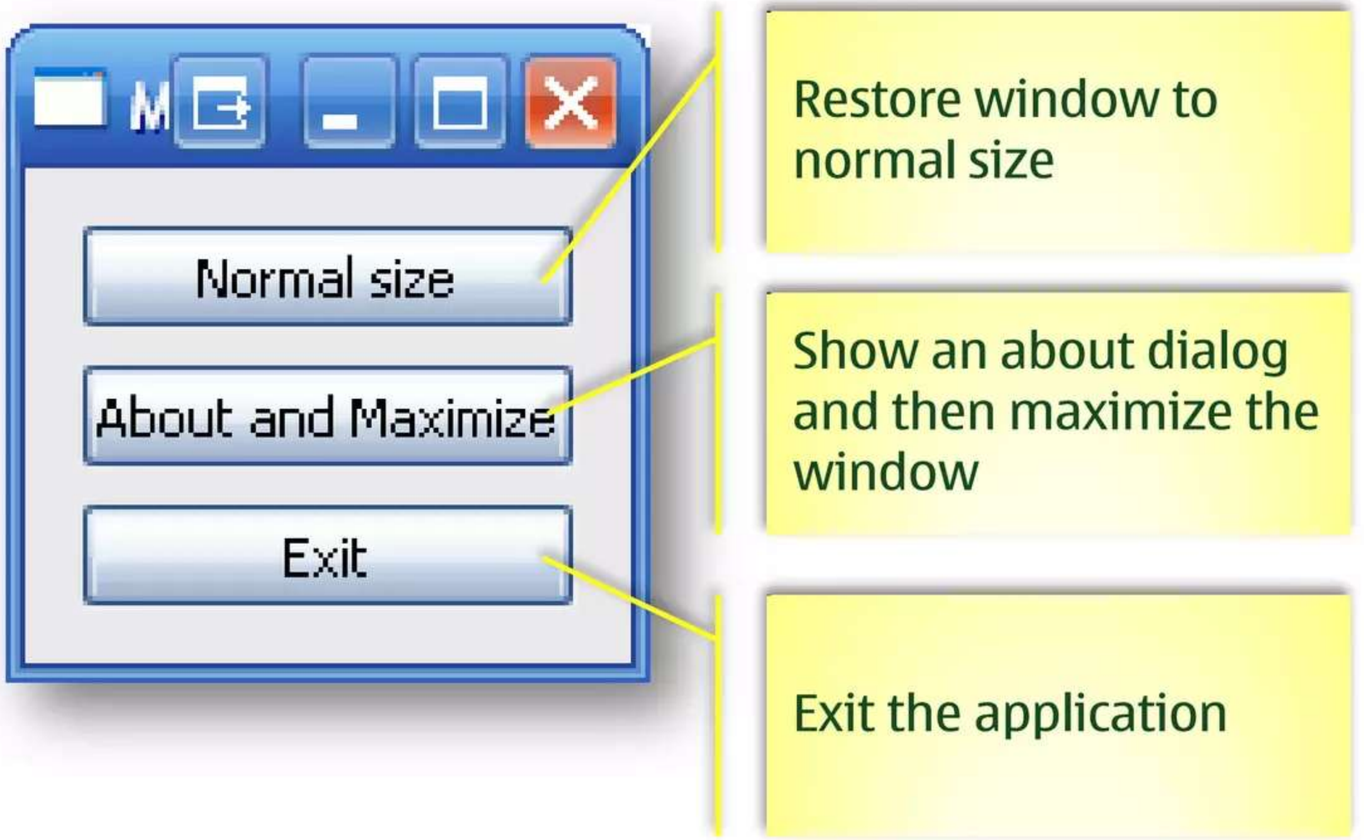


Find Signals and Slots

