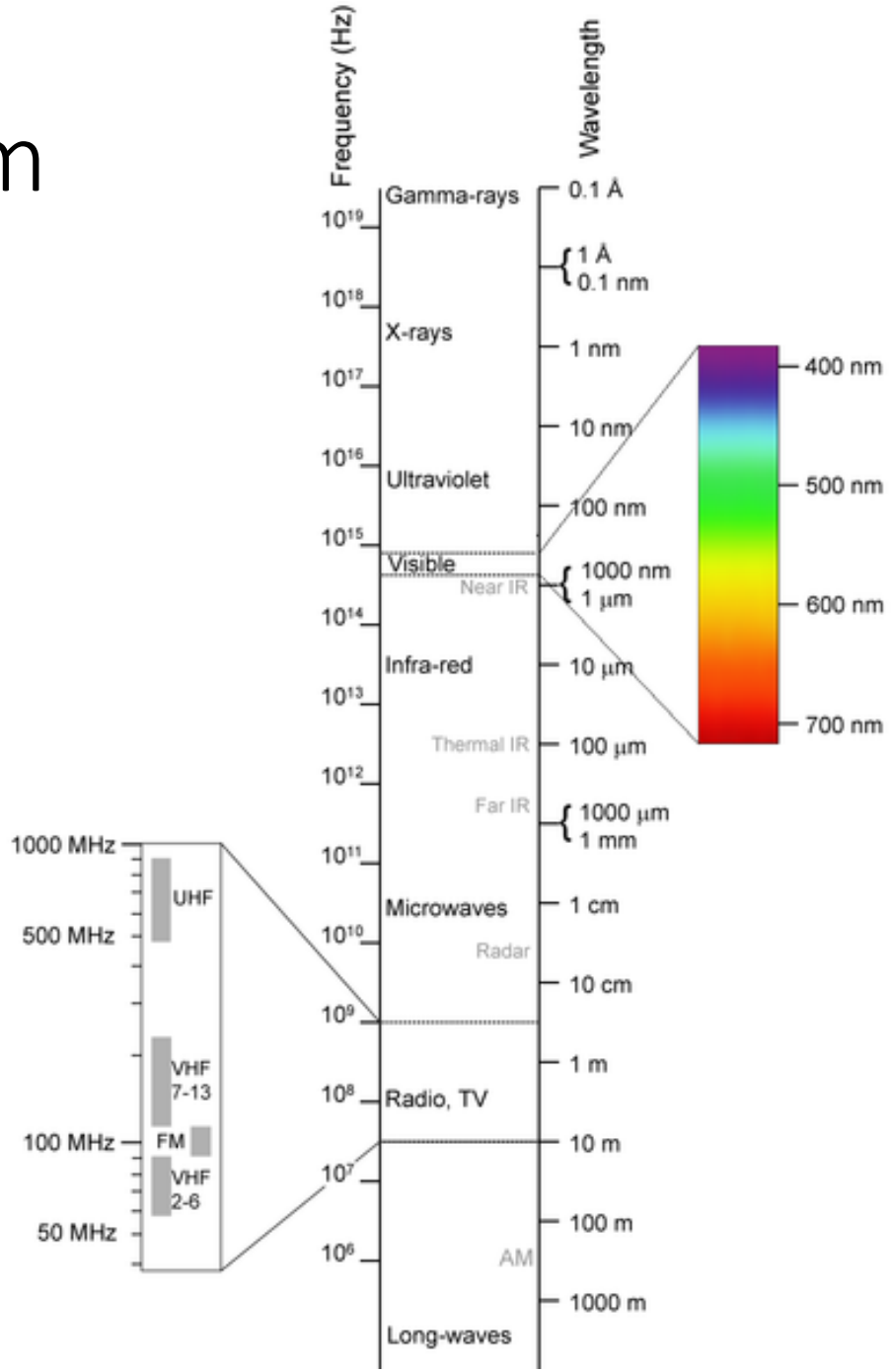
Video Compression

CS6025 Data Encoding

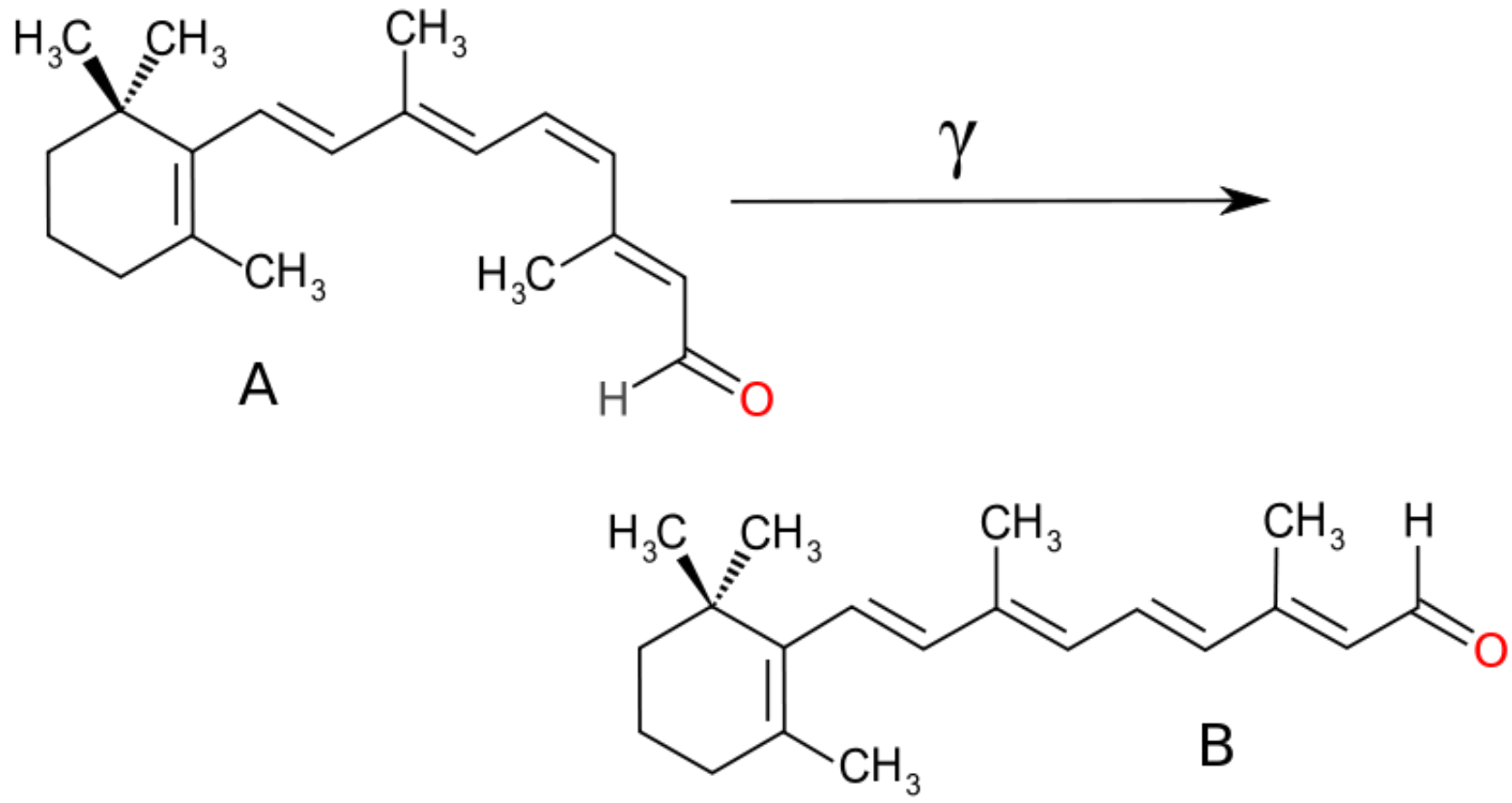
Yizong Cheng

4-21-15

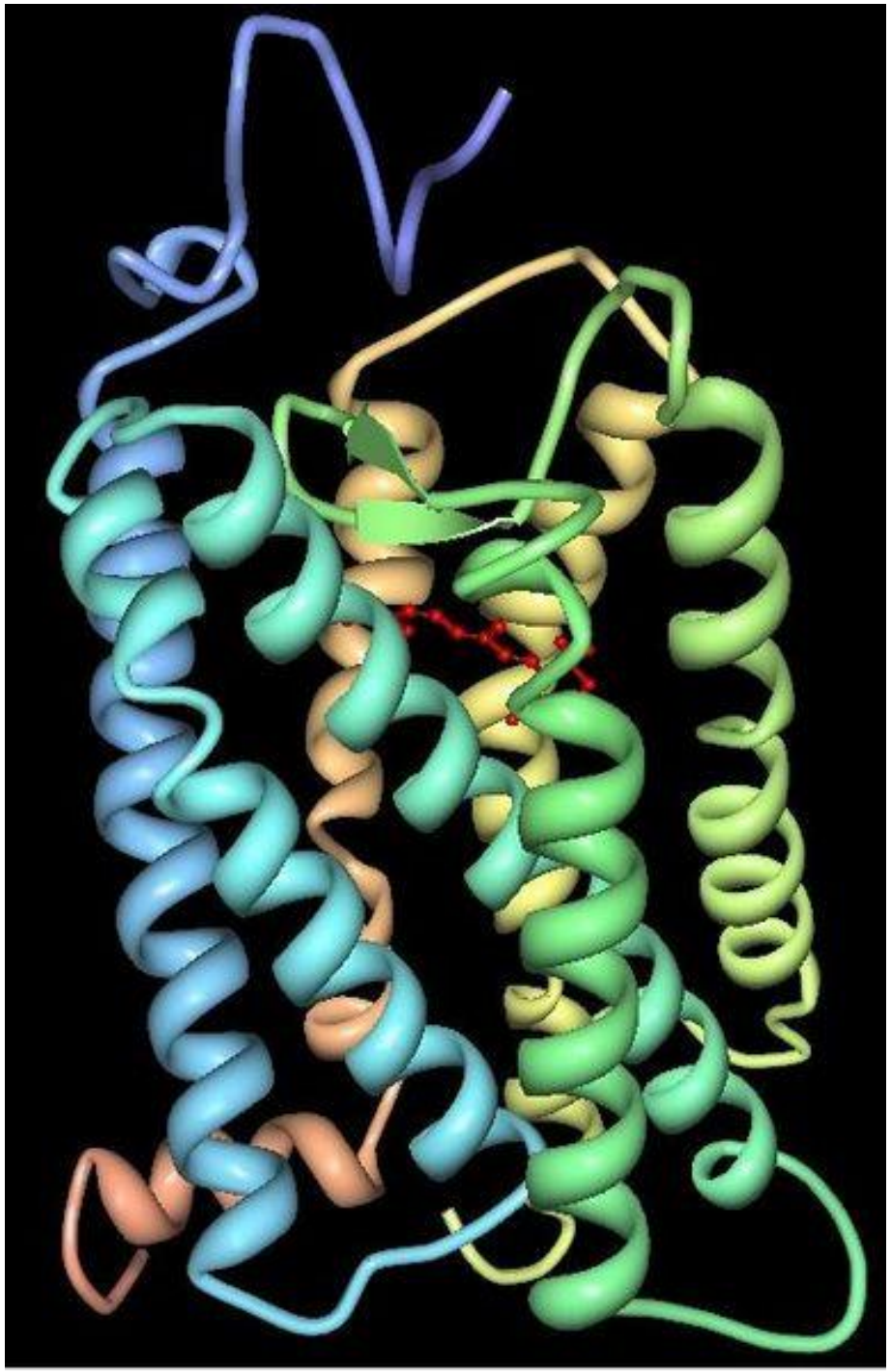
Frequency Spectrum



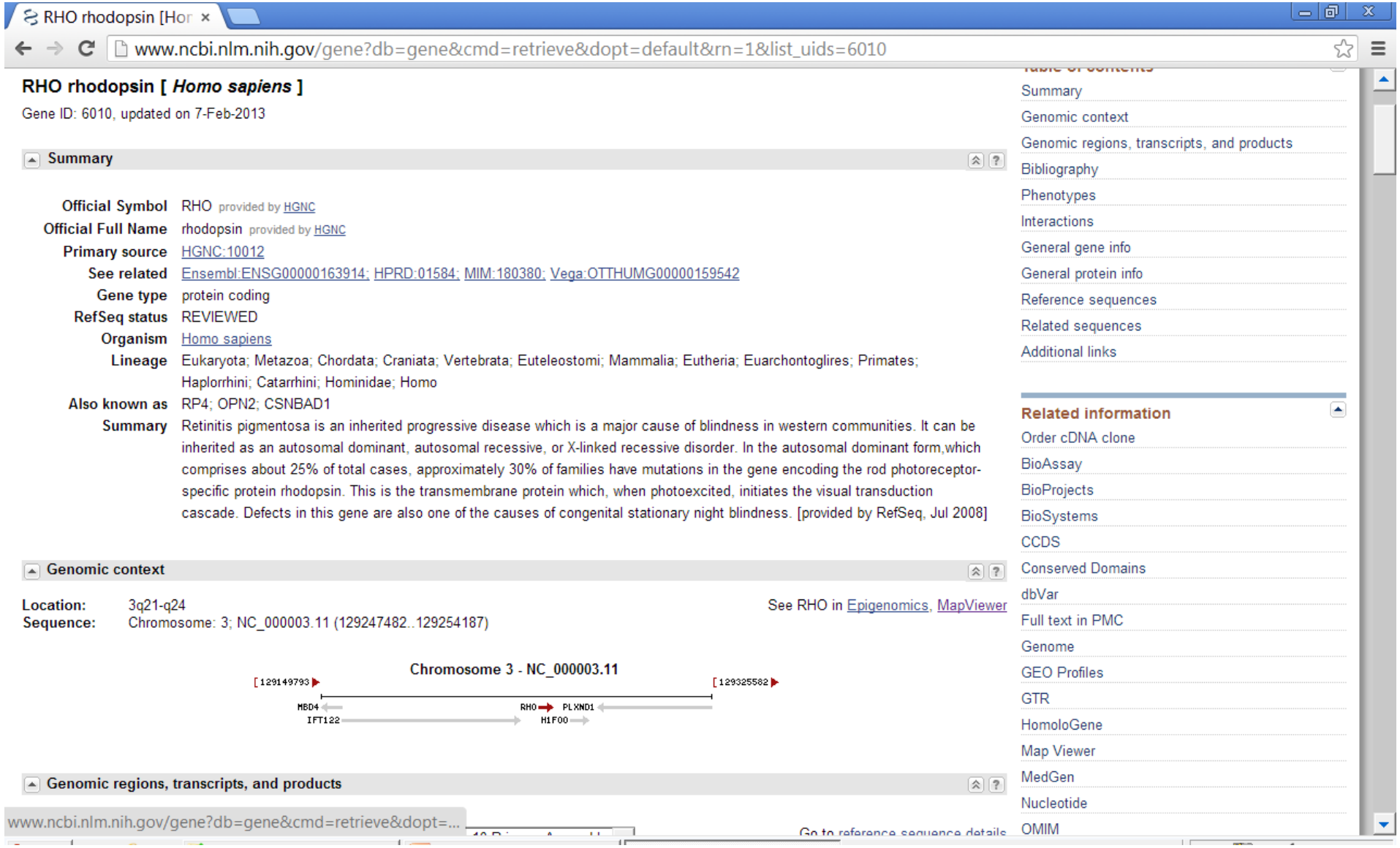
