Here we visualize filters and outputs using the network architecture proposed by Krizhevsky et al. for ImageNet and implemented in `caffe`.

(This page follows DeCAF visualizations originally by Yangqing Jia.)

First, import required modules and set plotting parameters

In [1]:

```
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline

# Make sure that caffe is on the python path:
caffe_root = '../'  # this file is expected to be in {caffe_root}/exa
mples
import sys
sys.path.insert(0, caffe_root + 'python')

import caffe
import caffe.imagenet

plt.rcParams['figure.figsize'] = (10, 10)
plt.rcParams['image.interpolation'] = 'nearest'
plt.rcParams['image.cmap'] = 'gray'
```

Follow instructions (http://caffe.berkeleyvision.org/getting_pretrained_models.html) for getting the pretrained models, load the net and specify test phase and CPU mode.

In [2]:

```
net = caffe.imagenet.ImageNetClassifier(caffe_root + 'examples/imagen
et/imagenet_deploy.prototxt',
                                        caffe_root + 'examples/imagen
et/caffe_reference_imagenet_model')
net.caffenet.set_phase_test()
net.caffenet.set_mode_cpu()
```

Run a classification pass

In [3]:

```
scores = net.predict(caffe_root + 'examples/images/lena.png')
```

The layer features and their shapes (10 is the batch size, corresponding to the the ten subcrops used by Krizhevsky et al.)

In [4]:

```
[(k, v.data.shape) for k, v in net.caffenet.blobs.items()]
```

Out[4]:

```
[('data', (10, 3, 227, 227)),
 ('conv1', (10, 96, 55, 55)),
 ('pool1', (10, 96, 27, 27)),
 ('norm1', (10, 96, 27, 27)),
 ('conv2', (10, 256, 27, 27)),
 ('pool2', (10, 256, 13, 13)),
 ('norm2', (10, 256, 13, 13)),
```

```
 ('conv3', (10, 384, 13, 13)),
 ('conv4', (10, 384, 13, 13)),
 ('conv5', (10, 256, 13, 13)),
 ('pool5', (10, 256, 6, 6)),
 ('fc6', (10, 4096, 1, 1)),
 ('fc7', (10, 4096, 1, 1)),
 ('fc8', (10, 1000, 1, 1)),
 ('prob', (10, 1000, 1, 1))]
```

The parameters and their shapes (each of these layers also has biases which are omitted here)

In [5]:

```
[(k, v[0].data.shape) for k, v in net.caffenet.params.items()]
```

Out[5]:

```
[('conv1', (96, 3, 11, 11)),
 ('conv2', (256, 48, 5, 5)),
 ('conv3', (384, 256, 3, 3)),
 ('conv4', (384, 192, 3, 3)),
 ('conv5', (256, 192, 3, 3)),
 ('fc6', (1, 1, 4096, 9216)),
 ('fc7', (1, 1, 4096, 4096)),
 ('fc8', (1, 1, 1000, 4096))]
```

Helper functions for visualization

In [6]:

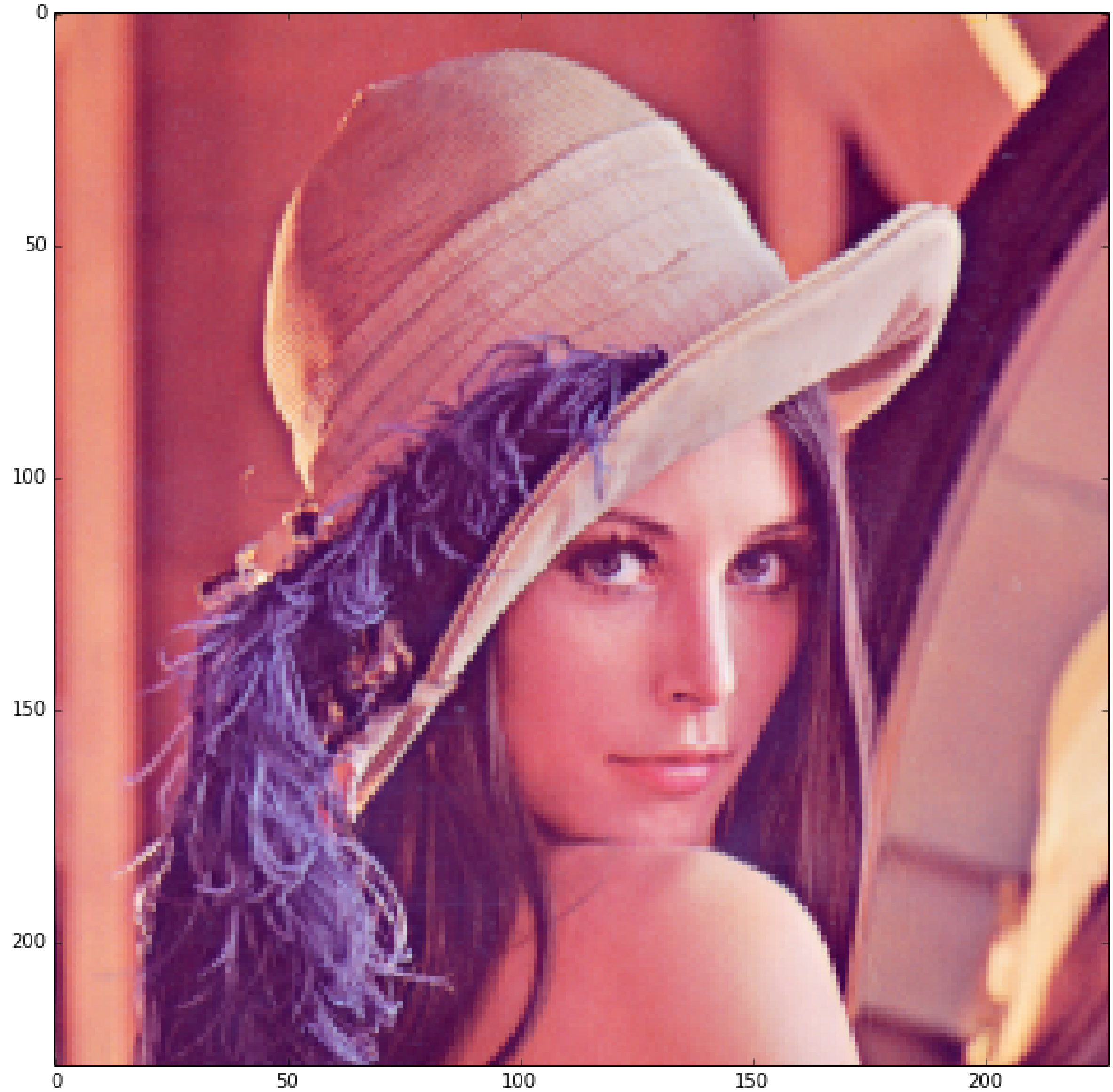
```
# our network takes BGR images, so we need to switch color channels
def showimage(im):
    if im.ndim == 3:
        im = im[:, :, ::-1]
    plt.imshow(im)

# take an array of shape (n, height, width) or (n, height, width, cha
nnels)
#  and visualize each (height, width) thing in a grid of size approx.
 sqrt(n) by sqrt(n)
def vis_square(data, padsize=1, padval=0):
    data -= data.min()
    data /= data.max()

    # force the number of filters to be square
    n = int(np.ceil(np.sqrt(data.shape[0])))
    padding = ((0, n ** 2 - data.shape[0]), (0, padsize), (0, padsize
)) + ((0, 0),) * (data.ndim - 3)
    data = np.pad(data, padding, mode='constant', constant_values=(pa
dval, padval))

    # tile the filters into an image
    data = data.reshape((n, n) + data.shape[1:]).transpose((0, 2, 1,
3) + tuple(range(4, data.ndim + 1)))
    data = data.reshape((n * data.shape[1], n * data.shape[3]) + data
.shape[4:])

    showimage(data)
```

