5. COLOR MODELS AND MODES

Let's move on to a very important and complex characteristic of an image, like *color*. An image can be *black and white* (that is, contain only two colors: white and black), *grayscale* (that is, contain different shades of the same color) and *color*. But the color image can be in a different color model. To choose the optimal color model or color mode, you need to have an understanding of the basics of color formation in computer graphics. The color of a bitmap pixel is determined by its bit depth.

5.1. Bit depth of color

Bit depth refers to how many bits of memory are allocated to store the color information for each pixel. The greater the color depth, the more shades can be displayed. So, in a monochrome black and white image, only one bit is allocated for each pixel: 2^1 – color can be either *black or white*.

The grayscale image uses 8-bit color depth, it is able to convey already 2^8, or 256, shades of color, from white to black (or any other color). Color images require even more memory. Depending on the color model, each pixel requires 2^8x2^8 x2^8, i.e. 24 bits for RGB and HLS models and 2^{8x4}, that is bits, for CMYK color model (8 bits for each primary color).

If the graphics are intended for screen viewing, how many colors the display monitor itself can convey begins to play a significant role, and this depends on the size of the computer's video memory in which the screen image is stored. Current versions of Adobe Photoshop allow you to work with images in which the pixel bit depth can be 16 and 32 bits. Increasing the bit depth of a pixel results in larger file sizes, but these images provide more tonal levels.

5.2. Color models

Depending on the application, different color models have been created: additive, subtractive and perceptual [2,4]. The additive models include the **RGB** color model, the subtractive models include the **CMYK** model, and the perceptual models include the **HSB** model.

Monitors use the RGB color model, which is based on three basic colors: red **(Red)**, green **(Green)** and blue **(Blue)**. The absence of all colors in this model gives black, and the presence of white.

In printing, the most commonly used color model is **CMYK**, based on four basic colors: cyan **(Cyan)**, magenta **(Magenta)**, yellow **(Yellow)** and black **(BlacK)**. In this model, the absence of all colors means white, the presence of black. A mixture of primary colors in equal proportions gives secondary colors for the respective models.

The primary and secondary colors of the **RGB** and **CMYK** models are shown in Figure 5.1, and are located in the *Model.jpg* image from the *Lesson 5* folder.

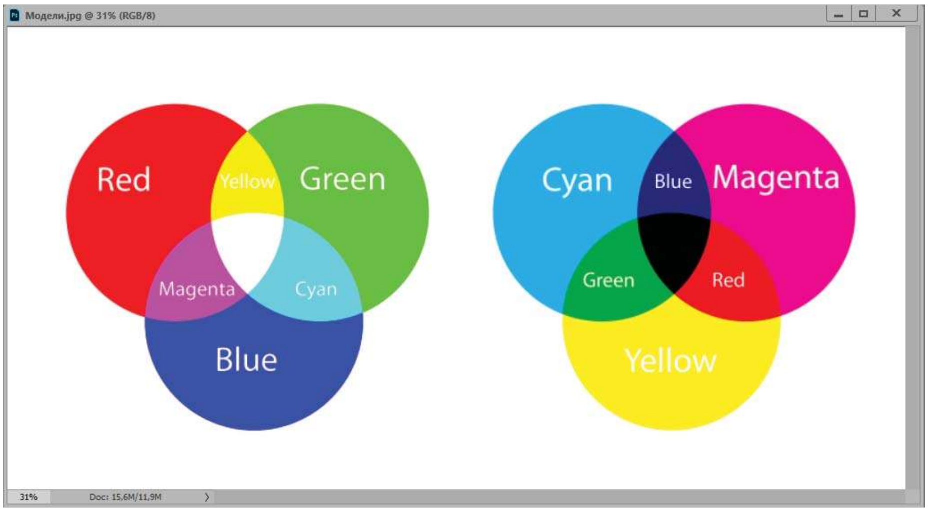

Fig.5.1. Primary and secondary colors of **RGB** and **CMYK** models

The **CMYK** and **RGB** palettes have different color gamuts (ranges of colors) that can be reproduced. The color gamut of the **RGB** palette is much wider than that of the **CMYK** palette. Therefore, some of the colors you see on your monitor screen can only be approximated by the printer.