Retinal



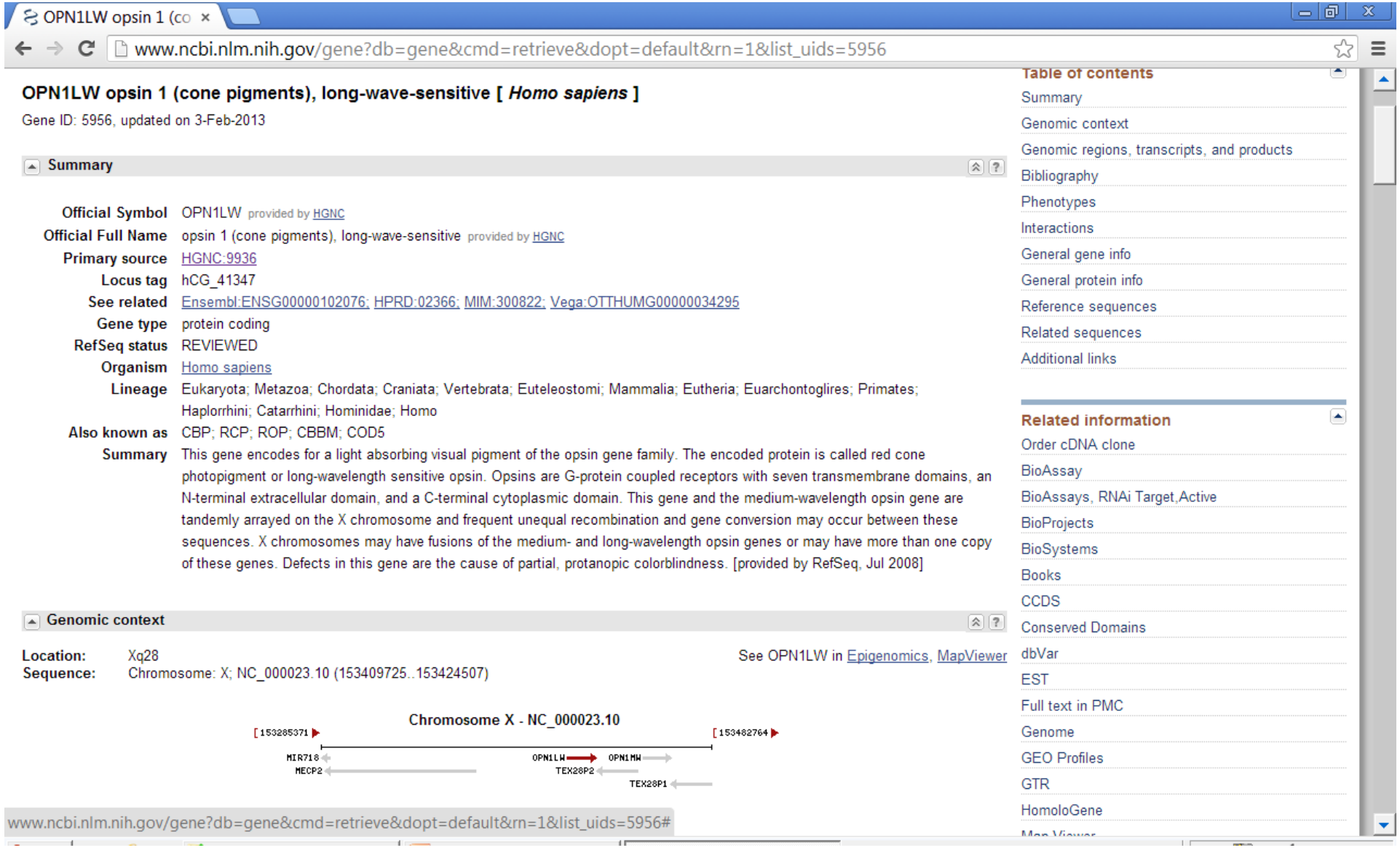
Opsin



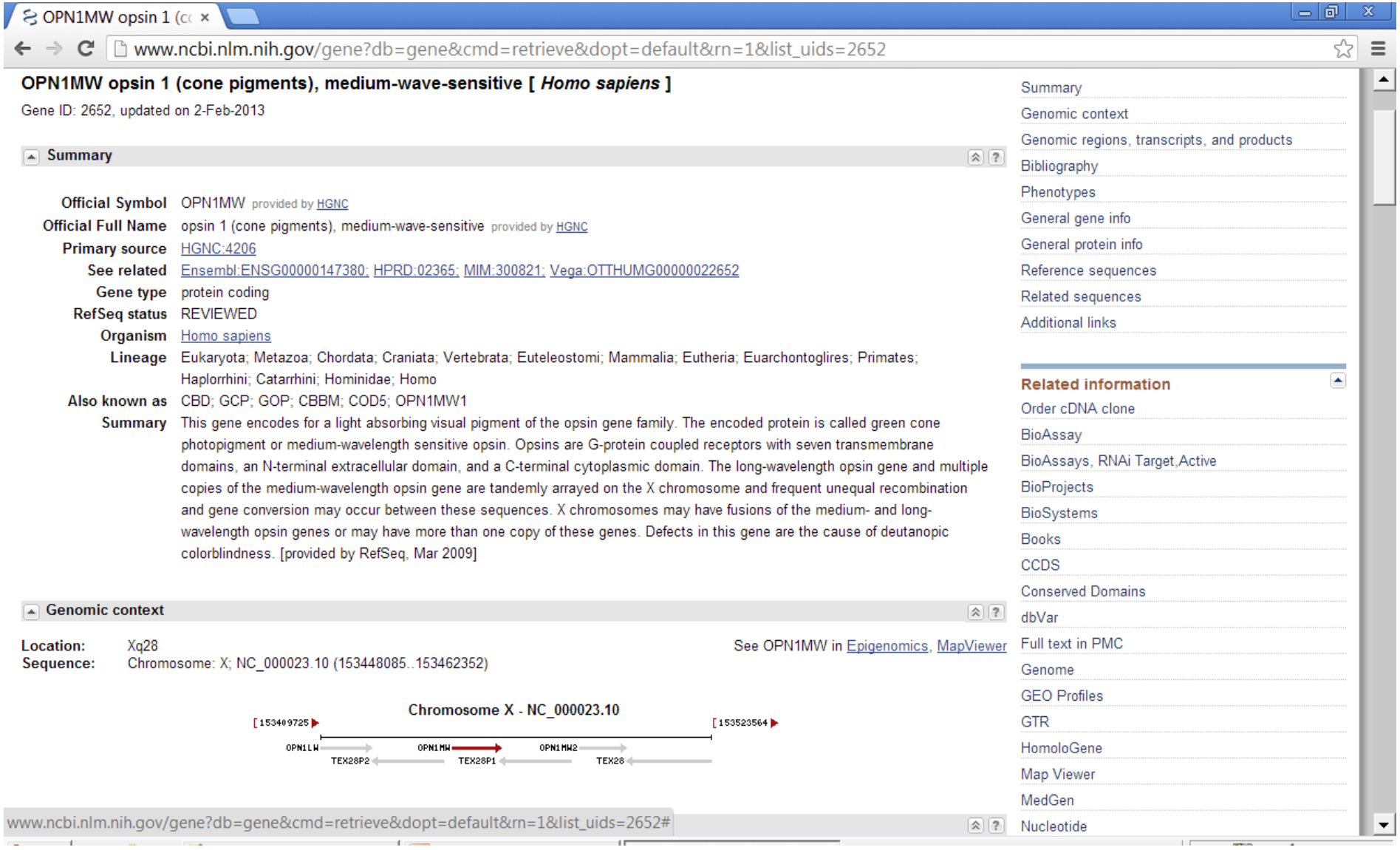
Gene RHO on Chromosome 3



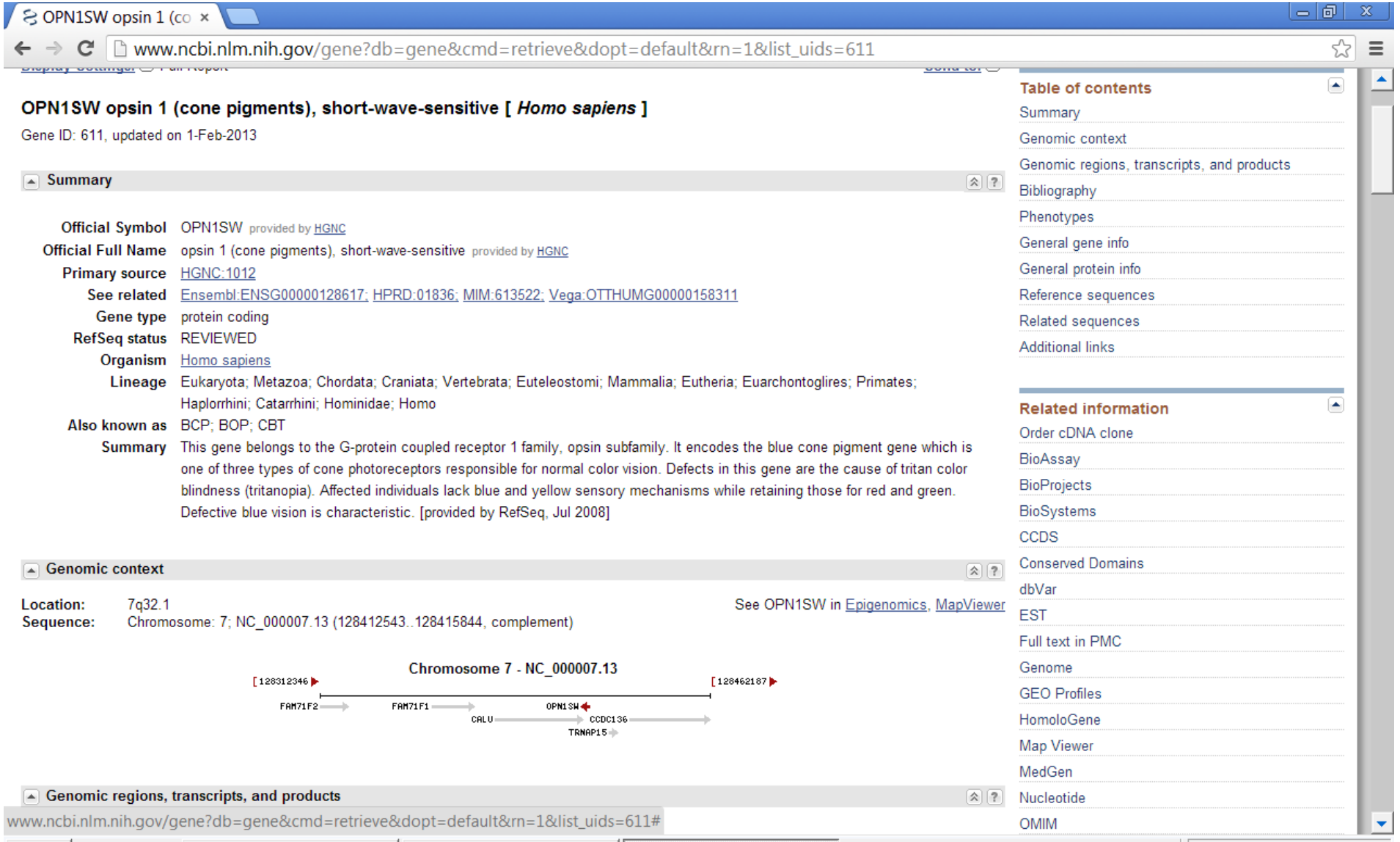
OPN1LW on the X Chromosome



OPN1MW on the X Chromosome