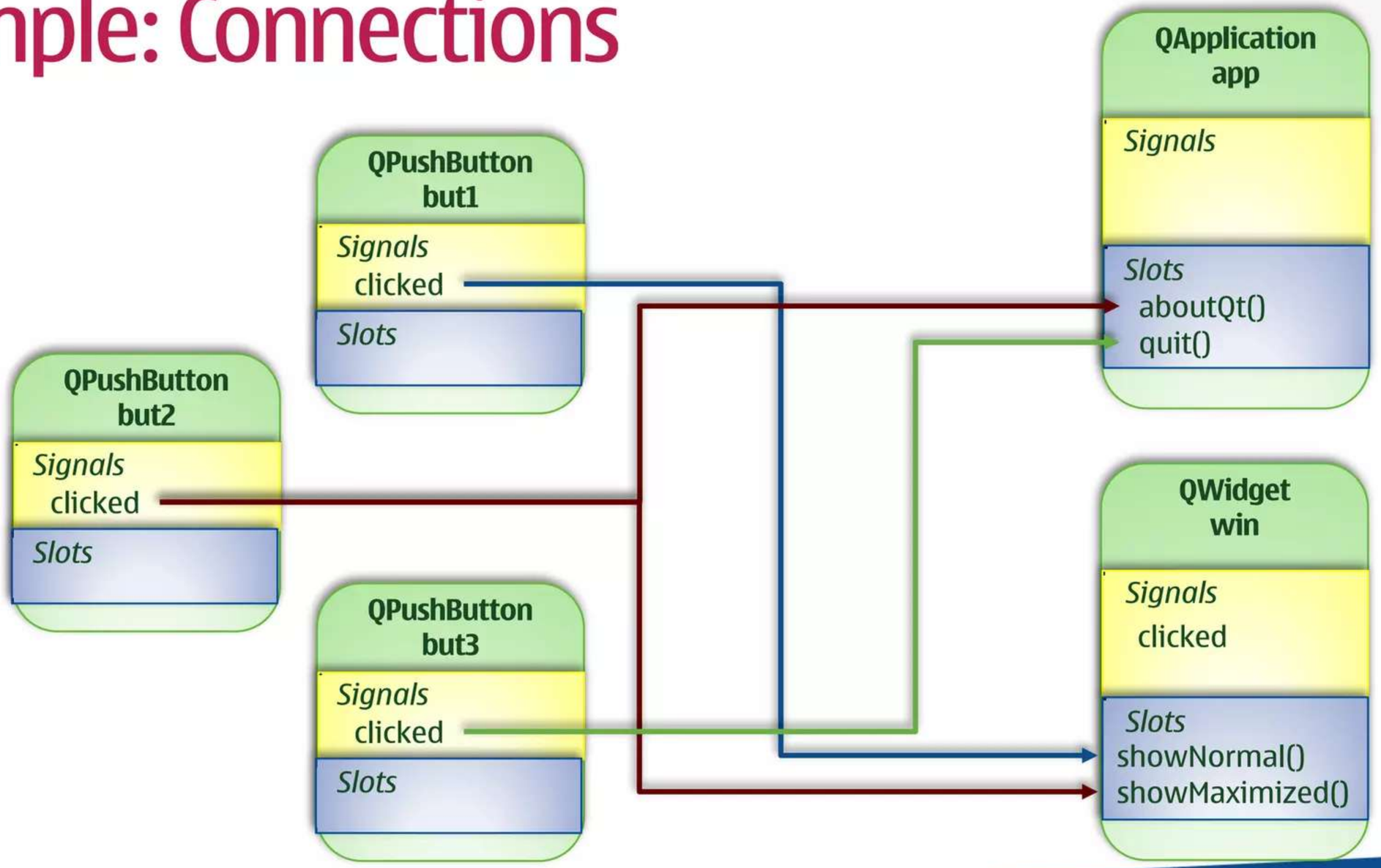
- Look up signals and slots of Qt classes in the documentation