In addition, Adobe Photoshop supports the **Lab Color** color model. This universal model allows you to get almost any color available to the human eye. Its colors look exactly the same on the monitor and on the printer. Adobe Photoshop uses this model to translate an image from one model to another.

When color correcting images, Adobe Photoshop uses the **HSB** and **HLS** perceptual models. In these models, the color is determined by three parameters: **Hue, Saturation** and **Brightness** or **Lightness**. **Hue** indicates the position of a color on the color wheel. **Saturation** reflects its intensity. The more saturation, the more saturated the color becomes. The smaller it is, the more faded, gray it becomes. Luminance reflects the amount of light passing through a transparent color object in the **HLS** system and the amount of black in a color for the **HSB** model. The greater the brightness, the closer the color to white, the lower it is, the darker the color. At minimum brightness it turns black.

To print an image, you must select the **CMYK** palette, and to display *on the screen*, the **RGB** palette is preferable.

5.3. Color channels

When 24 or 32 bits are assigned to each pixel, they are divided into three or four groups of 8 bits each. The bits of one group make up a channel, with an 8-bit color depth, an image can contain 256 shades of color, from white to black. Thus, we can consider that each channel is a monochrome halftone image (it is also called a gray scale image), and the final full color image is made up of three or four halftone images.

Each color model has its own channels. For example, in the **RGB** model, one channel describes the red component, the second - the green and the third - the blue component of the color. The **CMYK** model has four channels: cyan, magenta, yellow, and black. There are three channels in the **Lab** model, one of them describes the brightness **L**, and the other two describe the variables **a** and **b**.

By default black and white, grayscale, duplex and indexed palette images have only one channel, **RGB** and **Lab** images have three channels, and **CMYK** images have four channels. However, you can create additional channels in the form of alpha channels, which are necessary to store complex selections in documents.

5.4. Channel Palette

To view an image in different channels and to work with channels, use the **Channels** palette (Fig.5.2). To call it on the screen, execute the **Window/Channels** command. To view the color channels, open the *Flower.jpg* image from the *Lesson 5* folder.

In the left column of the palette there is a channel visibility indicator in the form of an eye icon. By default, all channels are enabled and you see a full color image with all channels mixed together. You can view the image in one, two or more channels. To return to showing all channels, click in the visibility indicator of the top line with the name of the color model (RGB, CMYK, Lab). To make one channel active, click on the line with its name.

For example, select the **Red** channel (this image is in the RGB color model) and you may see only a grayscale halftone instead of a reddish image. Don't worry if you suddenly think you're *hallucinating*. I can assure you that it is not.

In order to restore normal color perception, you must execute the following **Edit/Preferences** command and on the Interface tab check the **Show Channels in Color** checkbox.

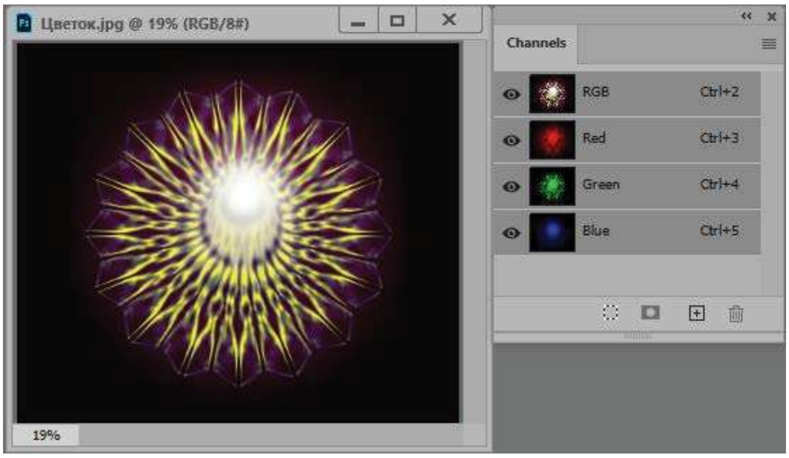

Fig.5.2. Palette **Channels**

However, this is not always convenient, since it is much more difficult to work with color halftone images: details are less distinguishable and eyes get tired faster. When viewing two or more channels, the image will always appear in color due to color mixing. When mixing channels, the secondary colors that appear are shown in Fig. 5.1.