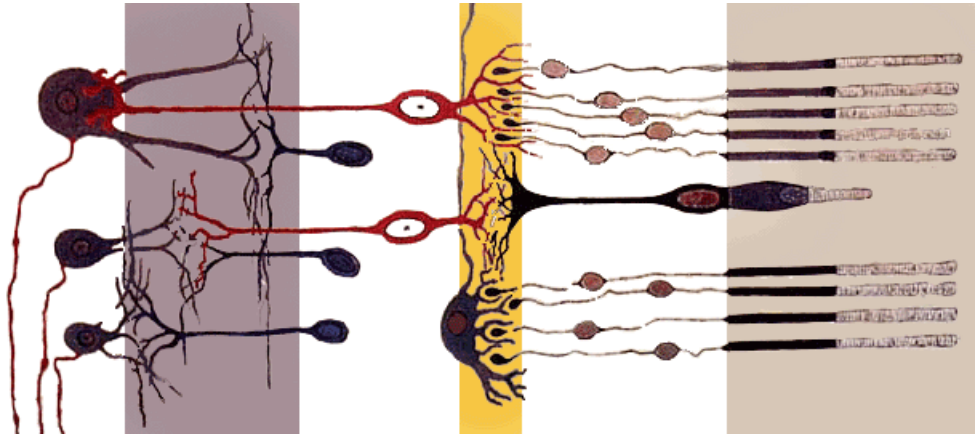


OPN1SW on Chromosome 7

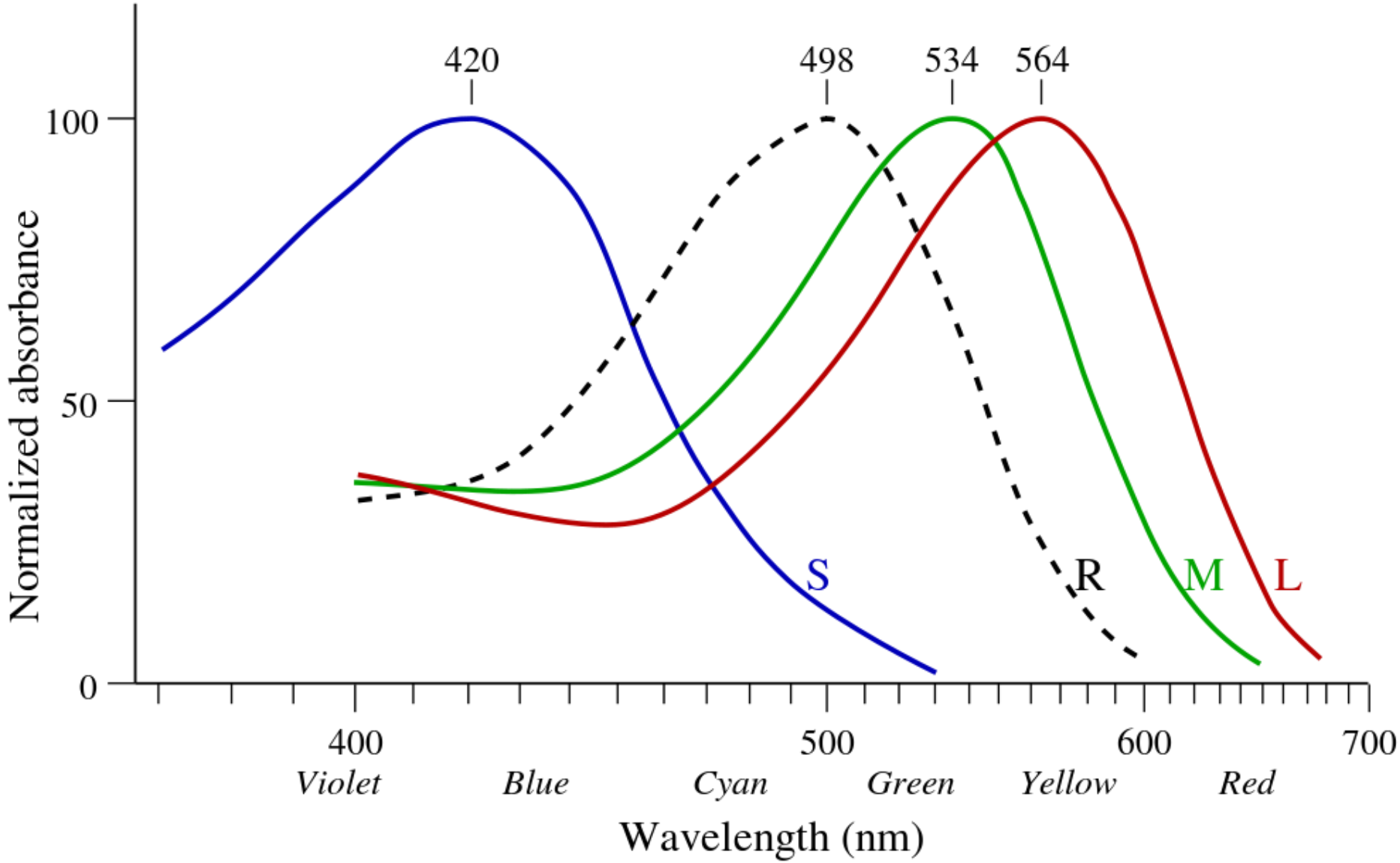


Rods, Cones and the Retina

- Photoreceptor cells of four kinds in retina
- 7 million cones and 120 million rods
- 1 million optic fibers