The input image

In [7]:

```
# index four is the center crop
```

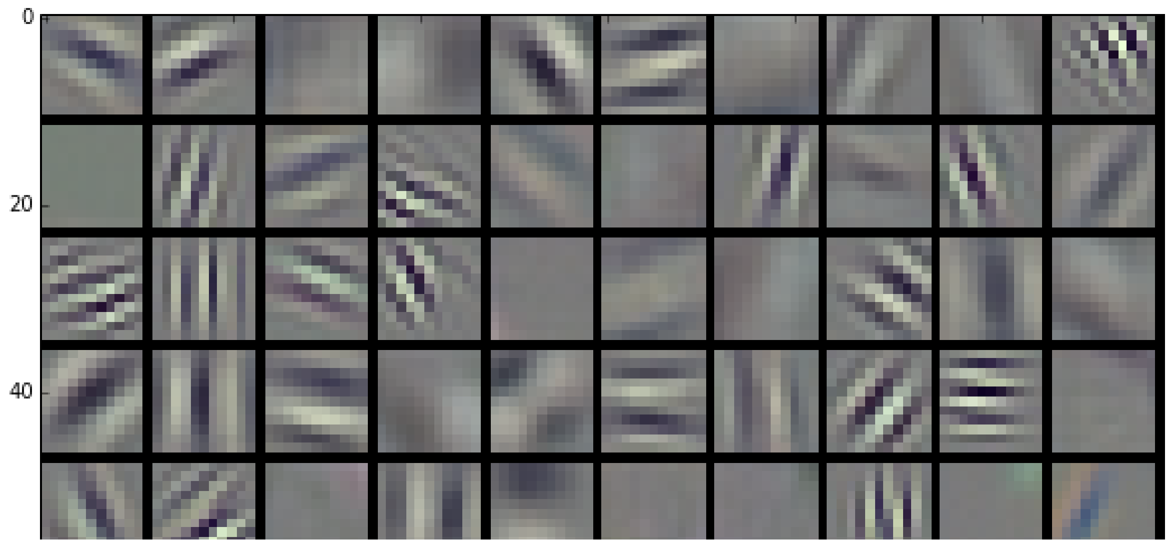
```
image = net.caffenet.blobs['data'].data[4].copy()
image -= image.min()
image /= image.max()
showimage(image.transpose(1, 2, 0))
```

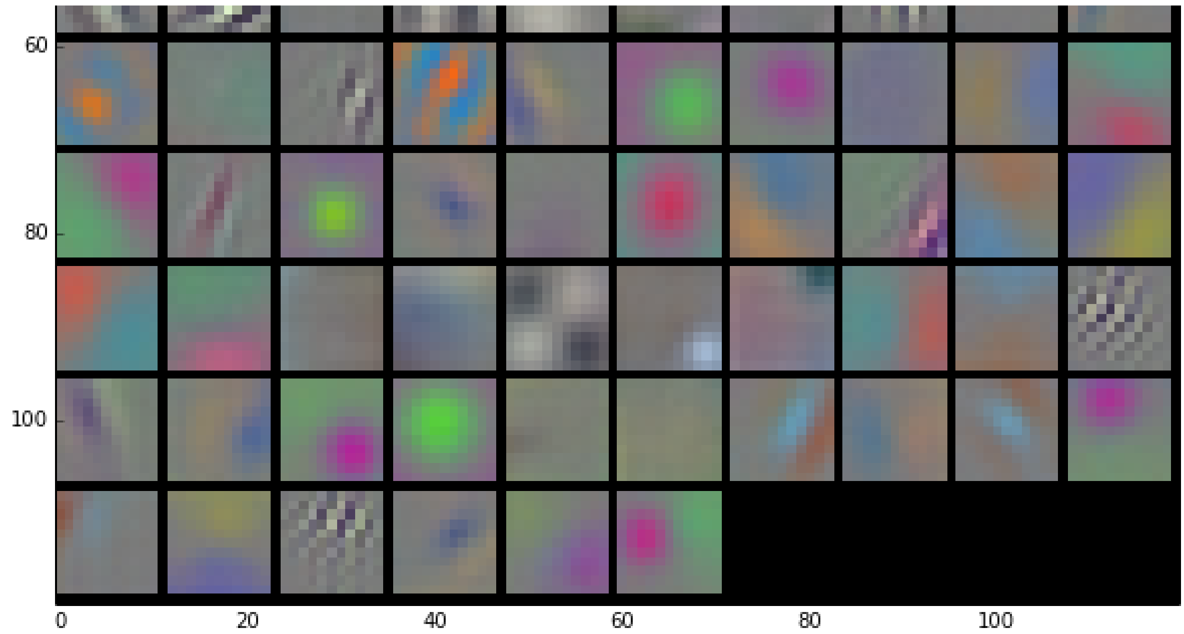



The first layer filters, conv1

In [8]:

```
# the parameters are a list of [weights, biases]
filters = net.caffenet.params['conv1'][0].data
vis_square(filters.transpose(0, 2, 3, 1))
```