By selecting channels one at a time, you can adjust them independently of each other. You can grayscale not a full color image, but only one channel if it looks better than the full color image after grayscale. Information about other channels will be lost.

5.5. Color modes

Color modes are the implementation of a color model within a particular graphics editor. To convert an image to another color model, use the **Image/Mode** command and then select the desired mode in the submenu:

- **Bitmap -** black and white image;
- **Grayscale -** halftone image, or image in gray scale;
- **Duotone -** duplex, that is, a halftone image to which one more color has been added (although a four-color option can also be selected here);
- **Indexed Color -** indexed colors;
- **RGB Color -** RGB mode;
- **CMYK Color** – CMYK mode;
- **Lab Color** – Lab mode;
- **Multichannel -** multichannel mode, when each channel exists separately, without mixing.

If the command is grayed out, then the current mode is not available. For example, a color image cannot be converted to black and white; you must first convert it to grayscale. Some commands are executed with confirmation of color loss information.

If the conversion from the **RGB** palette to **Lab** and vice versa does not lead to loss of color information, then the same cannot be said about the conversion from **RGB** or from **Lab** to **CMYK**. The **CMYK** color gamut is much smaller, and moreover, it depends on specific models of printers or phototypesetters. You will notice how bright colors fade, and some shades may change. Therefore, it is preferable to transfer to this palette before printing itself.

Exercise 5.1. Color modes

1. Refresh the workspace using the **Window/Workspace/Reset Basic-1** command.
2. Open the document *Flower.jpg* from the *Lesson 5* folder.
3. Duplicate the image with the **Image/Duplicate** command and place it next to the original image.
4. Click on the title of the duplicate and open the Channels palette. This image is in the **RGB** model, respectively, contains three channels, the file size is 6.71 MB.
5. View the content of each channel. Then turn on pairs of color channels (eyes) in order to get an image in tones of secondary colors: yellow, blue and purple.
6. Turn on all channels. To convert an image to the **CMYK** color model, run the following **Image/Mode/CMYK Color** command, and you may notice some fading in the yellow tones. You can compare the colors of the duplicate and the original.
7. In the **CMYK** color model, the image consists of four channels, the file size is already 8.94 MB, since one more channel has been added.
8. View the content of each channel. Then turn on color channels in pairs in order to get an image in tones of secondary colors in this model (Fig. 5.1): red, blue and green.
9. Turn on all channels. Convert the image to the **Lab Color** color model by executing the **Image/Mode/Lab Color** command.
10. View the contents of each channel and their pairings. The **Lightness** channel contains only luminance information, the **a** and **b** channels contain different color ranges of the color wheel. The file size is 6.71 MB because there are three channels.
11. Go back through the History palette to the line **CMYK Color**. Convert the image to the Multichannel color model using the **Image/Mode/Multichannel** command. The image consists of four independent channels, and the file size is 2.24 MB (this is the size of one channel).
12. Return to the line **Open** palettes **History**. Convert the image from the **RGB** color model to the **Multichannel color** model in the same way. The image

consists of three independent channels (colors from the **CMY** model), the file size is again independent of the number of channels, and is 2.24 MB. Also notice how much the hue of the background color has changed.