Example: Multiple Signal-Slot Connections



Example: Connections



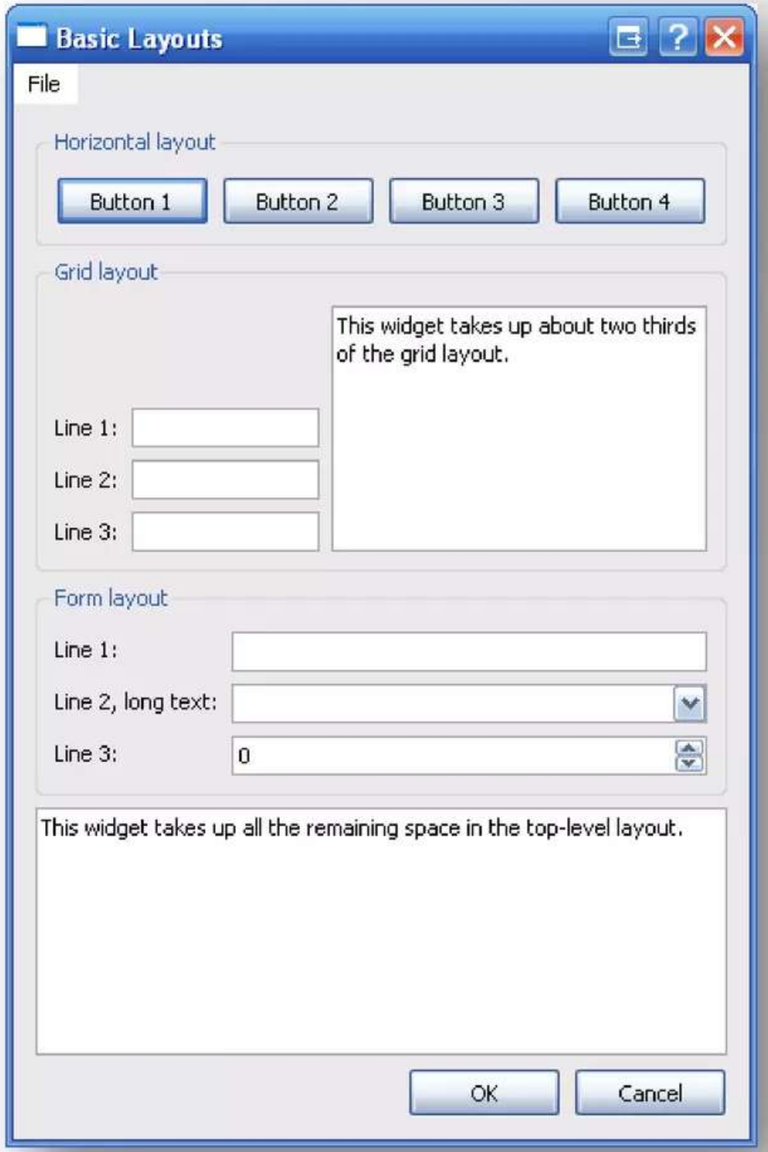
```
#include <QApplication>
#include <QPushButton>
#include <QVBoxLayout>

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);
    QWidget* win = new QWidget();
    QVBoxLayout* layout = new QVBoxLayout(win);

    QPushButton* but1 = new QPushButton("Normal size");
    but1->resize(150, 30);
    layout->addWidget(but1);

    QPushButton* but2 = new QPushButton("About and Maximize");
    but2->resize(150, 30);
    layout->addWidget(but2);

    QPushButton* but3 = new QPushButton("Exit");
    but3->resize(150, 30);
    layout->addWidget(but3);

    QObject::connect(but1, SIGNAL(clicked()), win, SLOT(showNormal()));
    QObject::connect(but2, SIGNAL(clicked()), &app, SLOT(aboutQt()));
    QObject::connect(but2, SIGNAL(clicked()), win, SLOT(showMaximized()));
    QObject::connect(but3, SIGNAL(clicked()), &app, SLOT(quit()));

    win->show();

    return app.exec();
}
```