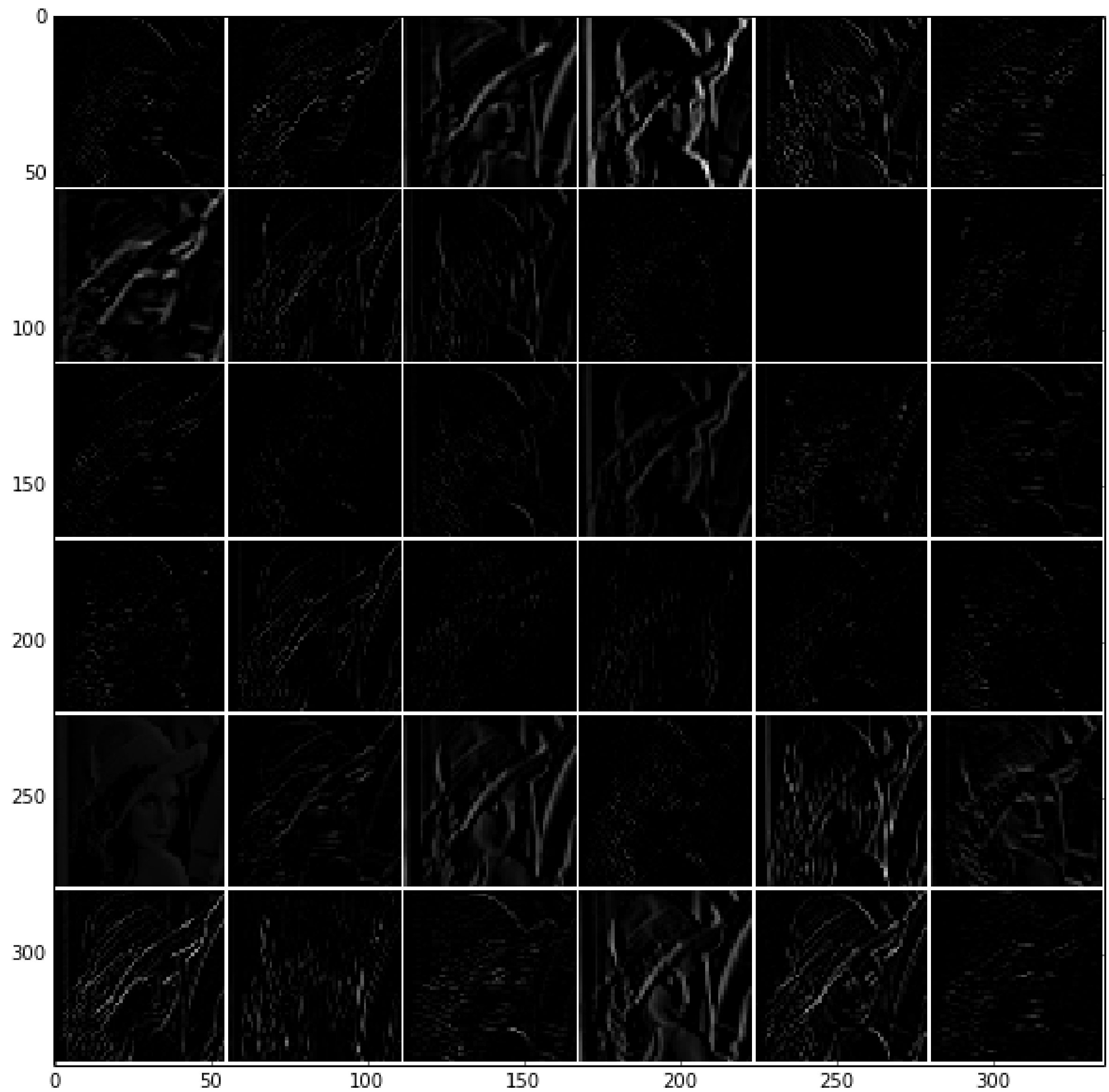




The first layer output, conv1 (rectified responses of the filters above, first 36 only)

In [9]:

```
feat = net.caffenet.blobs['conv1'].data[4, :36]
vis_square(feat, padval=1)
```

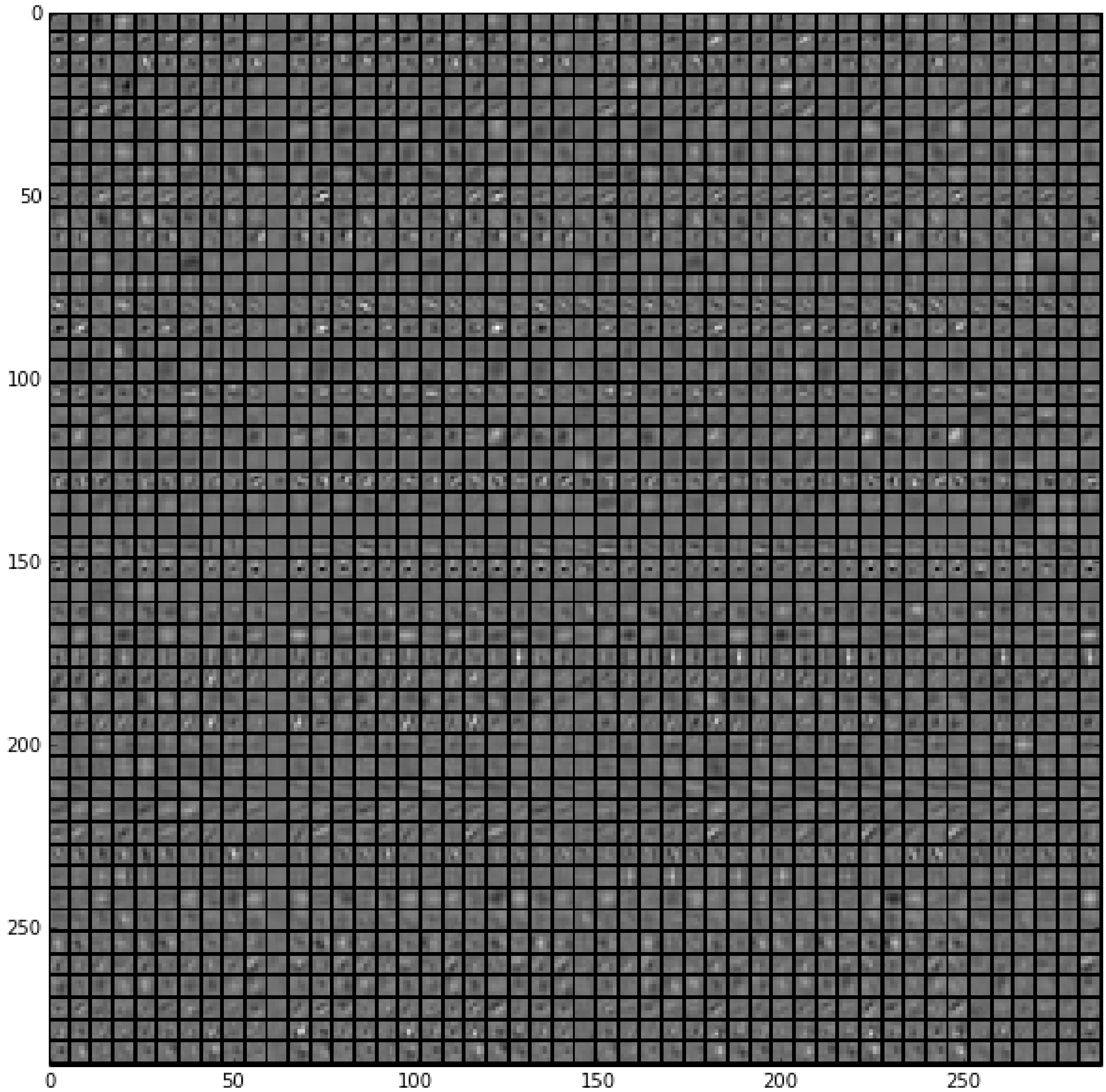


The second layer filters, conv2

There are 128 filters, each of which has dimension 5 x 5 x 48. We show only the first 48 filters, with each channel shown separately, so that each filter is a row.