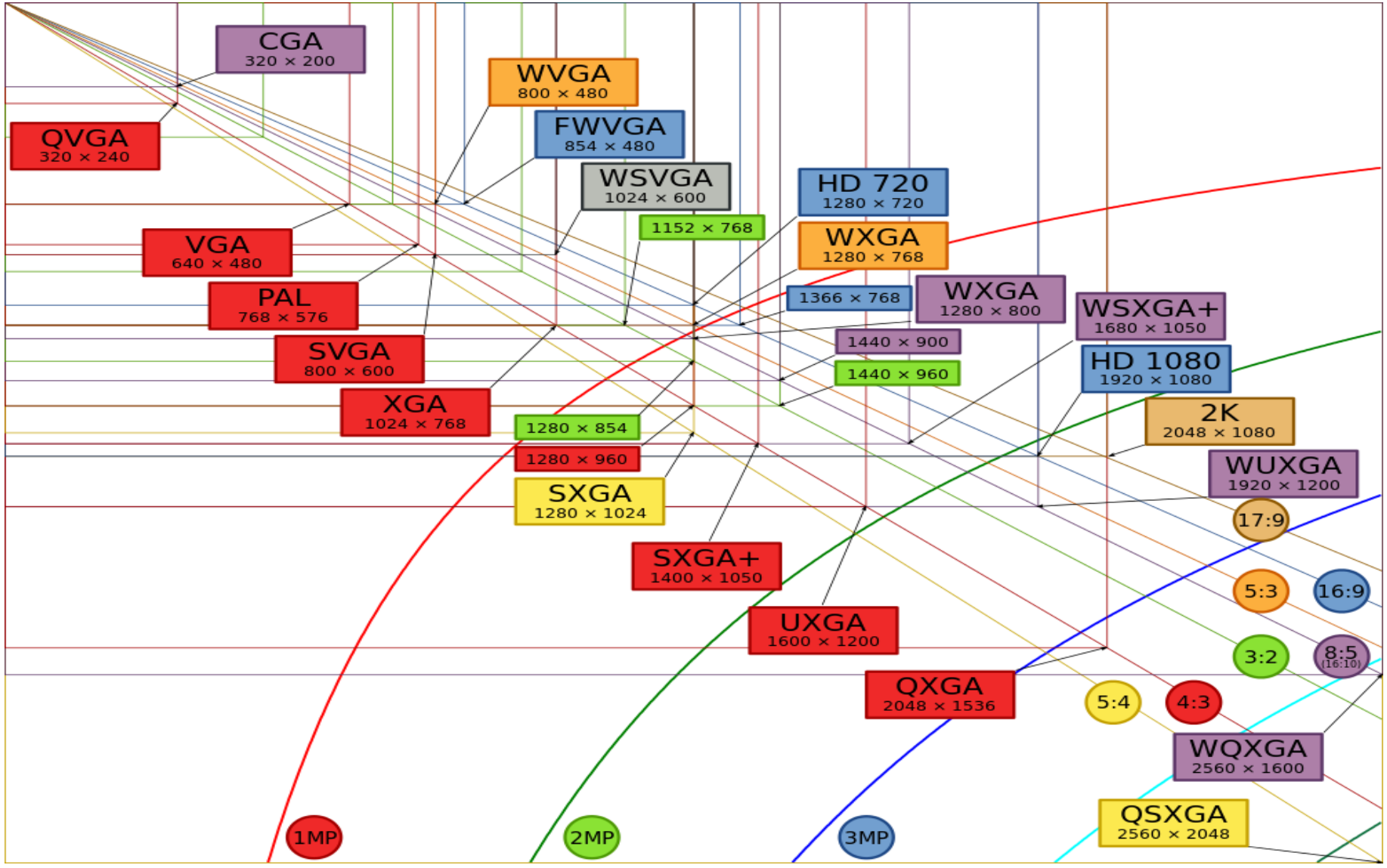


Photoreceptor Absorbance

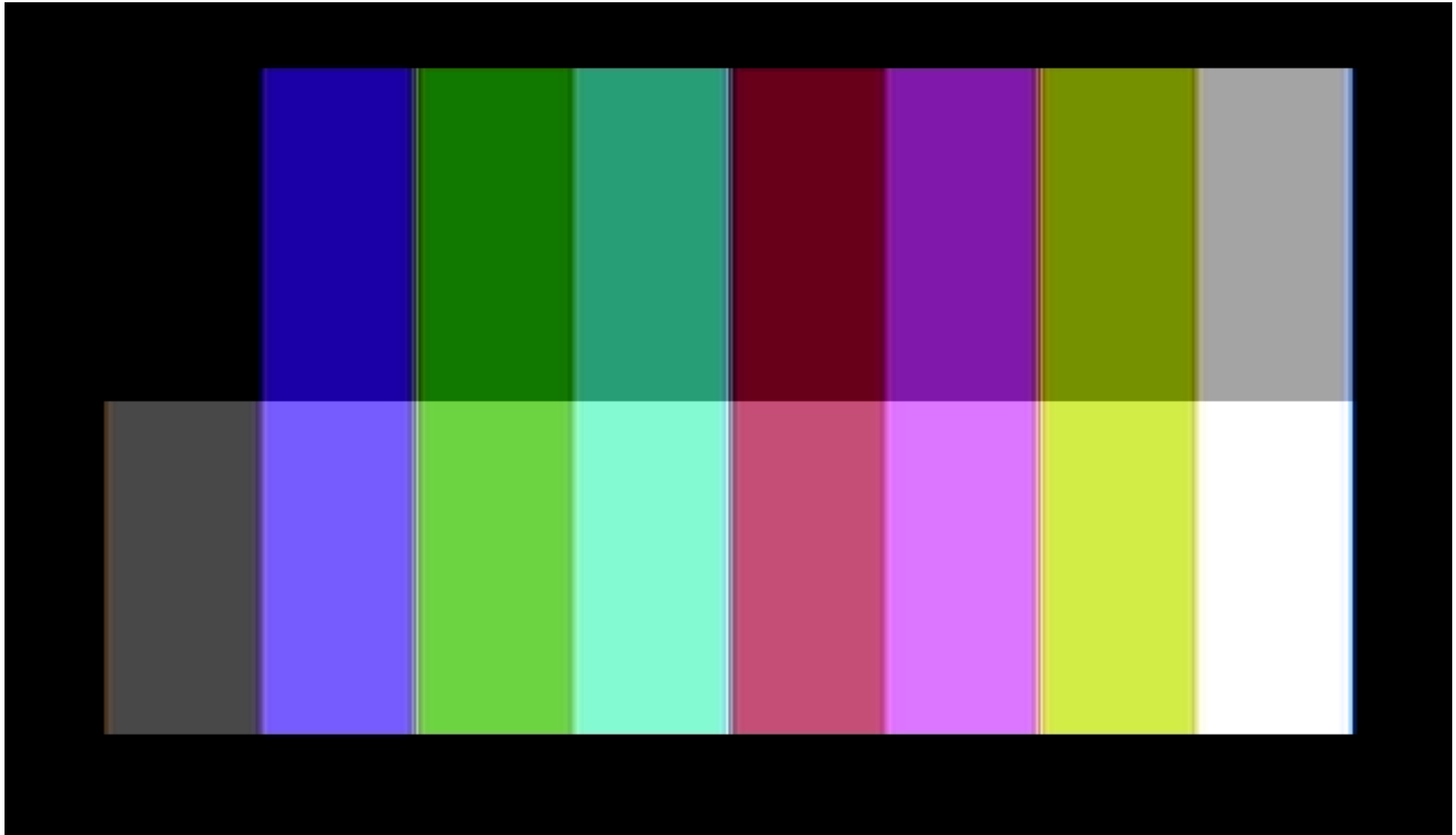


1911 Color Photography with Filters

Computer Display Standards

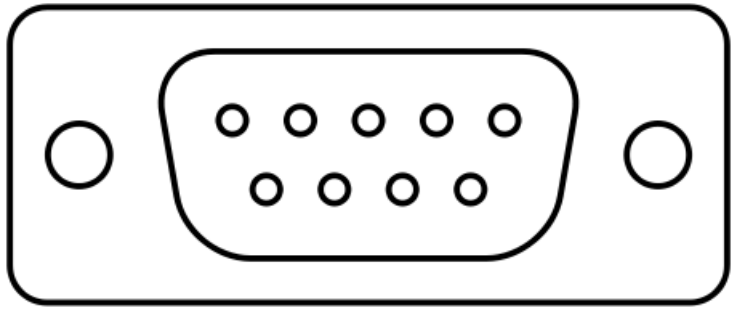


CGA for IBM PC Graphics Card 1981

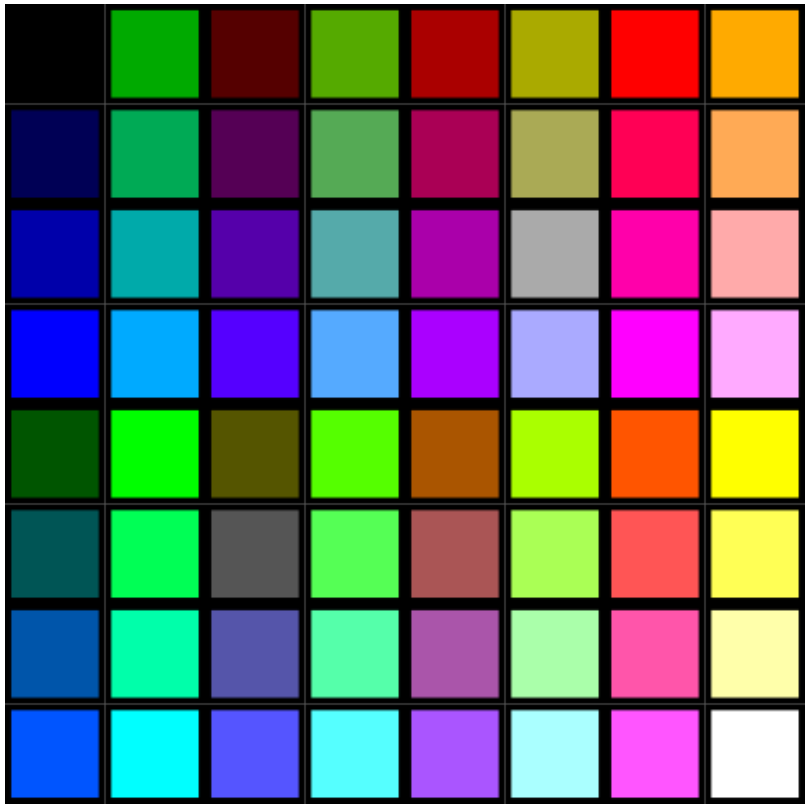


DE-9 Connector for CGA

Pin	Function
1	Ground
2	Ground
3	Red
4	Green
5	Blue
6	Intensity
7	Reserved
8	Horizontal sync
9	Vertical sync

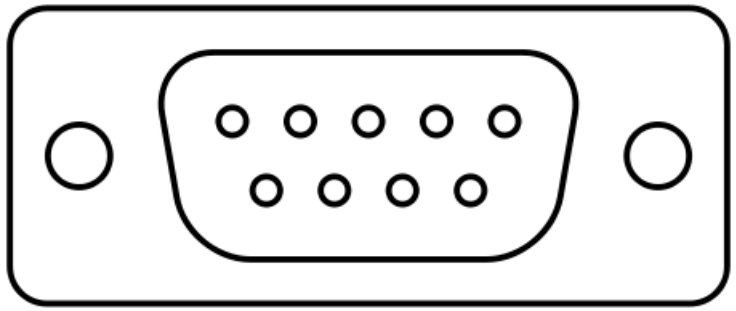


EGA (1984) Has 64 Colors



DE-9 Connector for EGA

Pin	Function
1	Ground
2	Secondary red
3	Red
4	Green
5	Blue
6	Secondary green
7	Secondary blue
8	Horizontal sync
9	Vertical sync

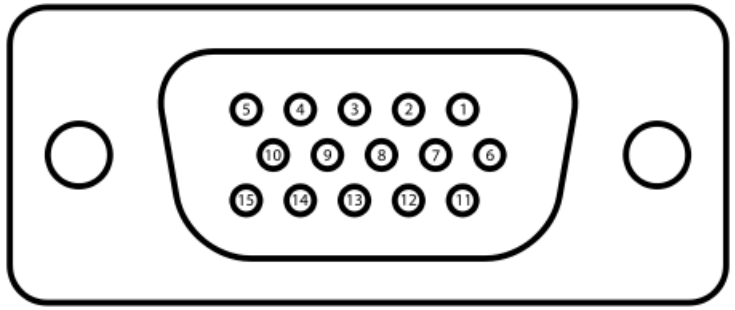


VGA Analog Display (1987)

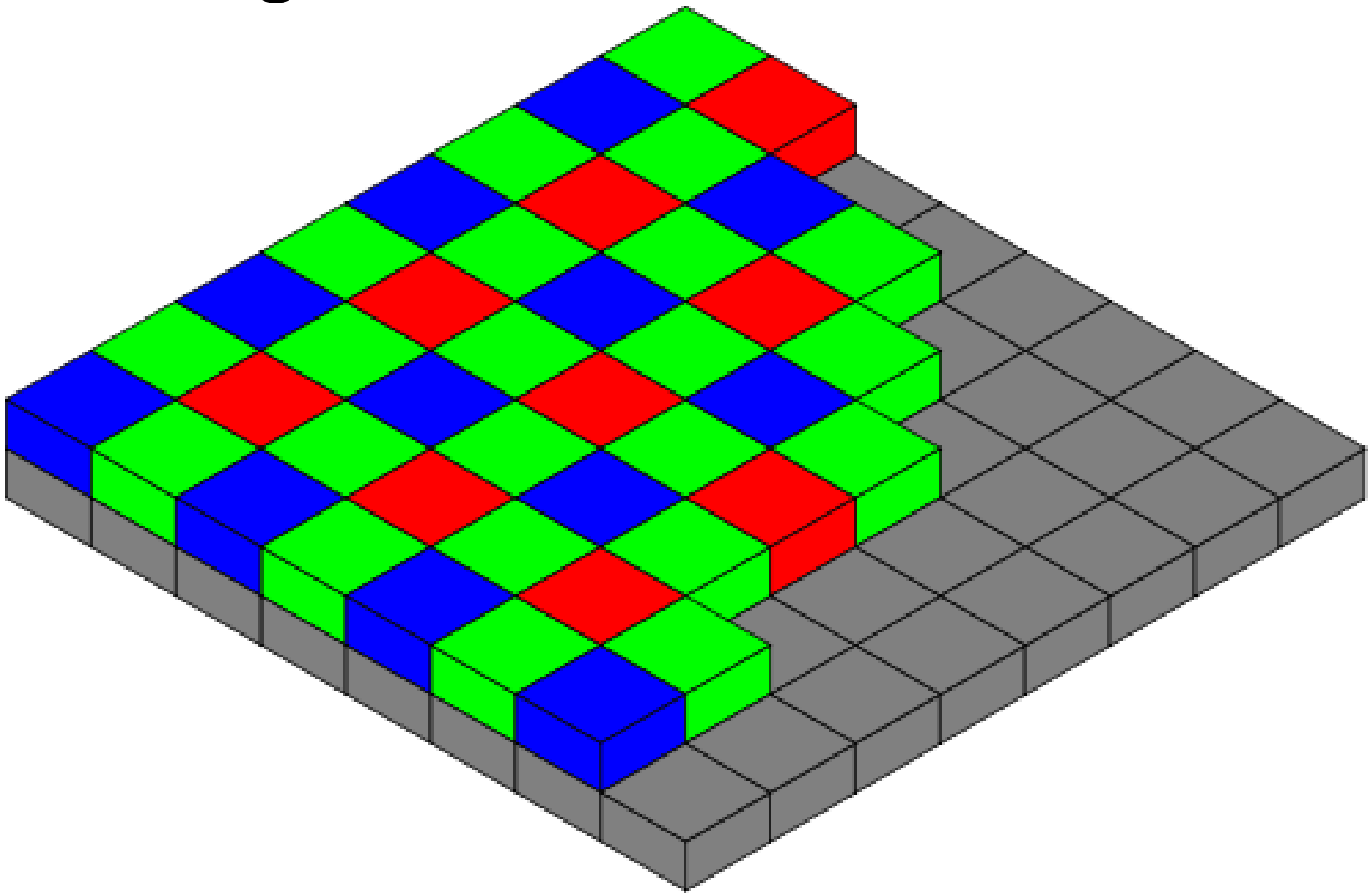
- 640x480
- Analog computer display standard
- 64 possible levels for RGB each.