aboutQt() and showMaximized() executed one after another

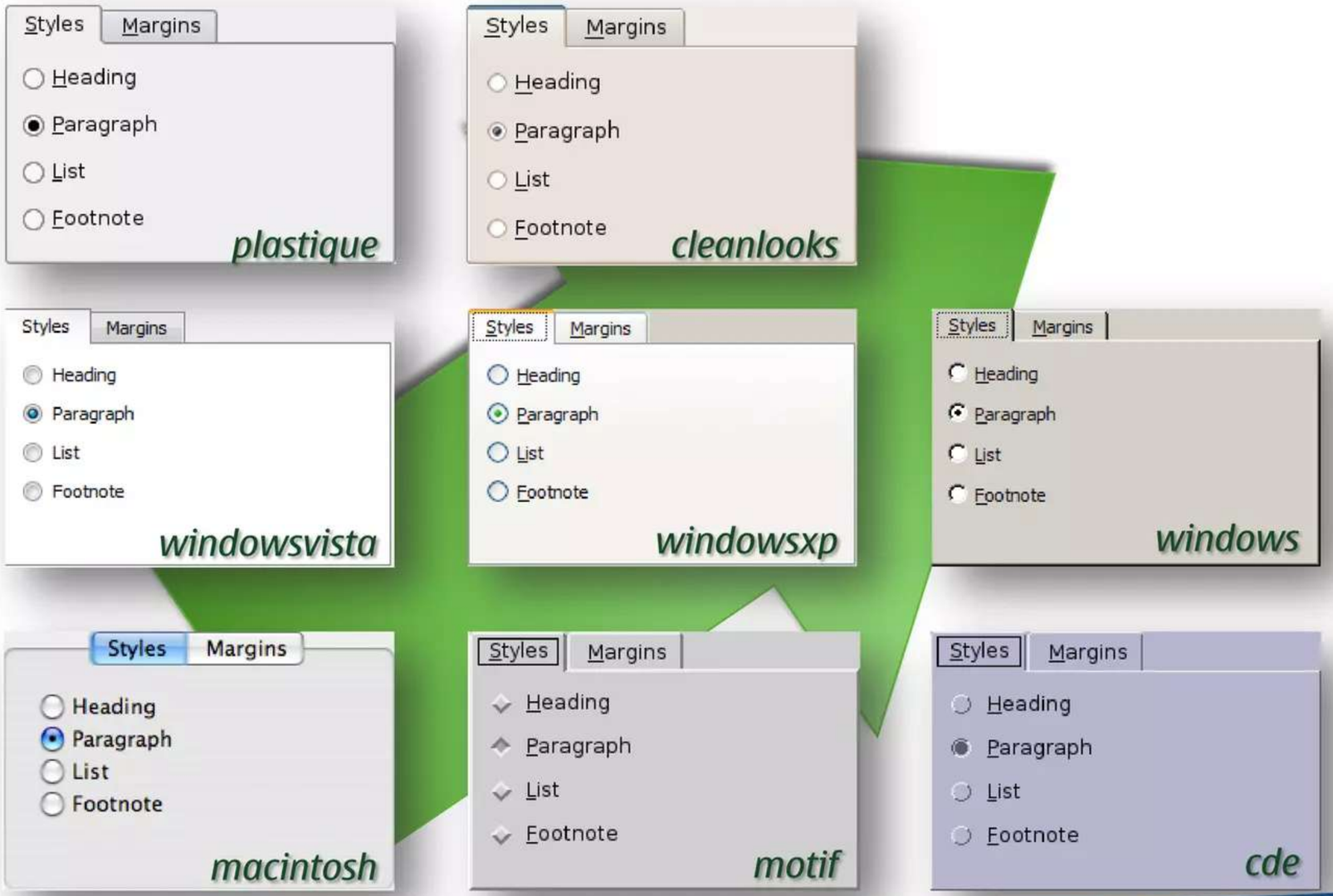
Layouts

- **Most common layouts**
  - **QHBoxLayout:** horizontal, from left to right (right to left for some cultures)
  - **QVBoxLayout:** vertical, top to bottom
  - **QGridLayout:** grid
  - **QFormLayout:** manages input widgets and associated labels
  - **QStackedLayout:** widgets on top of each other, switch index of currently visible widget
- **Layouts can be nested**
  - Add new layout to existing layout like a widget:

```
l->addLayout(l2)
```