In [10]:

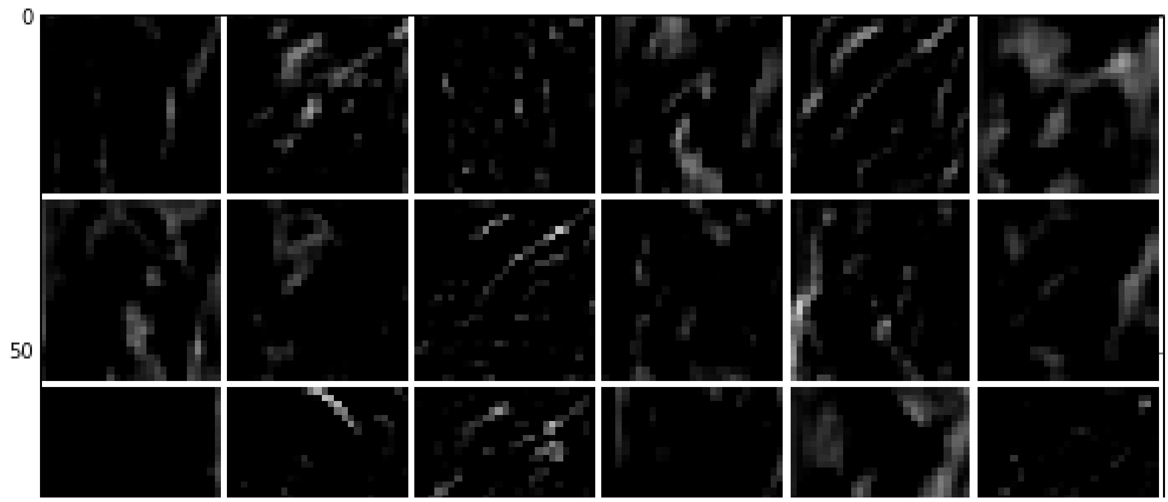
```
filters = net.caffenet.params['conv2'][0].data
vis_square(filters[:48].reshape(48**2, 5, 5))
```

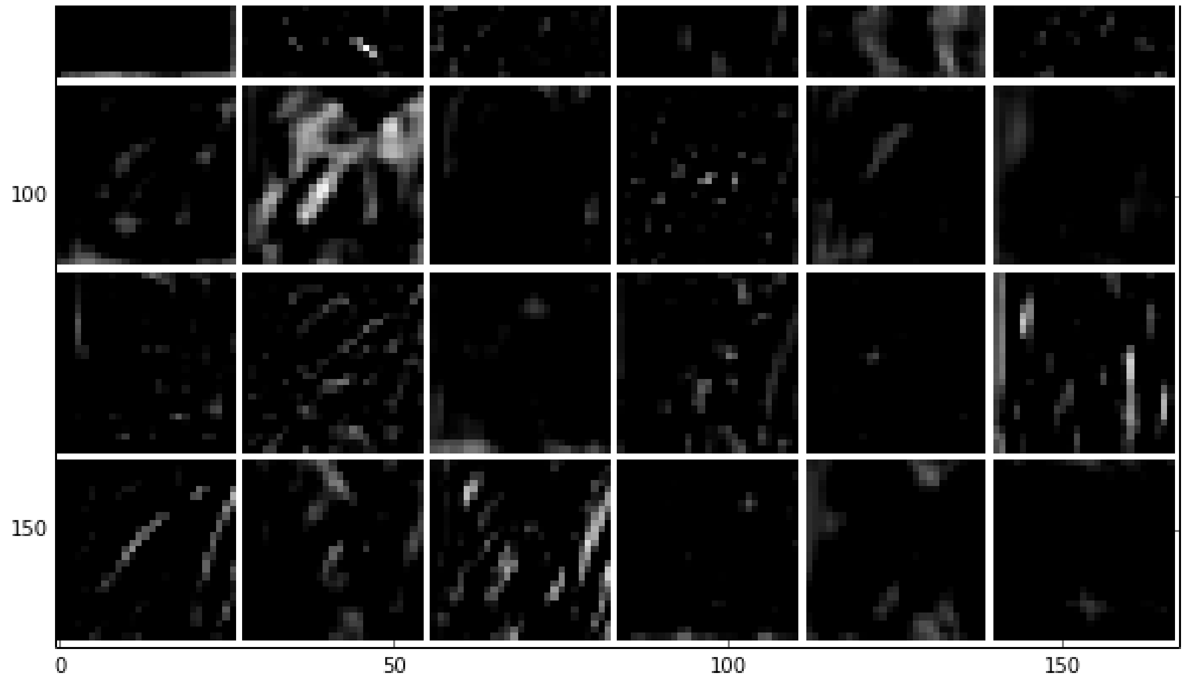



The second layer output, conv2 (rectified, only the first 36 of 256 channels)

In [11]:

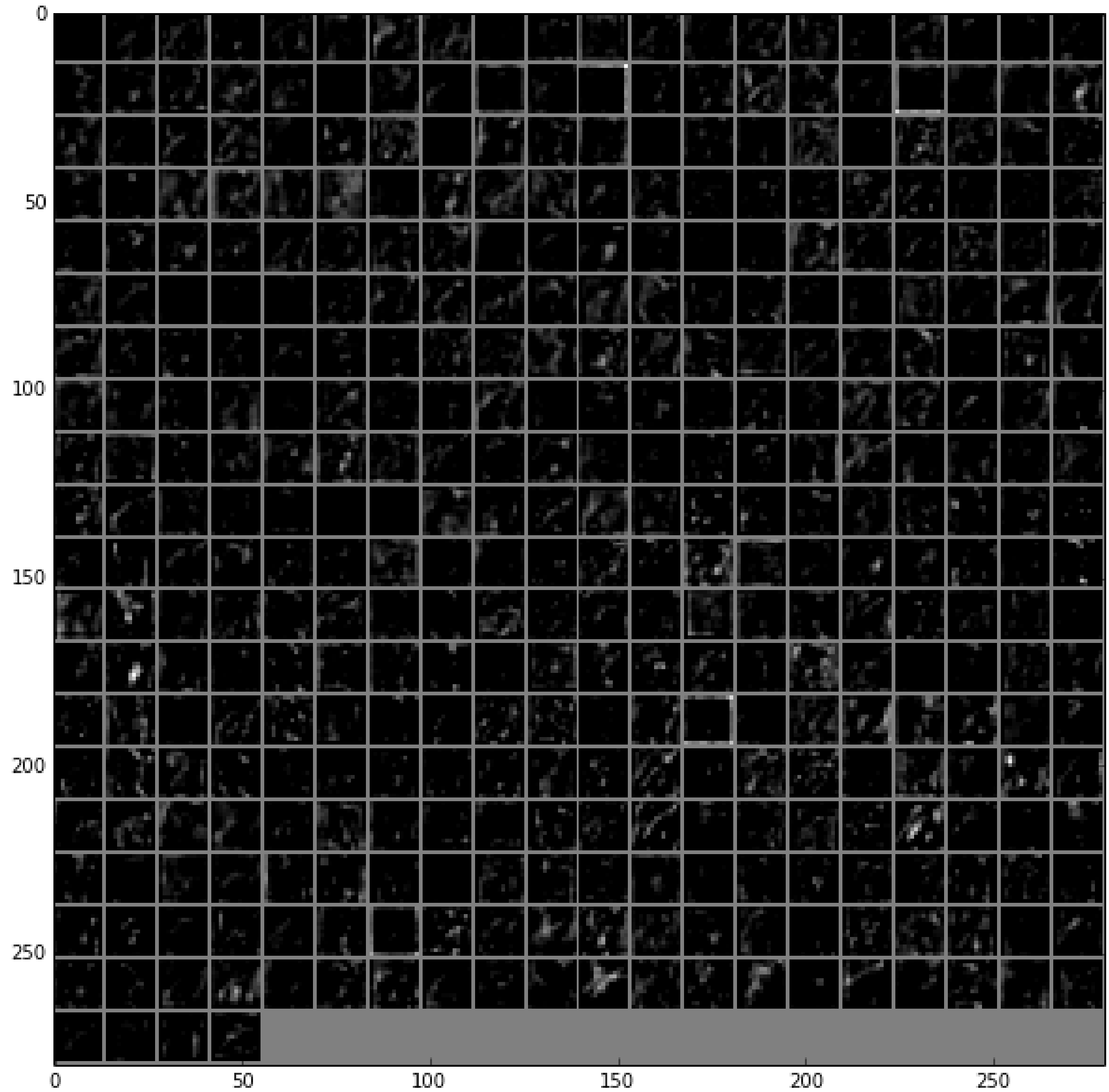
```
feat = net.caffenet.blobs['conv2'].data[4, :36]
vis_square(feat, padval=1)
```