DE15 VGA Connector

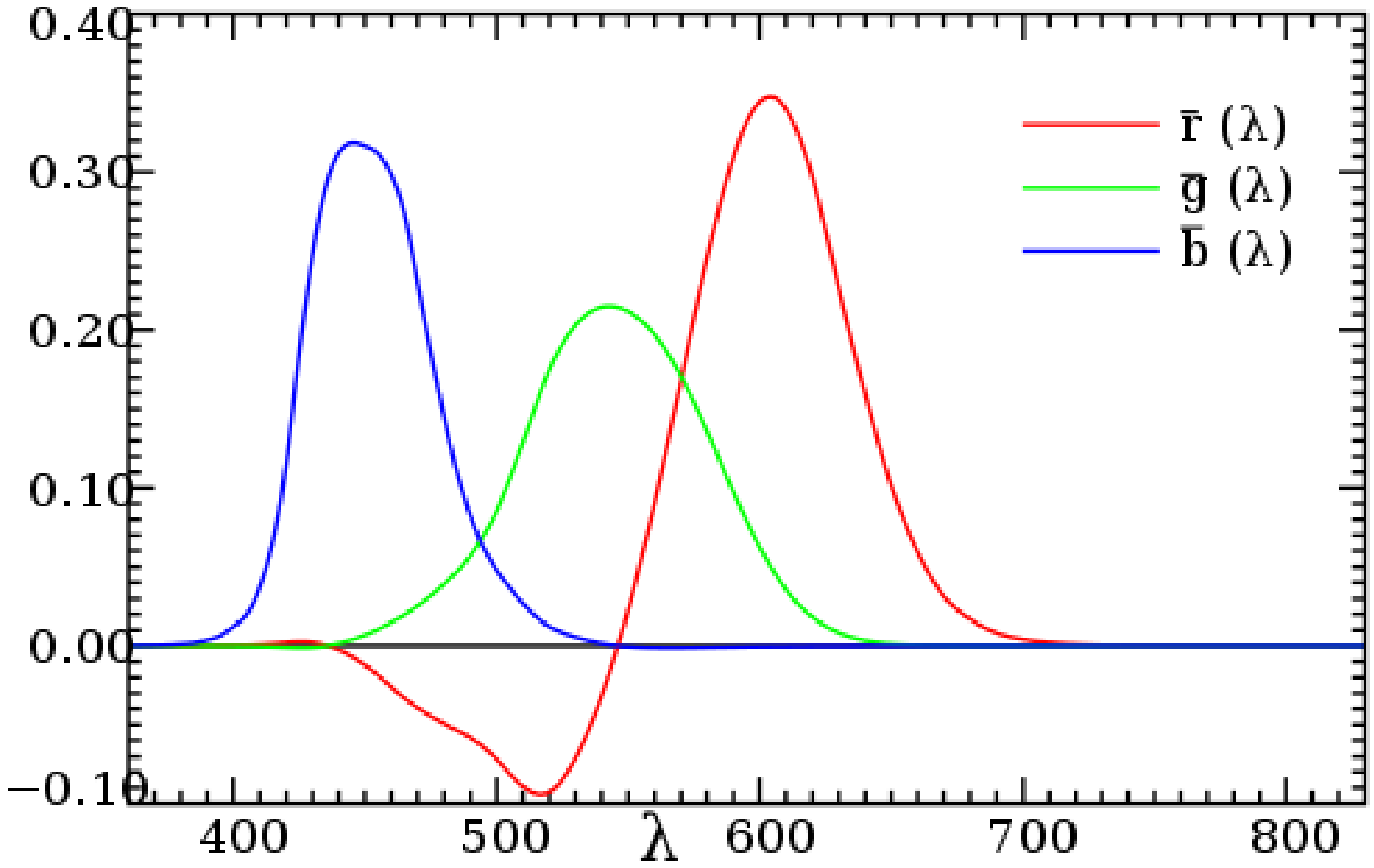
Pin	Function
1	Red
2	Green
3	Blue
4	Reserved
5	Ground
6	Red return
7	Green return
8	Blue return
9	+5V DC
10	Ground
11	Reserved
12	Reserved
13	Horizontal sync
14	Vertical sync
15	