Styles



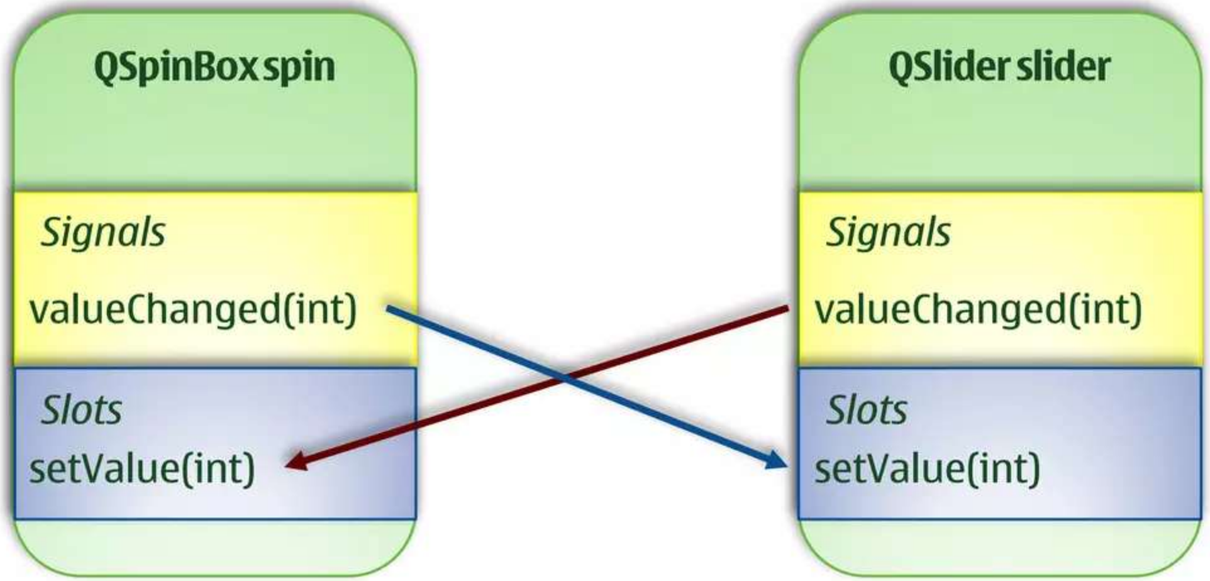
Style can be set using `-style <name>` command-line option.

Windows XP/Vista/7 and Macintosh styles are only available on native platforms (relies on platform's theme engines)

It's possible to create own styles.

Example 2

- **Synchronize two widgets**
  - Changing the value in one automatically changes the other



```
#include <QApplication>
#include <QHBoxLayout>
#include <QSpinBox>
#include <QSlider>

int main(int argc, char *argv[])  {
   QApplication app(argc, argv);
   QWidget* win = new QWidget();
   win->setWindowTitle("Synchronized Widgets");

   QHBoxLayout* layout = new QHBoxLayout(win);

   QSpinBox* spin = new QSpinBox();
   spin->setMinimum(0);
   spin->setMaximum(100);
   layout->addWidget(spin);

   QSlider* slider = new QSlider(Qt::Horizontal);
   slider->setMinimum(0);
   slider->setMaximum(100);
   layout->addWidget(slider);

   QObject::connect( spin, SIGNAL( valueChanged(int) ),
                     slider, SLOT( setValue(int) ) );
   QObject::connect( slider, SIGNAL( valueChanged(int) ),
                     spin, SLOT( setValue(int) ) );

   spin->setValue(50);

   win->show();
   return app.exec();
}
```

Signal Parameters

Transmit additional information

```
QObject::connect( spin, SIGNAL( valueChanged(int) ),
                        slider, SLOT( setValue(int) ) );
```

- Specify type of argument(s)
- Signal has to be compatible to the slot (same parameter type(s))

Signal Parameters

- **Types not automatically casted by Qt**
  - Signals & slots with exactly the specified parameters have to exist
  - **Otherwise:** no compilation error / warning
  - **But:** warning at runtime when executing connect():

```
QObject::connect: Incompatible sender/receiver arguments
QSpinBox::valueChanged(QString) --> QSlider::setValue(int)
```

- **→ Signals & slots are type safe**
  - No connection if either sender or receiver doesn't exist
  - Or if signatures of signal and slot do not match
- **connect() returns boolean value indicating success**

Signal & Slot Processing

setValue(50) is called in the source code

QSpinBox emits valueChanged(int) signal with int argument of 50

signal → slot

Argument is passed to QSlider's setValue(int) slot, sets slider value to 50

QSlider emits valueChanged(int) signal with int argument of 50

signal → slot

Argument is passed to QSpinbox's setValue(int) slot, but value is already set to 50.
→ doesn't emit any further signal to prevent infinite recursion.