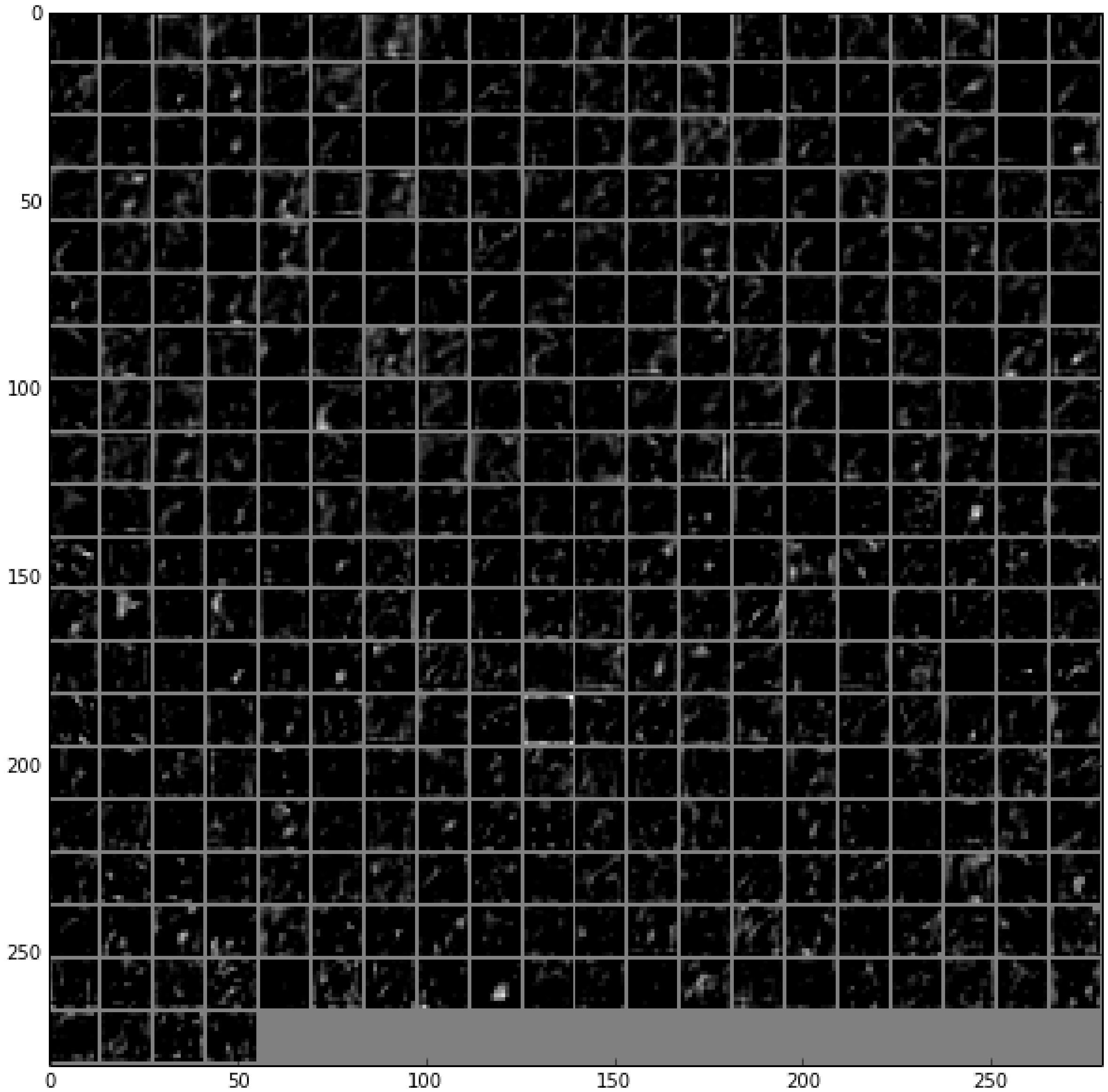

The third layer output, conv3 (rectified, all 384 channels)

In [12]:
```
feat = net.caffenet.blobs['conv3'].data[4]
vis_square(feat, padval=0.5)
```



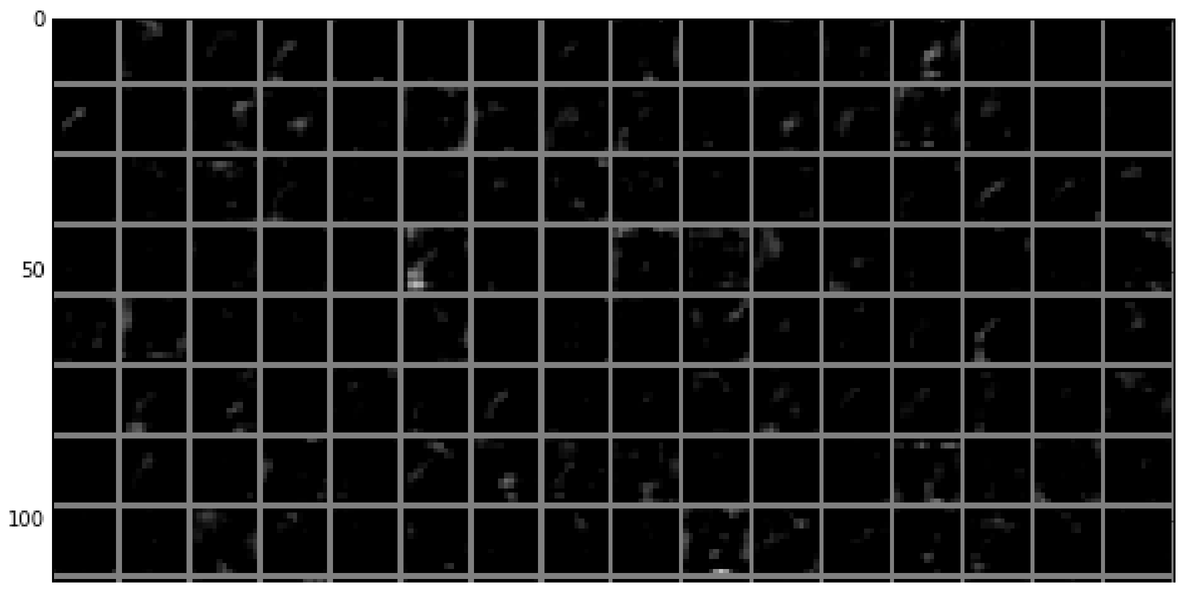

The fourth layer output, conv4 (rectified, all 384 channels)