Exercise 5.2. Converting to halftone modes

1. Open the *Flower.jpg* document from the *Lesson 5* folder.
2. Open palette **Channels**. Let's convert this image from **RGB** model to grayscale grayscale with **Image/Mode/Grayscale** command.
3. After executing the command, the program will need your consent to the loss of color information. After confirming in the channels palette, you will find only one gray channel. Pay attention to the file size, it has decreased from 6.71 MB to 2.24 MB. A threefold decrease is associated with a decrease in the number of channels.
4. Convert the image to duplex mode with the **Image/Mode/Duotone** command.
5. In the dialog box, in the **Type** rollout, you can select the number of color inks (up to four **Quadtones**) and adjust the duplex curve to the left of the color sample window.
6. One channel with the name of the selected number of colors will appear in the channels palette. The file size has not changed and does not depend on the number of colors.
7. This model is used to prepare an image for poster printing, usually no more than two colors are used in practice. Increasing the number of colors leads to the resulting brown color.
8. Using the **Monotone** mode in the **Type** rollout, you can tint gray images or photos with one color.

5.6. Indexed Colors

Color depth characterizes the amount of memory for each pixel. Each color when shown on the display is decomposed into three components: **R** - red, **G** - green and **B** - blue. Thus, the pixel color information is divided into three channels, that is, into parts that reflect the brightness of each component.

At an early stage in the development of computer technology, displays were mainly used that were unable to display more than 256 colors, then there was another way to store color information - indexed colors. In this mode, for each pixel, only its index is stored, or a number in a palette of 256 colors common to the entire graphic file. When exporting to this model, the colors that are present in the original full-color image are selected, which makes it possible to achieve quite normal color rendering.

The file size is significantly reduced when indexed colors are used. Although the need to use this method disappeared with the disappearance of old displays, the Internet appeared, and in connection with this, it became necessary to minimize file sizes in order to reduce the time for transferring them over the network.

You can convert a grayscale image or an image in the **RGB** model to indexed colors. When translating a color image, a dialog box appears (Figure 5.3, left), in which the conversion parameters are defined. If the image has more than 256 colors, then some of them are discarded during conversion. Adobe Photoshop uses various palettes for this: **Local, Exact, Uniform, Custom, Adaptive, System (Windows, Mac OS)**.

By selecting the **Custom** type in this rollout, you will be able to manually edit the palette in the **Color Table** dialog box (Figure 5.3, right), selectively replacing some colors with others or choosing one of the standard palettes. This table is called by the command **Image/Mode/Color Table**.

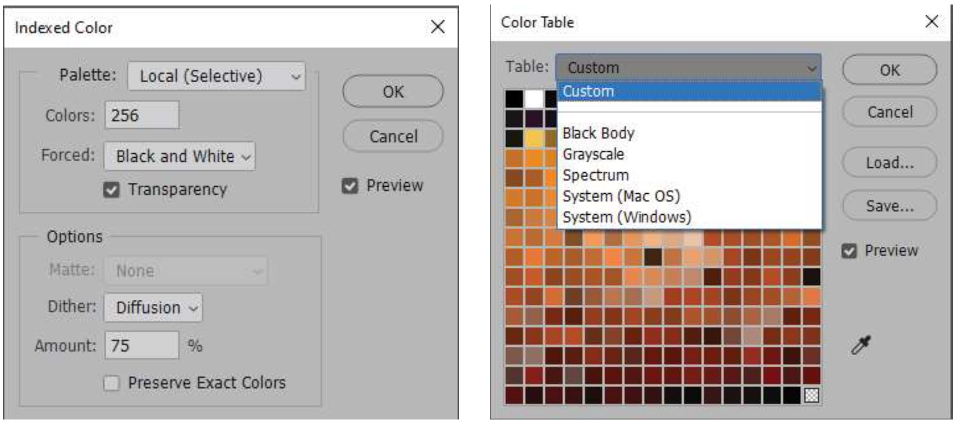

Fig.5.3. Indexed Palette Settings Window and Color Tabl

In the **Table** rollout, you can select one of the standard indexed palettes: **Black Body -** a set of colors emitted when a black body is heated, **Grayscale -** a gray scale, **Spectrum -** the spectrum of sunlight, **System -** two standard system scales for **Windows** and **Macintosh**.