Signals & Slots

- **Type safe**
  - Signal signature must match signature of receiving slot
  - (Slot might also have shorter signature and ignore rest of the arguments)
- **Loosely coupled**
  - Emitter doesn't know or care which slots receive signal
  - Information encapsulation
- **Integrated, independent components**
  - Slots are normal C++ member functions
  - Don't know if signals are connected to them

Manual Signal & Slots

counter.h

```
#ifndef COUNTER_H
#define COUNTER_H

#include <QObject>

class Counter : public QObject
{
    Q_OBJECT

public:
    Counter() { m_value = 0; }
    int value() const { return m_value; }

public slots:
    void setValue(int value);

signals:
    void valueChanged(int newValue);

private:
    int m_value;
};

#endif // COUNTER_H
```

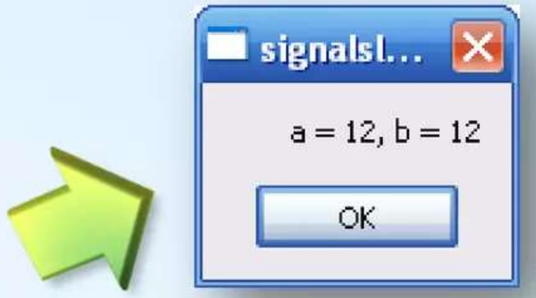
counter.cpp

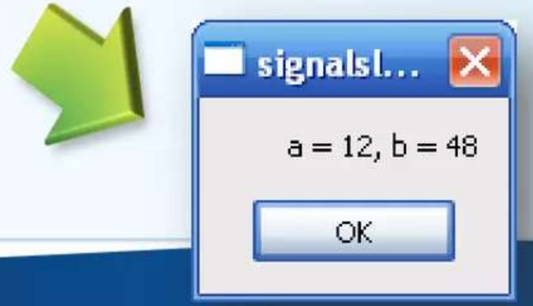
```
#include "counter.h"

void Counter::setValue(int value)
{
    if (value != m_value)
    {
        m_value = value;
        emit valueChanged(value);
    }
}
```

Own Class that represents behaviour of Example 2

main.cpp

```
#include <QtGui/QApplication>
#include <QMessageBox>
#include "counter.h"

int main(int argc, char *argv[])
{
    QApplication app(argc, argv);

    Counter a, b;
    QObject::connect(&a, SIGNAL(valueChanged(int)),
                     &b, SLOT(setValue(int)));

    a.setValue(12);     // a.value() == 12, b.value() == 12

    QMessageBox msgBox;
    msgBox.setText("a = " + QString::number(a.value()) + ", b = " + QString::number(b.value()));
    msgBox.exec();

    b.setValue(48);     // a.value() == 12, b.value() == 48

    msgBox.setText("a = " + QString::number(a.value()) + ", b = " + QString::number(b.value()));
    msgBox.exec();

    app.quit();
    return 1;
}
```





Meta Objects

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Qt Meta-Object System

- **C++ extended** with meta-object mechanism: **Introspection**
  - Obtain **meta-information about QObject subclasses** at runtime
  - **Used for:** getting list of signals & slots, properties and text translation

QObject

- **Meta information** not supported by standard C++
  - QObject class
    - Base class for objects that use meta-object system
  - Q_OBJECT macro
    - Enables meta-object features
    - Without ;
  - “moc” tool
    - Parses Q_OBJECT macro
    - Extends source code with additional functions (extra files)
    - Removes the signals, slots and emit keywords so compiler sees standard C++
- **Advantage:** works with any C++ compiler

```
#include <QObject>
class Counter : public QObject
{
    Q_OBJECT
[...]
};
```

Meta-Object Features

- **Features provided by meta-object code:**
  - **Signals and slots**
  - **metaObject()** – returns associated meta-object for the class
  - **QMetaObject::className()** – returns class name as a string, without requiring native run-time type information (RTTI) support through the C++ compiler
  - **inherits()** – returns whether this instance inherits the specified QObject class
  - **tr()** – translate strings
  - **setProperty()** and **property()** – dynamically set and get properties by name