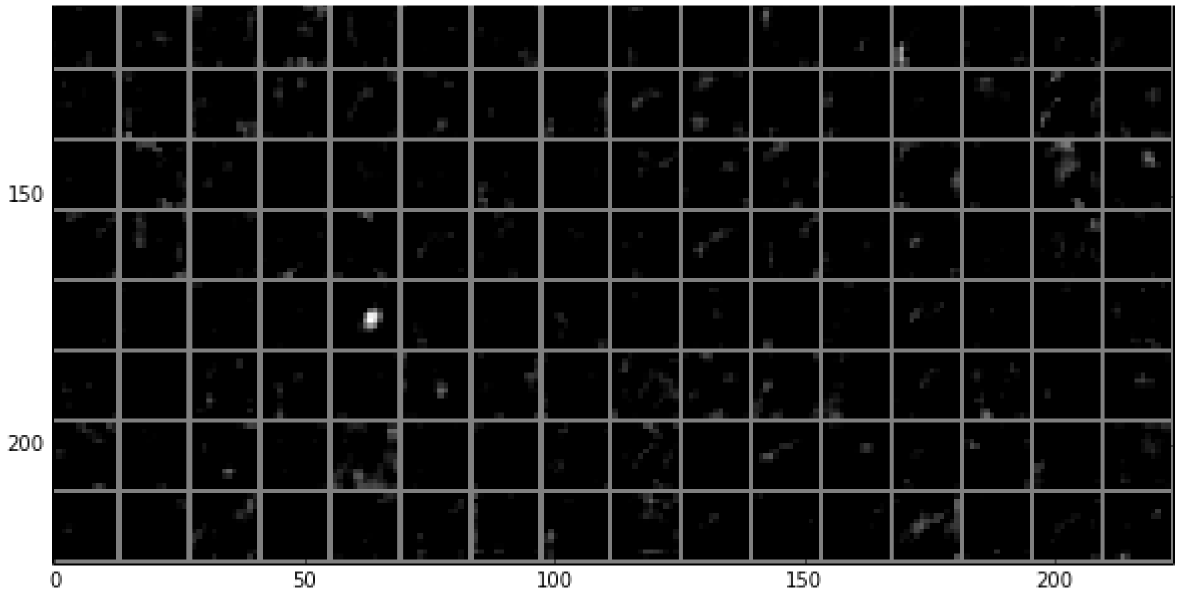
In [13]:
```
feat = net.caffenet.blobs['conv4'].data[4]
vis_square(feat, padval=0.5)
```



The fifth layer output, conv5 (rectified, all 256 channels)

In [14]:
```
feat = net.caffenet.blobs['conv5'].data[4]
vis_square(feat, padval=0.5)
```

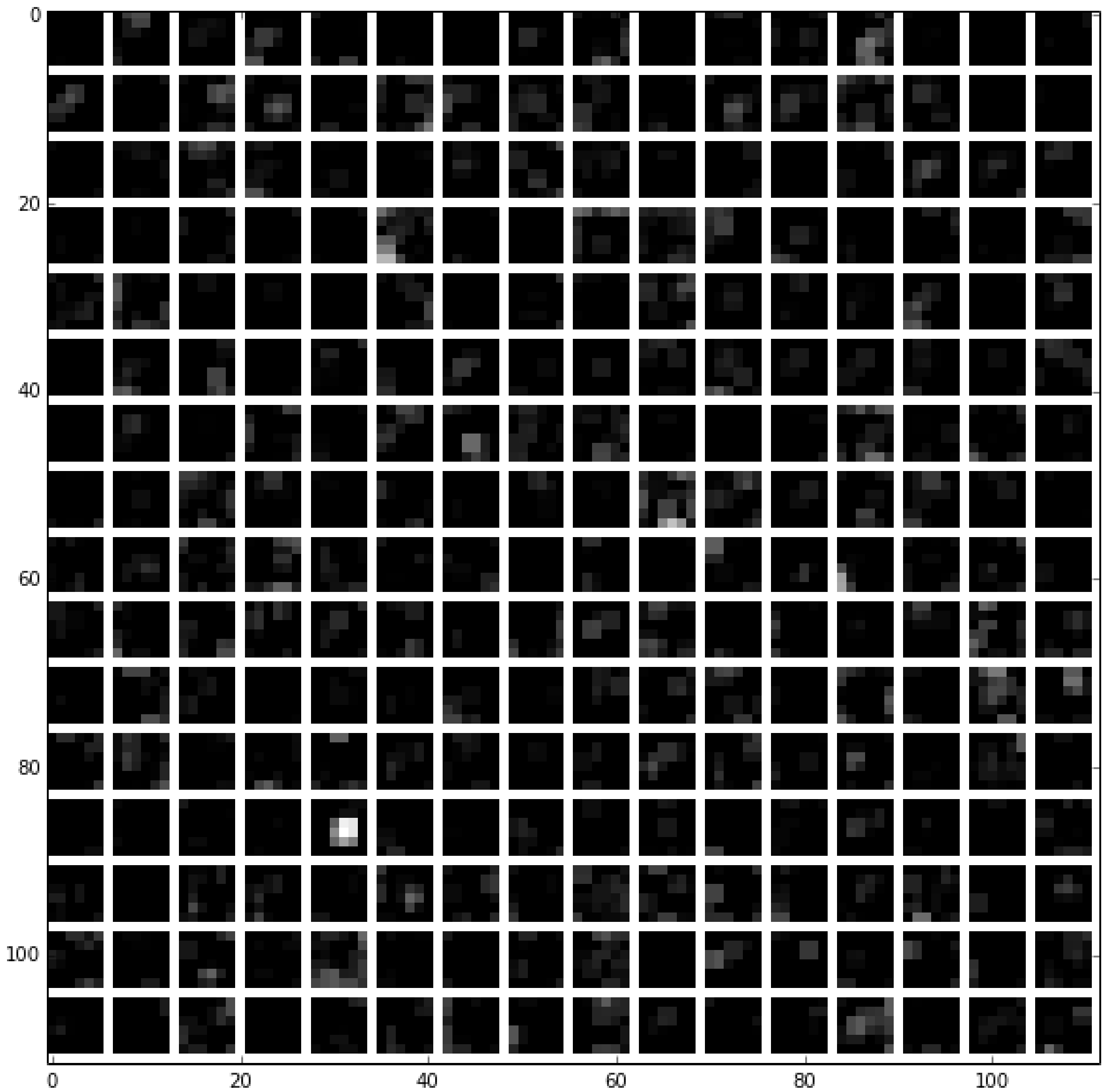





The fifth layer after pooling, `pool5`

In [15]:

```
feat = net.caffenet.blobs['pool5'].data[4]
vis_square(feat, padval=1)
```