To change the color manually, click on the corresponding square, select the desired color in the **Color Picker** window. When indexing a color image, you can simultaneously convert it to a gray scale and replace it with a scale with a color transition between any two colors.

As an exercise, let's convert an image from an **RGB** model to a grayscale image and then tone it by replacing the grayscale with shades of other colors.

Exercise 5.3. Toned Sunset

1. Open the *Sunset.jpg* image from the *Lesson 5* folder.

2. Duplicate the image. For a duplicate, run the **Image/Mode/Grayscale** command. The image will turn gray halftone, but we will try to restore these colors.
3. Convert it to an indexed scale with the command **Image/Mode/Indexed Color**.
4. Call up the color table with the **Image/Mode/Color Table** command. The table consists of 256 colors (squares). Click on *the upper left* color square and drag the pointer to the *opposite corner* of the table, thus selecting all the squares.
5. After that, the **Color Picker** window will appear on the screen to select two new colors. First you have to replace the top color i.e. black. Click, for example, in the dark orange part of the narrow vertical spectral scale, then in the left square box, click on any dark red hue. Click the **OK** button. The image will be filled with a solid color.
6. Now in the same window, select the end color of the transition. Choose a light *yellow color* in the left square box. Click the **OK** button.
7. If you have the Preview check box checked, the image will immediately be repainted in shades of *orange-red*, becoming tinted.
8. Compare the resulting image with the original, so you can tone any gray image. The result is shown in Figure 5.4, also in the *Sunset tinted.psd* file in the *Lesson 5* folder.

Fig.5.4. Toned image

Self-study

Tint the *Sunset.jpg* image based on the standard **Black Body** indexed color table from the **Table** rollout, and also try a combination of dark blue with yellow color in the custom palette (or any other combination you like).

5.7. Monochrome image

Only a grayscale image can be converted to a *monochrome* black and white image, after which the file size is significantly reduced (especially if the image is a graphic image). It should be noted that halftone images are printed using a halftone screen, i.e. gray tones in raster printing are transmitted only using black ink.

The entire image is divided into square raster cells, consisting of several pixels. The darker the tone, the more black pixels in the raster cell and vice versa. The cells line up in lines inclined at some angle. These lines are called raster lines. Black pixels can be grouped within a cell in the form of lines, circles, diamonds, etc., forming a halftone dot. The shape of this dot can also be selected when adjusting the raster.

To convert a gray image to black and white, execute the **Image/Mode/Bitmap** command. In the dialog box (Fig.5.5) the transformation parameters are set. In the **Output** rollout of the **Resolution** section, enter the resolution of the target output device.

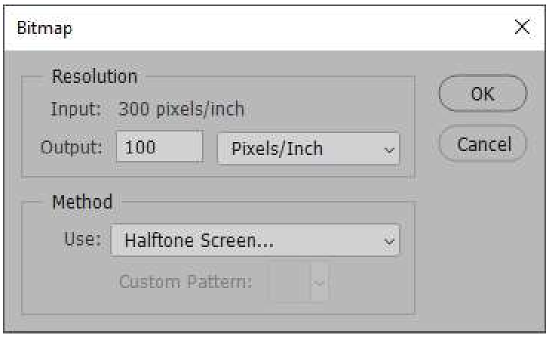

Fig.5.5. Convert to Monochrome Dialog Box

- In the **Method** rollout, the conversion method is selected:
- **50% Threshold**, all pixels whose brightness exceeds 50% turn white, the rest turn black;
- **Pattern Dither** - black and white pixels in a raster cell are arranged in a standard geometric pattern;
- **Diffusion Dither** - black and white pixels in a raster pattern are arranged randomly;
- **Halftone Screen** - this mode gives a wide range of options for setting the raster parameters: lineature, tilt angle, shape of the halftone dot;

- **Custom Pattern -** a ready-made raster pattern is selected.