Bayer Mask over Charge-Coupled Device (CCD) for Digit Cameras



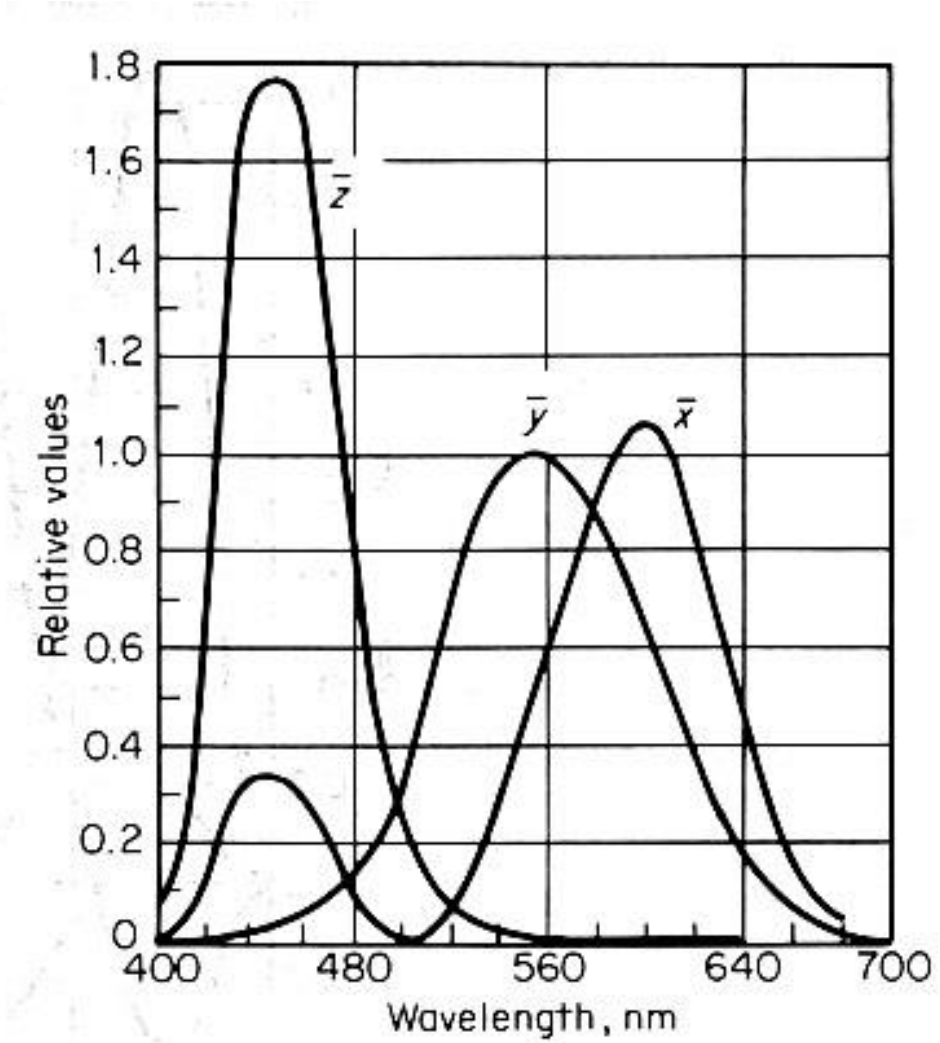
Tristimulus Values



RGB to XYZ in CIE 1931

$$X = 2.7690R + 1.7518G + 1.1300B$$
$$Y = 1.0000R + 4.5907G + 0.0601B$$
$$Z = 0.0000R + 0.0565G + 5.5943B$$

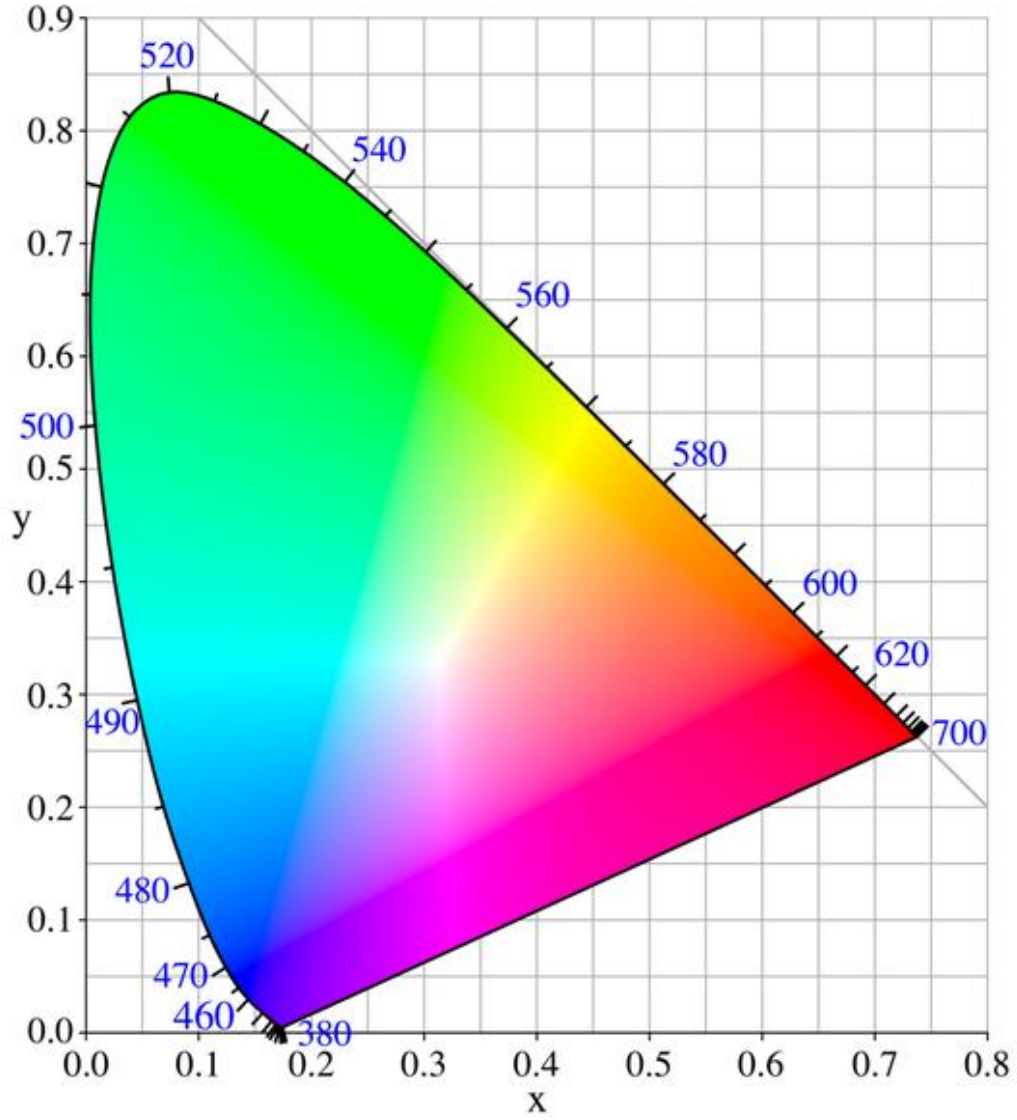
Nonphysical Tristimulus Values



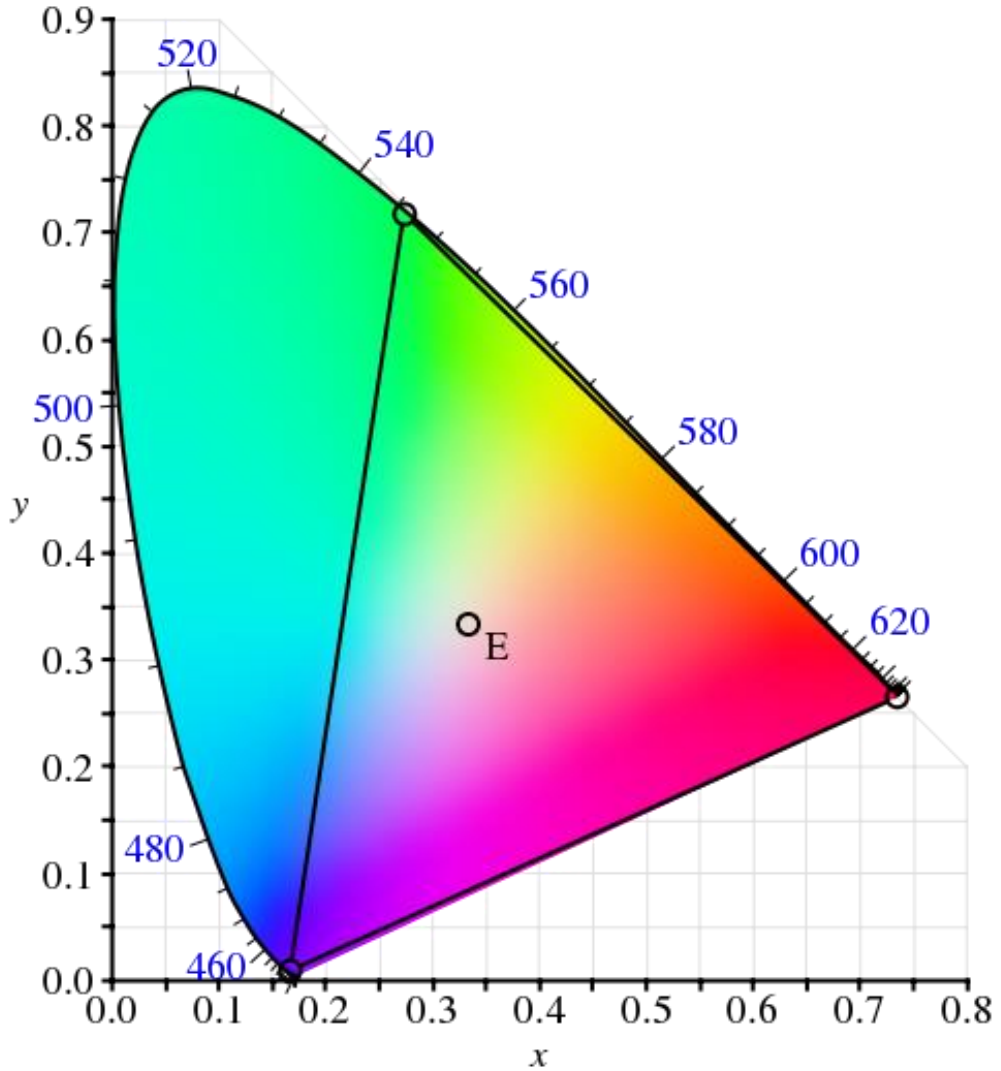
Normalized XYZ

- $x = X / (X + Y + Z)$
- $y = Y / (X + Y + Z)$
- $z = Z / (X + Y + Z) = 1 – x – y$ is redundant

Spectral Locus and Chromaticity



RGB Primaries



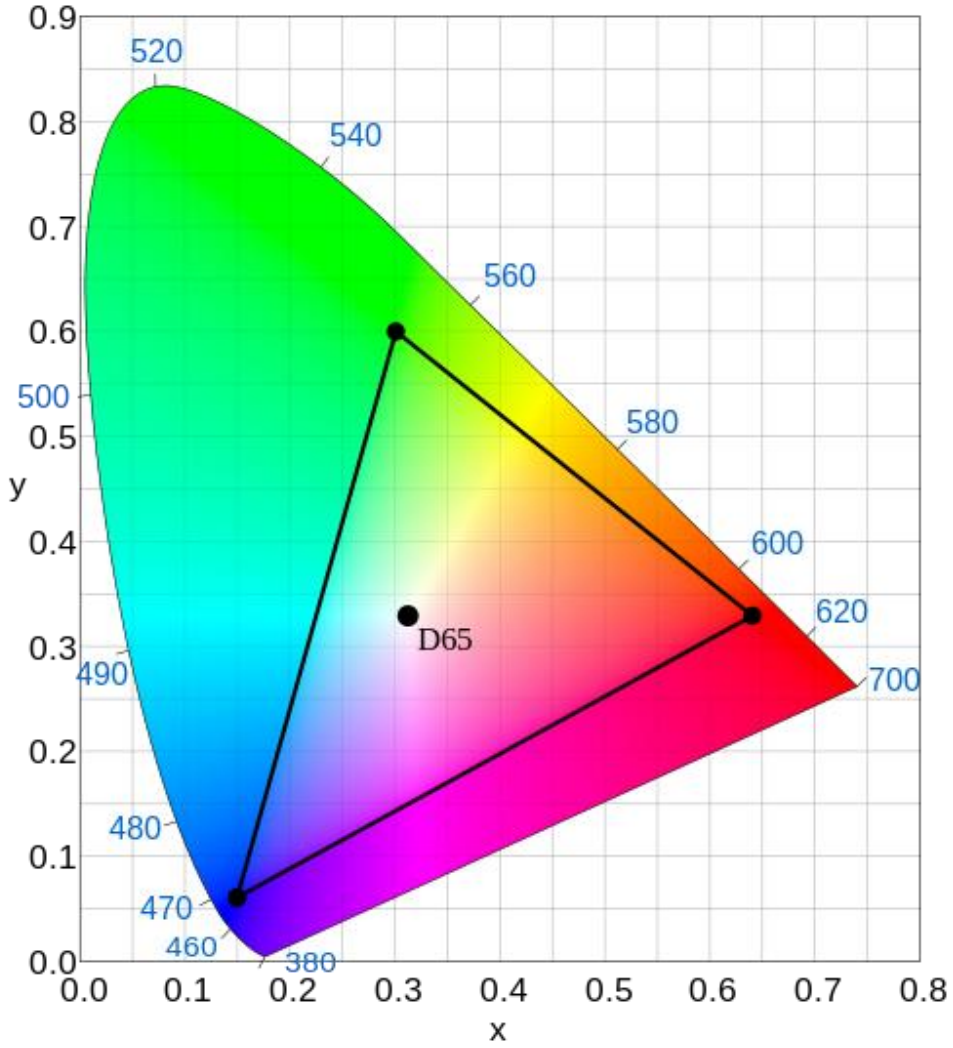
Luminance (ITU-R BT.601, 1982)

- CIE (Commission Internationale de L'Eclairage, International Committee on Illumination) luminance, a characteristic of vision, is the radiant power.
- $Y=(65.738R+129.057G+25.064B)/256 + 16$
- To be compatible to black-and-white TV.

YCbCr Chrominance

- ITU-R BT.601 standard
- Color space transformation
- Cb=(-37.945R-74.494G+112.439B)/256+128
- Cr=(112.439R-94.154G-18.285B)/256+128
- The eye is sensitive to small changes in luminance but not in chrominance.
- ITU-R BT.709 is the standard for HDTV.

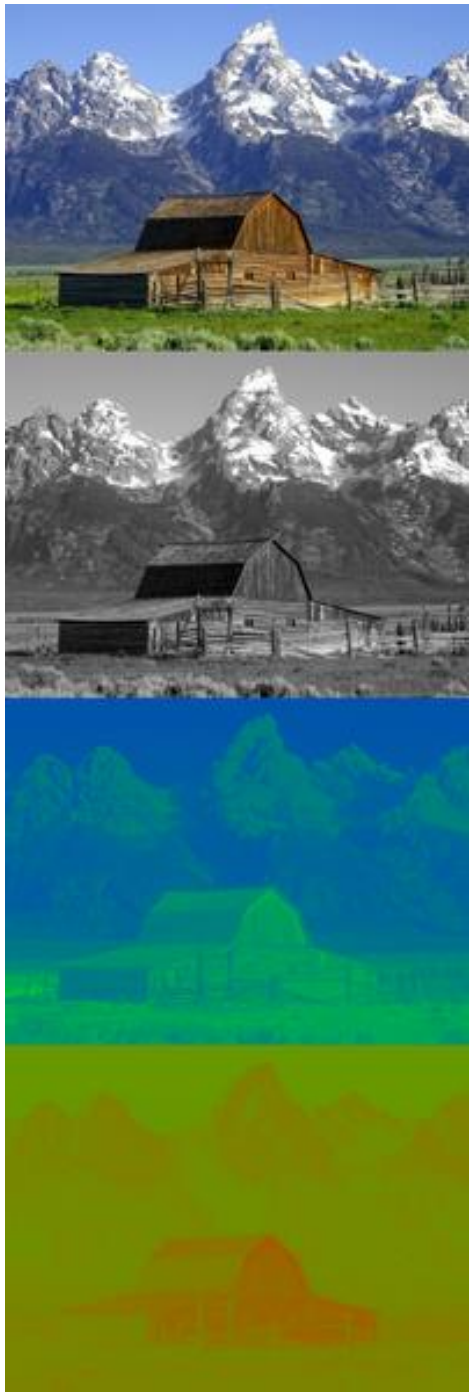
BT 709 (1990) for HDTV



YCbCr (YUV) to RGB

- R = (298(Y – 16) + 409(Cr – 128))/256
- G = (298(Y – 16) – 100(Cb – 128) – 208(Cr – 128))/256
- B = (298(Y – 16) + 516(Cb – 128))/256
- When Cr = Cb = 128, R = G = B = 298(Y – 16)/256 (grey level)

YUV

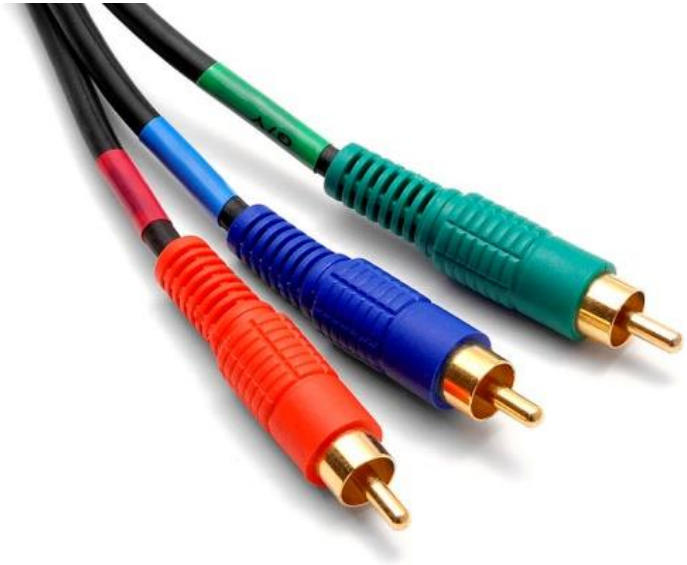


YUV420

Single Frame YUV420:

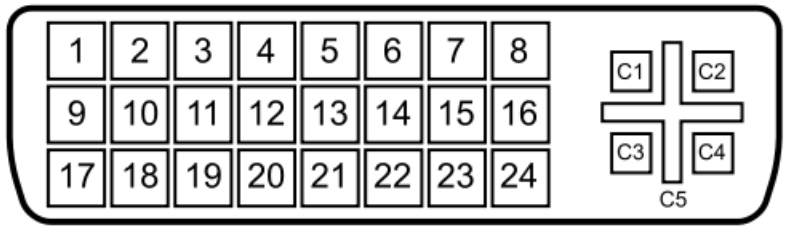
Position in byte stream:

Component Video



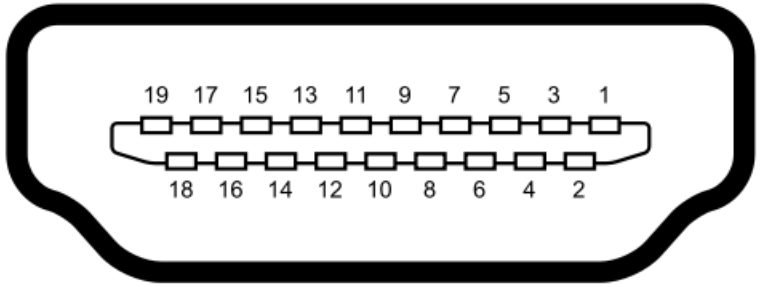
Digital Visual Interface (DVI, 1999)

Pins	Function
1, 2	Red
9, 10	Green
17, 18	Blue
14, 15	Power
6	Clock



HDMI (2002)

Pins	Function
1-3	Data 2
4-6	Data 1
7-9	Data 0
10-12	Clock
18	+5V
19	Hot plug detect



Video Parameters

Application	Frame rate	Resolution	Pixel depth
Surveillance	5	640×480	12
Video telephony	10	320×240	12
Multimedia	15	320×240	16
Analog TV	25	640×480	16
HDTV (720p)	60	1280×720	24
HDTV (1080i)	60	1920×1080	24
HDTV (1080p)	30	1920×1080	24

Table 9.6: Video Parameters for Typical Applications.

Video Resolutions

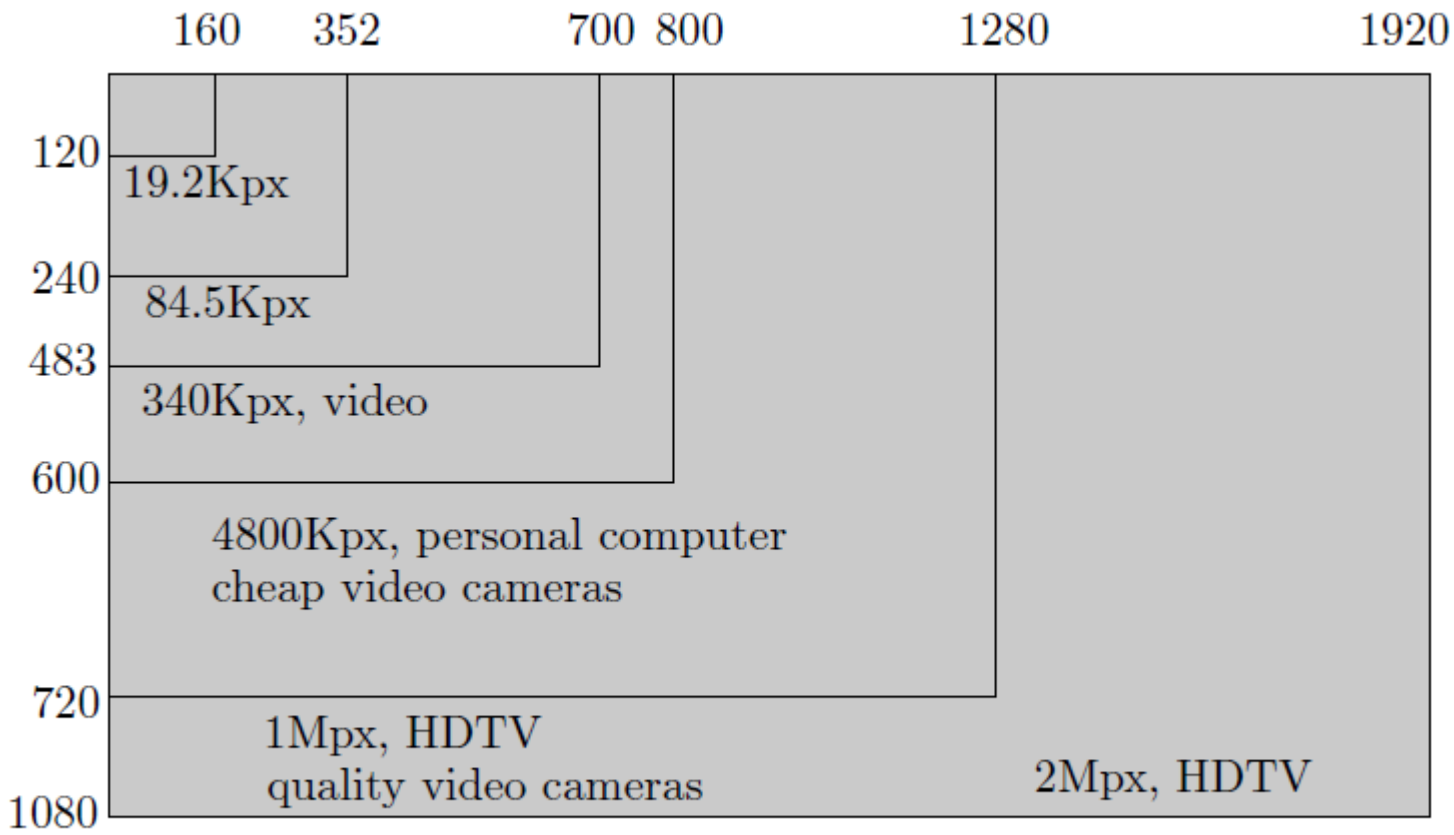


Figure 9.8: Various Video Resolutions.

H.264 or AVC

- H.264/MPEG-4 Part 10 or AVC (Advanced Video Coding) is a standard for video compression, and is currently one of the most commonly used formats for the recording, compression, and distribution of high definition video.
- The final drafting work on the first version of the standard was completed in May 2003.

Development of H.264

- H.264/MPEG-4 AVC is a block-oriented motion-compensation-based codec standard developed by the ITU-T Video Coding Experts Group (VCEG) together with the ISO/IEC JTC1 Moving Picture Experts Group (MPEG).
- The project partnership effort is known as the Joint Video Team (JVT).
- The ITU-T H.264 standard and the ISO/IEC MPEG-4 AVC standard (formally, ISO/IEC 14496-10 – MPEG-4 Part 10, Advanced Video Coding) are jointly maintained so that they have identical technical content.

H.264 is used in

- High Definition DVDs (Blu-Ray)
- High Definition TV broadcasting in Europe
- Apple products including iTunes video downloads, iPod video and MacOS
- NATO and US DoD video applications
- Mobile TV broadcasting
- Many mobile video services
- Many internet video services
- Videoconferencing
- Consumer camcorders.

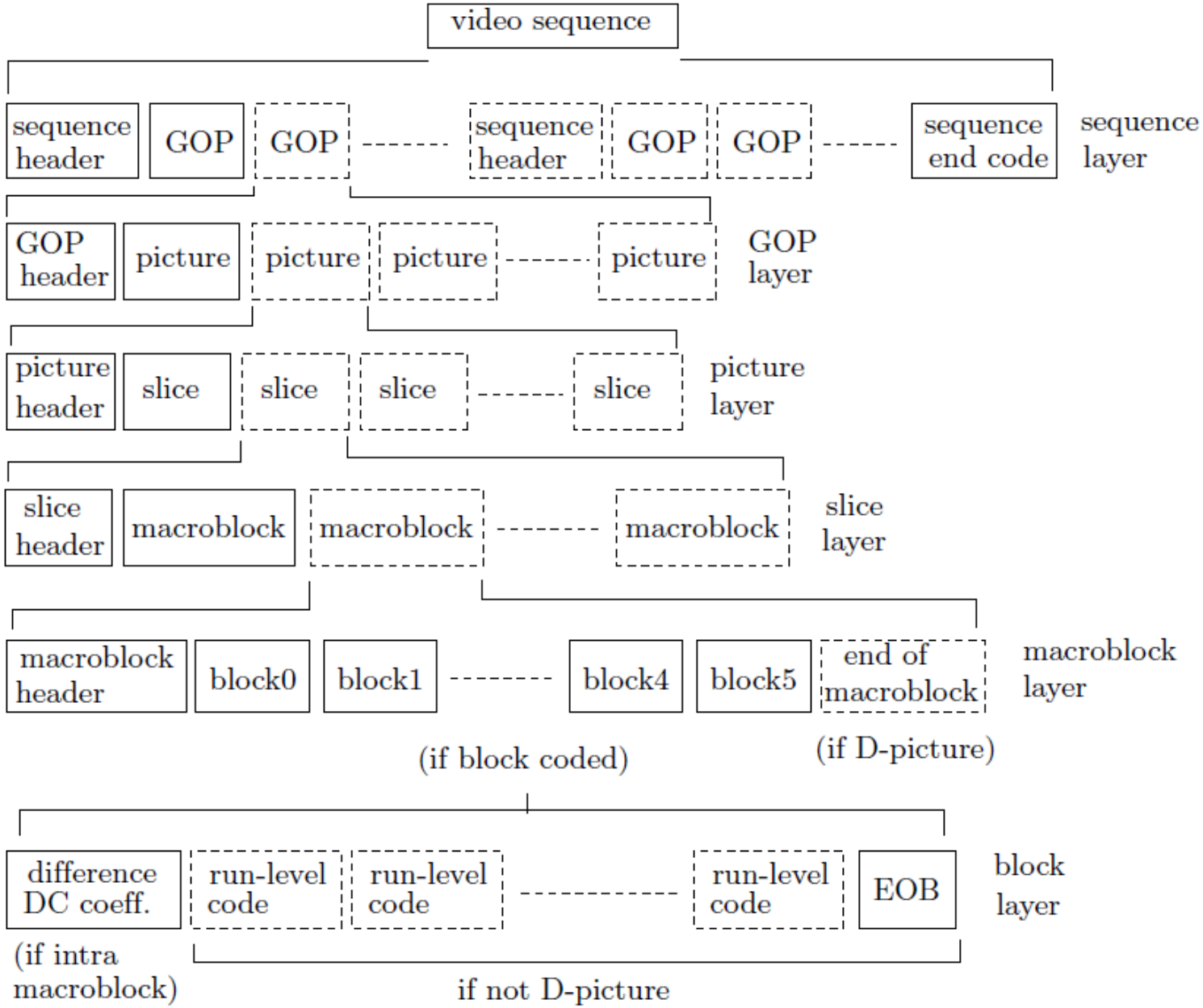


Figure 9.24: The Layers of a Video Stream.