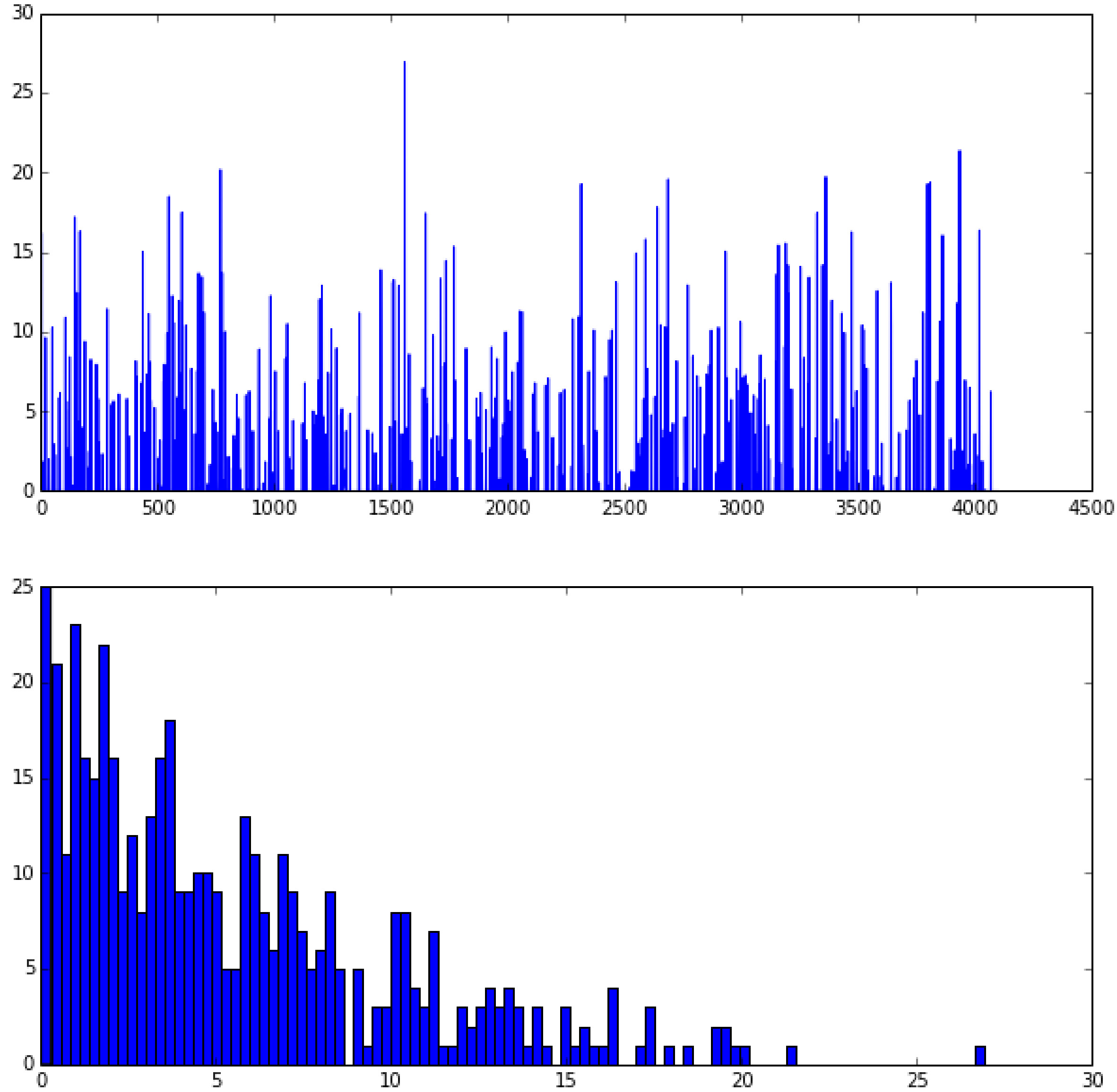



The first fully connected layer, `fc6` (rectified)

We show the output values and the histogram of the positive values

In [16]:

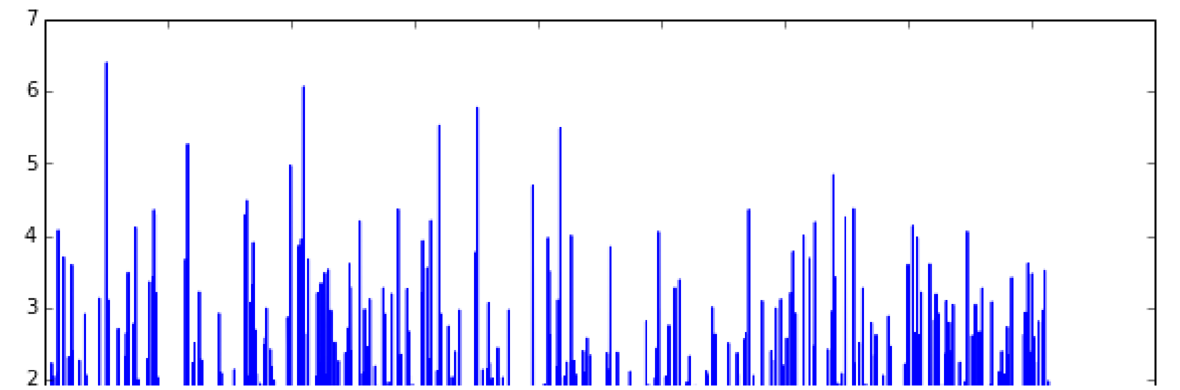
```
feat = net.caffenet.blobs['fc6'].data[4]
plt.subplot(2, 1, 1)
plt.plot(feat.flat)
plt.subplot(2, 1, 2)
_ = plt.hist(feat.flat[feat.flat > 0], bins=100)
```