Casting

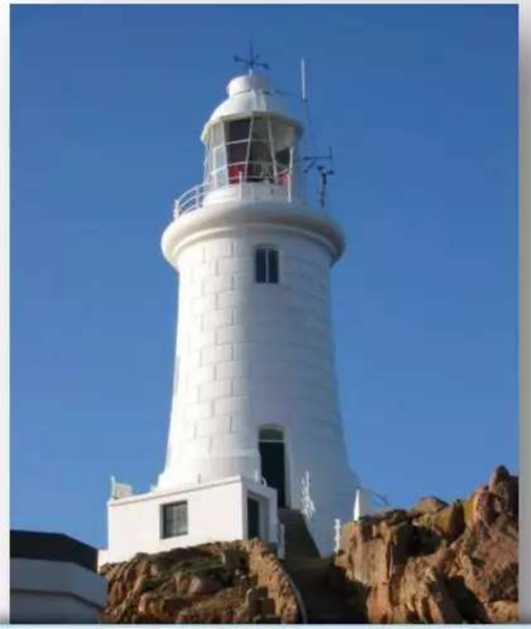
- **Meta-object information can be used for casting:**

```
if (widget->inherits("QAbstractButton")) {
    QAbstractButton *button = static_cast<QAbstractButton*>(widget);
    button->toggle();
}
```

- **Similar, but less error-prone:**

```
if (QAbstractButton *button = qobject_cast<QAbstractButton*>(widget))
    button->toggle();
```

More on... Signals



- **Emitted signal**
  - Slot usually **executed immediately** (like normal function call)
  - Code after emit keyword executed after all slots returned
  - **Queued connections:** slots executed later
- **1 signal → n slots**
  - Slots executed **one after another** (arbitrary order)
- **Implementation**
  - **Automatically generated** by moc
  - **Define in .h, do not implement** in .cpp file
  - Can never have return values (→ use void)
  - **Good style:** arguments should not use special types (reusability)

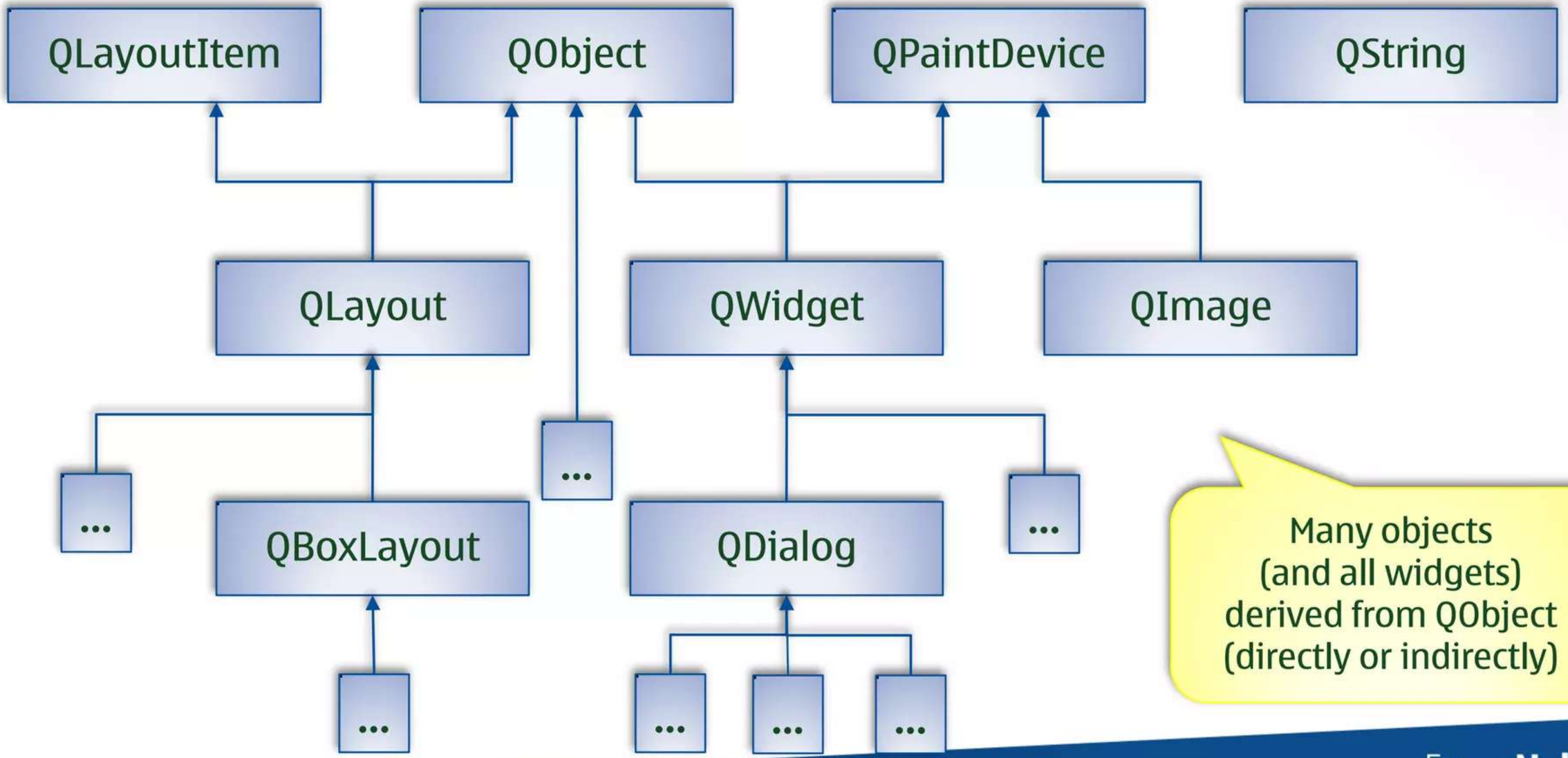
```
#include <QObject>
class Counter : public QObject {
    Q_OBJECT
    [...]
signals:
    void valueChanged(int newValue);
    [...]
};
```