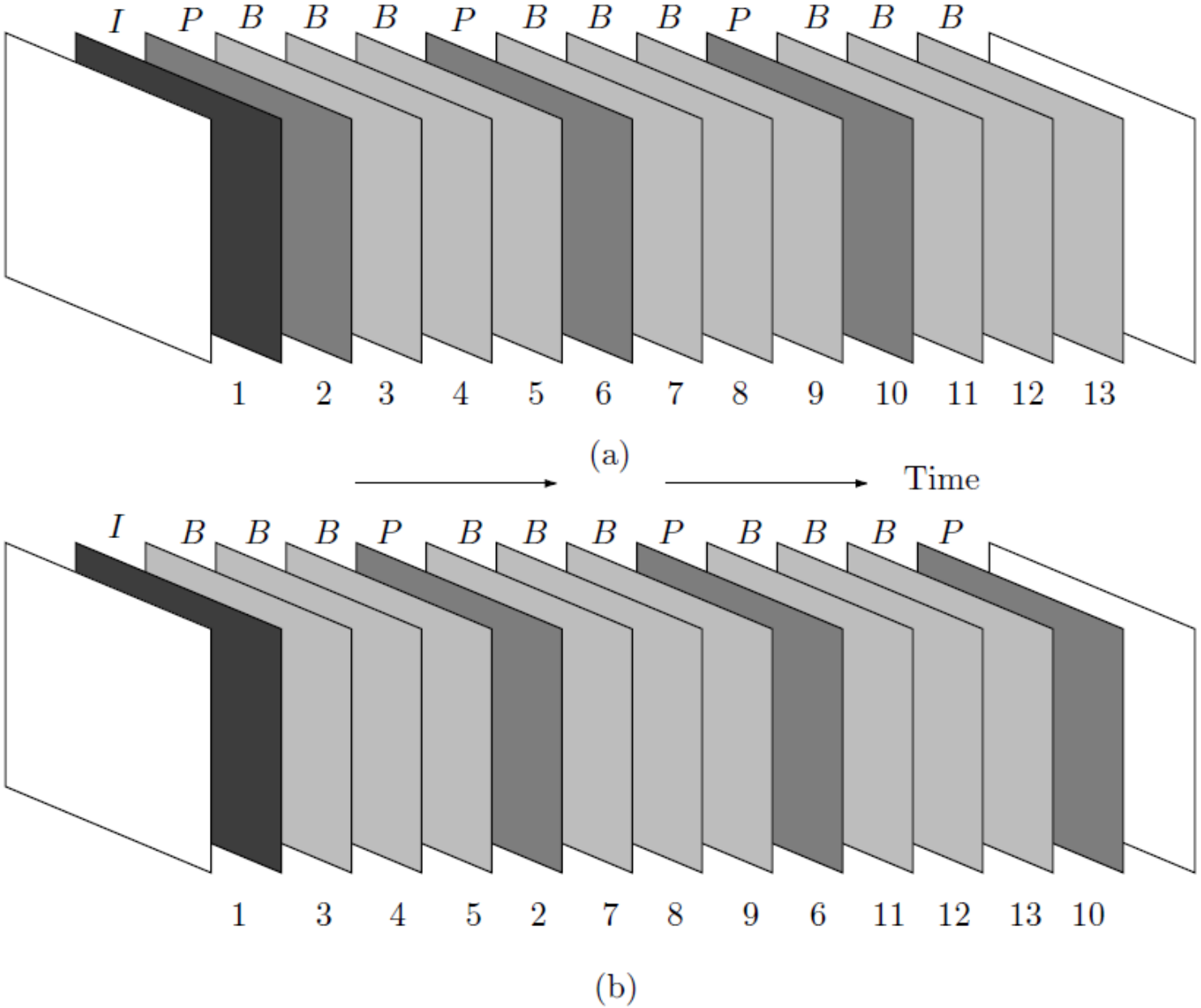


Figure 9.9: (a) Coding Order. (b) Display Order.

Motion Compensation

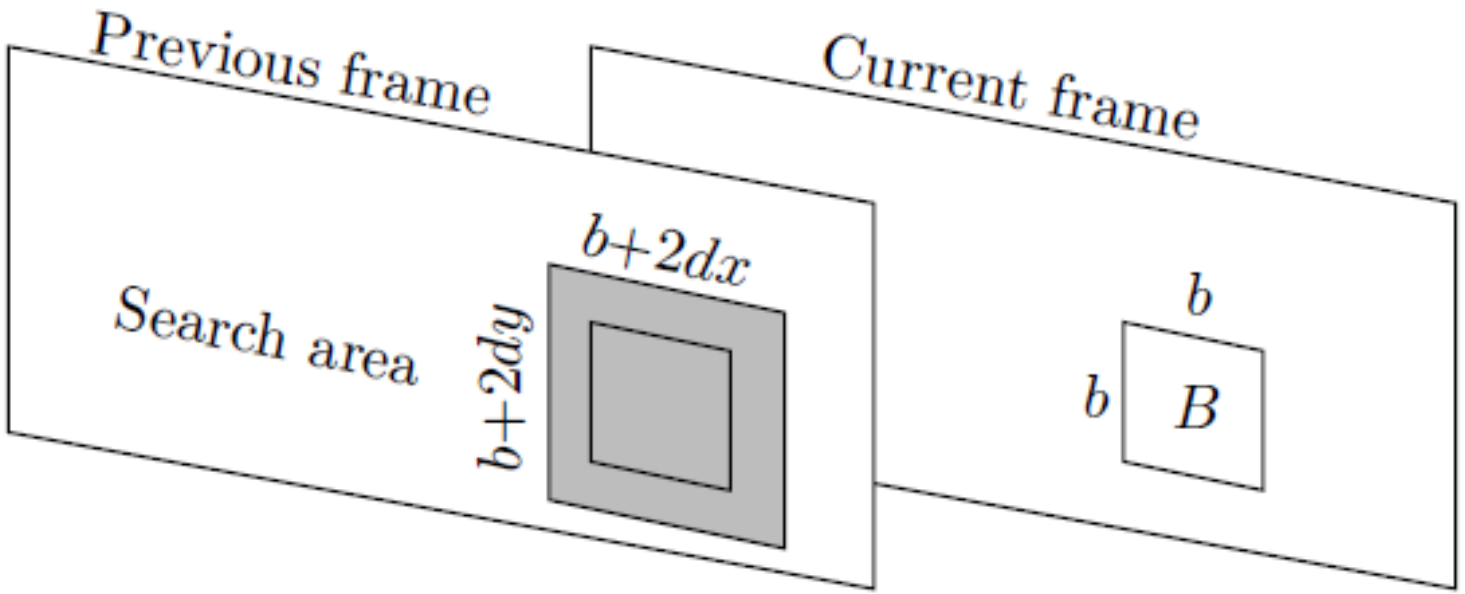


Figure 9.11: Search Area.

H25C: Playback YUV video

```
public class H25C extends JFrame{
    static final int width = 352;
    static final int height = 288;
    static final int halfWidth = width / 2;
    static final int halfHeight = height / 2;
    InputStream in = null;
    int pause = 50;
    int[] pix = new int[height * width];
    int frameSize = height * (width + halfWidth);
    byte[] raw = new byte[frameSize];
    int[][][] yuv = new int[height][width][3];
```

readFrame, raw2yuv, yuv2rgb, drawImage

```
public void playback(){
     Graphics g = getGraphics();
  while (true){
     int len = readFrame();
     if (len < frameSize) return;
     raw2yuv();
     yuv2rgb();
     Image im = createImage(new MemoryImageSource(width,
        height, pix, 0, width));
     g.drawImage(im, 0, 30, null);
     try {
      Thread.sleep(pause);
     } catch (InterruptedException e){}
   }
  }
```

```
int readFrame(){
   int len = 0;
   try{
     len = in.read(raw);
   }catch(IOException e){
    System.err.println("IOException");
    System.exit(1);
   }
   return len;
 }

 void raw2yuv(){
   int index = 0;
   for (int i = 0; i < height; i++)
      for (int j = 0; j < width; j++){
        yuv[i][j][0] = (raw[index] < 0) ?
           (raw[index] + 256) * 298 : raw[index] * 298;
        index++;
   }
```

```
  for (int i = 0; i < halfHeight; i++)
     for (int j = 0; j < halfWidth; j++){
       int i2 = i << 1; int j2 = j << 1;
       yuv[i2][j2][1] = yuv[i2][j2 + 1][1] =
       yuv[i2 + 1][j2][1] = yuv[i2 + 1][j2 + 1][1] =
         (raw[index] < 0) ?
          raw[index] + 128 : raw[index] - 128;
       index++;
  }
  for (int i = 0; i < halfHeight; i++)
     for (int j = 0; j < halfWidth; j++){
       int i2 = i << 1; int j2 = j << 1;
       yuv[i2][j2][2] = yuv[i2][j2 + 1][2] =
       yuv[i2 + 1][j2][2] = yuv[i2 + 1][j2 + 1][2] =
         (raw[index] < 0) ?
          raw[index] + 128 : raw[index] - 128;
       index++;
  }
}
```

```
void yuv2rgb(){
   int index = 0;
   for (int i = 0; i < height; i++){
      for (int j = 0; j < width; j++){
        int red = yuv[i][j][0] + 409 * yuv[i][j][2] + 128;
        red >>= 8;
        if (red < 0) red = 0; else if (red > 255) red = 255;
        int green = yuv[i][j][0] - 100 * yuv[i][j][1] - 208 * yuv[i][j][2] + 128;
        green >>= 8;
        if (green < 0) green = 0; else if (green > 255) green = 255;
        int blue = yuv[i][j][0] + 516 * yuv[i][j][1] + 128;
        blue >>= 8;
        if (blue < 0) blue = 0; else if (blue > 255) blue = 255;
        pix[index++] = (255 << 24) | (red << 16) |
          (green << 8) | blue;
      }

   }
}
```

H25A.java: video compression

```
static final int width = 352;
static final int height = 288;
static final int numberOfFrames = 200;
static final int frameSize = width * height * 3 / 2;
byte[] buffer = new byte[frameSize * numberOfFrames];
byte[] result = new byte[numberOfFrames * frameSize];
int compressedDataLength = 0;

void readFrames(){
   try{
     System.in.read(buffer);
   }catch(IOException e){
      System.err.println("IOException");
      System.exit(1);
   }
}
```

Simple Prediction Using Previous Frame

```
void differential(){
   for (int frame = numberOfFrames - 1; frame > 0; frame--){
    int frameBase = frame * frameSize;
    for (int j = 0; j < frameSize; j++){
      int v = buffer[frameBase + j];
      int u = buffer[frameBase - frameSize + j];
      int diff = v - u;
      buffer[frameBase + j] = (byte)diff;
    }
   }
 }
```

Compression Using Deflater

```
void compress(){
     Deflater compresser = new Deflater();
     compresser.setInput(buffer);
     compresser.finish();
     compressedDataLength = compresser.deflate(result);
     System.out.write(result, 0, compressedDataLength);
     System.out.flush();
 }
```

```
void readCompressedData(){
     try{
       compressedDataLength = in.read(result);
     }catch(IOException e){
      System.err.println("IOException");
      System.exit(1);
     }
 }

void decompress(){
  try {
    Inflater decompresser = new Inflater();
    decompresser.setInput(result, 0, compressedDataLength);
    int resultLength = decompresser.inflate(buffer);
    decompresser.end();
    if (resultLength != numberOfFrames * frameSize){
     System.err.println(resultLength);
     System.exit(1);
    }
   } catch (java.util.zip.DataFormatException ex) {
    System.err.println(ex.getMessage());
    System.exit(1);
   }
 }
```

H25B.java: Video Decompression and Playback

```
public void playback(){
    Graphics g = getGraphics();
for (int i = 0; i < numberOfFrames; i++){
    getFrame(i);
    raw2yuv();
    yuv2rgb();
    Image im = createImage(new MemoryImageSource(width,
       height, pix, 0, width));
    g.drawImage(im, 0, 30, null);
    try {
     Thread.sleep(pause);
    } catch (InterruptedException e){}
 }
}
```

```
 void getFrame(int frame){
    int frameBase = frame * frameSize;
    if (frame > 0)
     for (int j = 0; j < frameSize; j++){
/*  This is how we got buffer[frameBase + j} in H25A.java:

      int v = buffer[frameBase + j];
      int u = buffer[frameBase - frameSize + j];
      int diff = v - u;
      buffer[frameBase + j] = (byte)diff;

     We need its inverse.
     Given the recovered preceding frame value u and the differential
     in buffer[frameBase + j], write the code to replace buffer[frameBase + j}
     with the recovered v.
*/
    }
    for (int i = 0; i < frameSize; i++) raw[i] = buffer[frameBase + i];
   }
```

Homework 25: due 4-27-15

- Complete the getFrame() function in H25B.java and run it on test25.