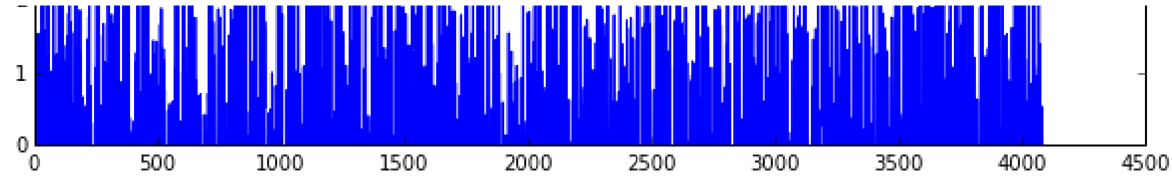


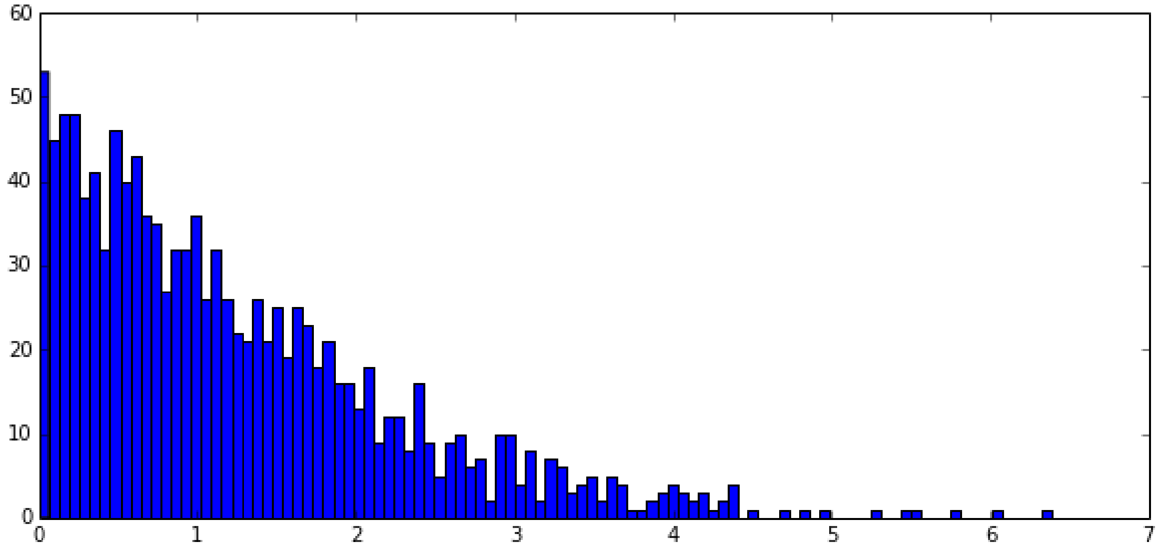

The second fully connected layer, `fc7` (rectified)

In [17]:

```
feat = net.caffenet.blobs['fc7'].data[4]
plt.subplot(2, 1, 1)
plt.plot(feat.flat)
plt.subplot(2, 1, 2)
_ = plt.hist(feat.flat[feat.flat > 0], bins=100)
```



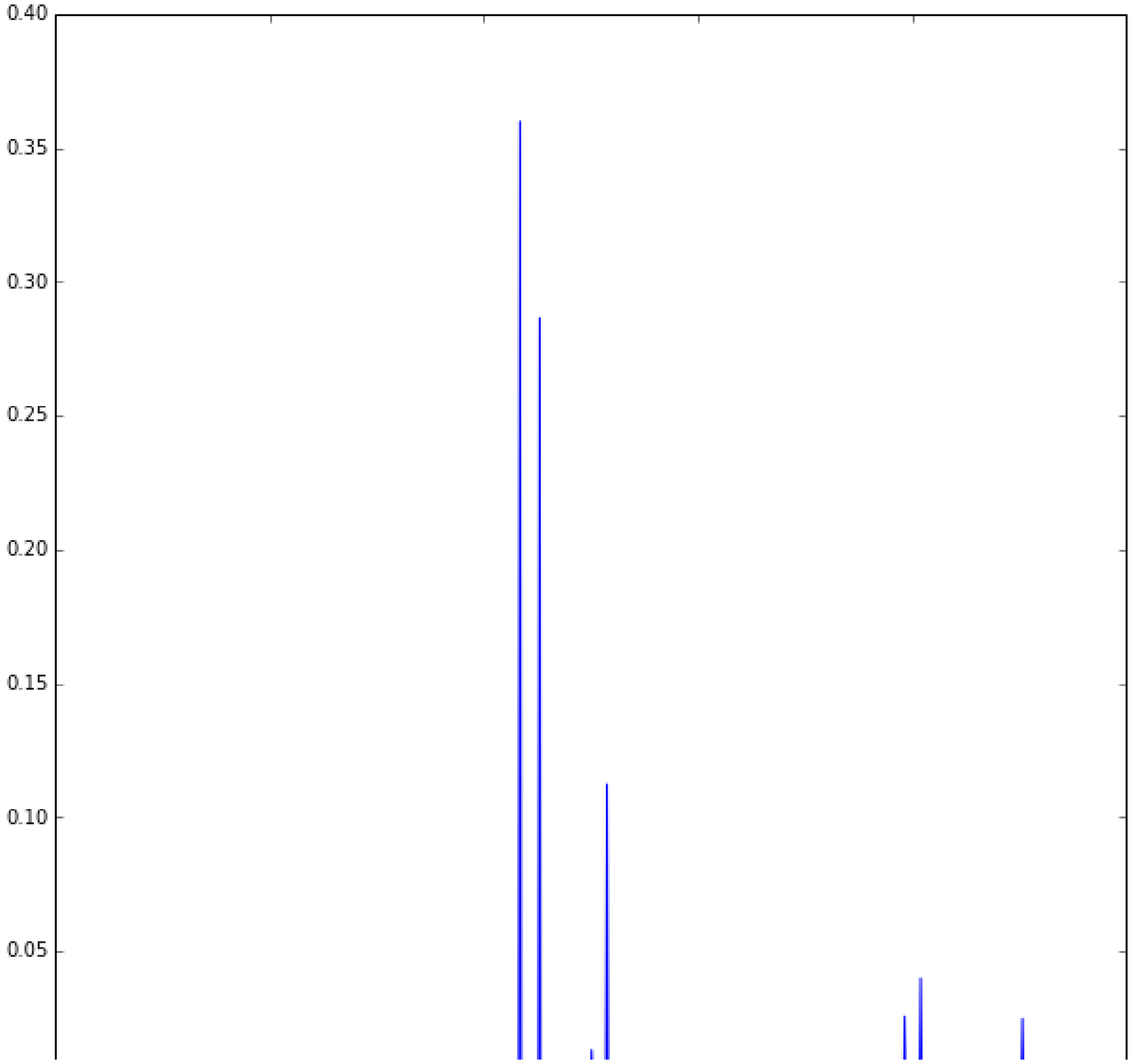


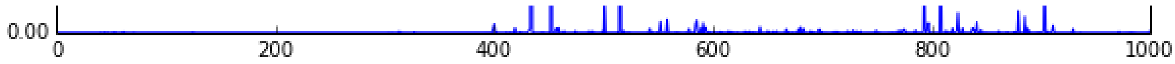


The final probability output, prob

```
In [18]: feat = net.caffenet.blobs['prob'].data[4]
         plt.plot(feat.flat)
```

Out[18]: [<matplotlib.lines.Line2D at 0x13617f250>]






Let's see the top 5 predicted labels.

In [19]:

```
imagenet_labels_filename = caffe_root + 'data/ilsvrc12/synset_words.t
xt'
try:
    labels = np.loadtxt(imagenet_labels_filename, str, delimiter='\t'
)
except:
    !../data/ilsvrc12/get_ilsvrc_aux.sh
    labels = np.loadtxt(imagenet_labels_filename, str, delimiter='\t'
)
```

In [20]:

```
top_k = net.caffenet.blobs['prob'].data[4].flatten().argsort()[-1:-6:
-1]
print labels[top_k]
```

```
['n02808304 bath towel' 'n02869837 bonnet, poke bonnet'
 'n03124170 cowboy hat, ten-gallon hat' 'n04259630 sombrero'
 'n04209133 shower cap']
```

Funnily enough, ImageNet does not include portraits as a category, so the classifier is quite bad at classifying images as containing people.