More on... Slots

- **C++ function**
  - Can be called directly/normally
  - If connected to and invoked by signal: works regardless of access level. Arbitrary class can invoke private slot of an unrelated class instance.
  - Slots can be virtual, but not static
- **Overhead compared to direct call**
  - **Does not matter in practice**
  - Around 10x slower than direct, non-virtual call
  - Sounds a lot, but isn't compared to for example new/delete operations
  - i586-500: emit per second
    2,000,000 signals → 1 slot.
    1,200,000 signals → 2 slots.

```
#include <QObject>
class Counter : public QObject {
    Q_OBJECT
    [...]
public slots:
    void setValue(int value);
    [...]
};
```

Qt Class Hierarchy



Memory Management

- **Parent-child hierarchy implemented in QObject**
  - **Initialization with pointer to parent QObject →** parent adds new object to list of its children
  - **Delete parent:** automatically deletes all its children (recursively)
  - **Delete child:** automatically removed from parent's child list
  - → Some memory management handled by Qt, only **delete objects created with new without parent**
- **Widgets**
  - **Parent has additional meaning:** child widgets shown within parent's area

Example: Parent-Child


```
QWidget* win = new QWidget();
QVBoxLayout* layout = new QVBoxLayout(win);
QPushButton* but = new QPushButton("Label");
layout->addWidget(but);
win->show();
```

- Layout is a child of parent widget
- Push button added to layout, but widget takes ownership

```
QWidget* win = new QWidget();
QVBoxLayout* layout = new QVBoxLayout(win);
QPushButton* but = new QPushButton("Label", win);
win->show();
```

- **Directly adding push button to the parent widget:**
  - Also displays push button, but not managed by layout manager

Example: Parent-Child II

- **Helpful:** print parent-child relationship

```
QWidget* win = new QWidget();
QVBoxLayout* layout = new QVBoxLayout(win);
QPushButton* but = new QPushButton("Label");
layout->addWidget(but);
win->dumpObjectTree();
```

Console

```
QWidget::
    QVBoxLayout::
    QPushButton::
```

Creating Objects

- **Objects inheriting from `QObject` are allocated on the heap using `new`**
  - If a parent object is assigned, it takes ownership of the newly created object – and eventually calls delete

```
QLabel *label = new QLabel("Some Text", parent);
```

- **Objects not inheriting `QObject` are allocated on the stack, not the heap**

```
QStringList list;
QColor color;
```

- **Exceptions**
  - `QFile` and `QApplication` (inheriting `QObject`) are usually allocated on the stack
  - Modal dialogs are often allocated on the stack, too

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Thank You.