Exercise 5.4. Convert to monochrome image

1. Open the *Portrait.jpg* image from the *Lesson 5* folder.
2. This sketch is *"brought"* out of the right spot with the drawing tools. Convert it to grayscale with the **Image/Mode/Grayscale** command.
3. Execute the **Image/Mode/Bitmap** command to convert to black and white, this will reduce the file size by several orders of magnitude due to one bit depth.
4. In the **Output** rollout, from the Resolution section, enter the resolution of the target output device, for example, 100 dpi (pixels per inch). The higher the resolution, the better the quality of the monochrome image.
5. In the **Method** rollout, select the **Diffusion Dither** method. Click the **OK** button.
6. Go back to the gray image in the **History** palette by clicking on the **Grayscale** line. During transformations, the size of the document window will change.
7. Now we will again convert the gray image to monochrome, but using a halftone screen.
8. Run the **Image/Mode/Bitmap** command again. This time in the **Method** rollout select **Pattern Dither** first, then **Custom Pattern** and **50% Threshold.** At the same time, after each transformation on the **History** palette, we return to the gray image by clicking on the line Grayscale.

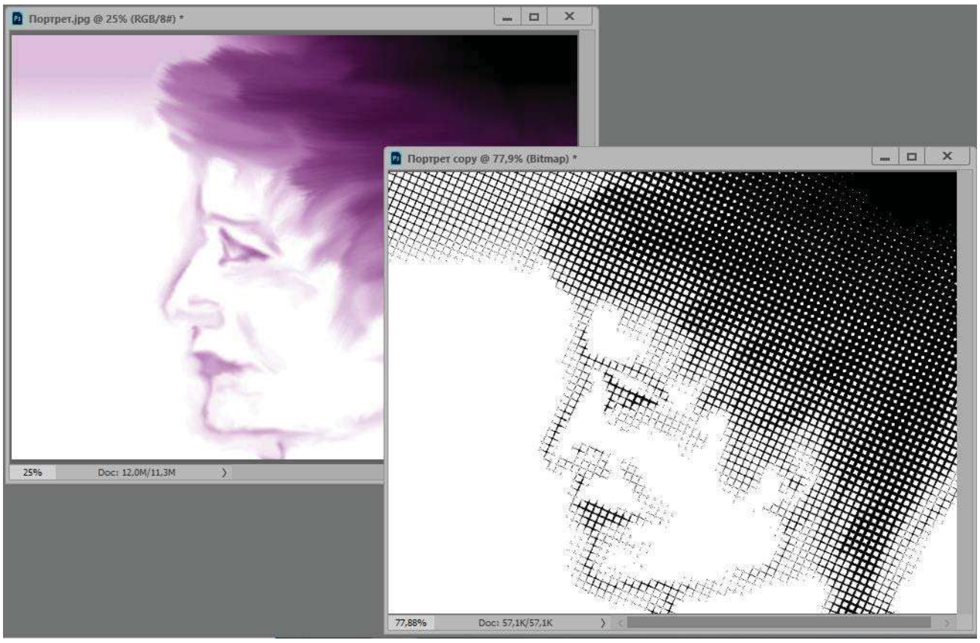

Fig.5.6. Original and monochrome black and white image

9. Call the dialog box again and select the **Halftone Screen** method. In the dialog box, in the **Frequency** rollout, enter the raster lineature, that is, the number of raster elements per inch, set **50 lines/inch**. The greater the difference between resolution and lineature, the more shades a monochrome image can convey.
10. In the **Angle** field, leave the angle at **45°**. This is the standard angle of inclination of the raster lines.
11. In the **Shape** rollout, select the shape of the halftone dot. You can choose: **Round, Diamond, Ellipse, Line, Square, Cross**. Select **Line**, click the **OK** button.
12. If you look at the resulting image at a scale of 200% or 400%, you will see how the raster works. You will see lines at a **45°** angle.
13. Figure 5.6 on the right shows a monochrome image with the following parameters: *resolution 100 dpi, Halftone Screen method, Frequency 10, angle 25°, Cross*).

Self-study

Convert portrait to black and white image in **Halftone Screen** mode with **Frequency** *20 lines/inch*, *300 scanline* angle and different halftone dot shapes.