HTML 5 Canvas

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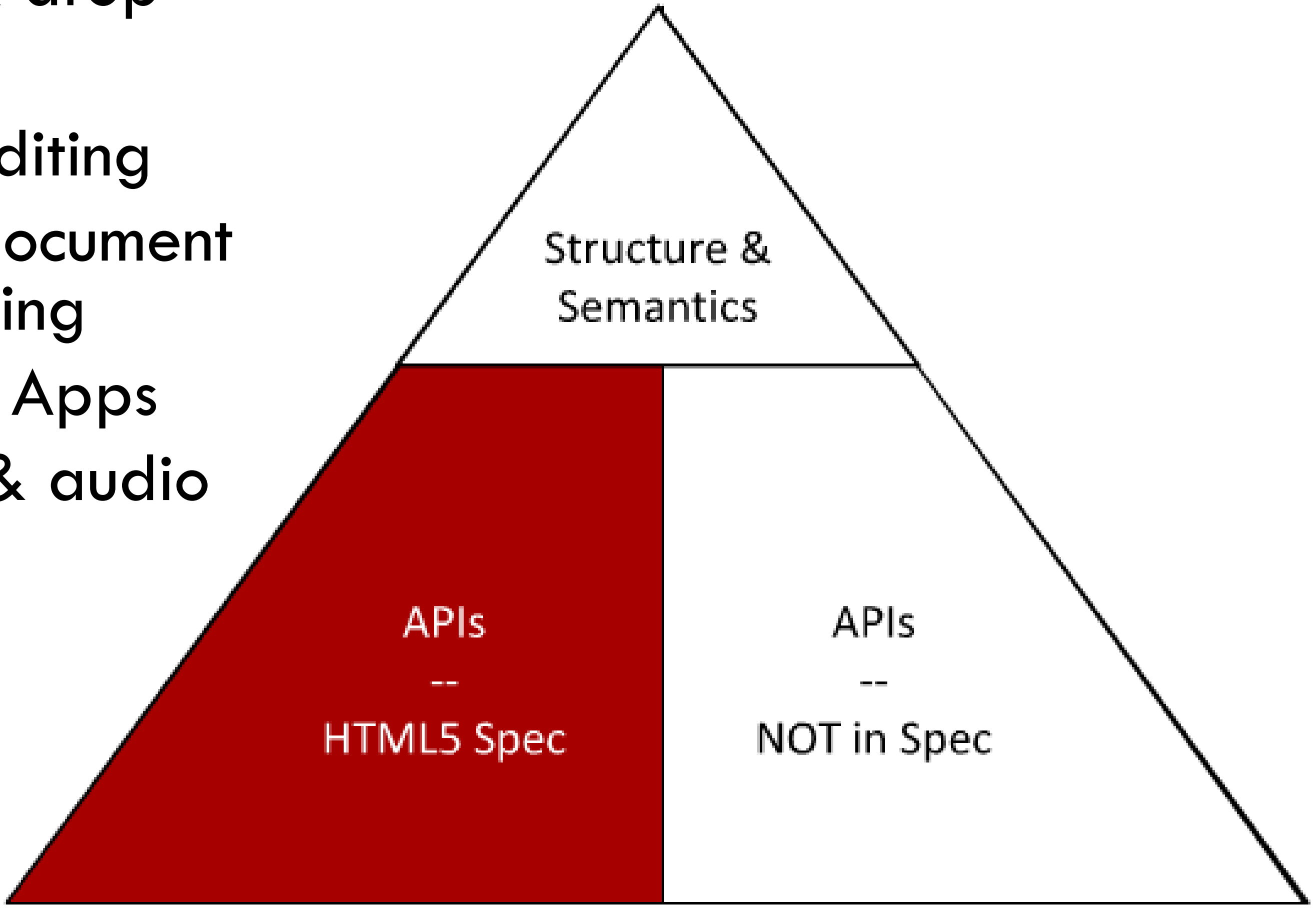
What's new in HTML5

- Canvas
- Drag & drop
- History
- Inline editing
- Cross-document messaging
- Offline Apps
- Video & audio



Drawing on a Web page

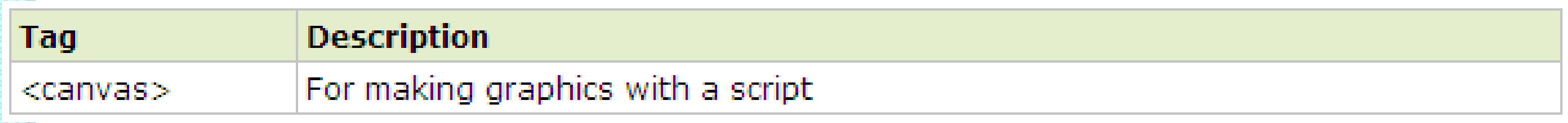
- Possible just very recently
- SVG and canvas
  - Provide native drawing functionality on the Web
  - Completely integrated into HTML5 documents (part of DOM)
  - Can be styled with CSS
  - Can be controlled with JavaScript

Canvas

- HTML5 element and plugin-free 2D drawing API that enables to dynamically generate and render graphics, charts, images, animation
- Scriptable bitmap canvas
  - Images that are drawn are final and cannot be resized
  - Can be manipulated with JavaScript and styled with CSS
  - 2D Context
  - 3D Context (Web GL)
- Canvas was originally introduced by Apple to be used in Mac OS

Canvas

- The HTML5 <canvas> element is used to draw graphics, on the fly, via scripting (usually JavaScript)



Tag	Description
<canvas>	For making graphics with a script

- A canvas is a rectangular area, where it is possible to control every pixel
- The canvas element has several methods for drawing paths, boxes, circles, characters, and adding images

```
<canvas id="myCanvas" width="200" height="100">
</canvas>
```

Canvas features

- The <canvas> element is only a container for graphics
  - You must use a script to actually draw the graphics
- Canvas can draw text
  - Colorful text, with or without animation
- Canvas can draw graphics
  - Great features for graphical data presentation
- Canvas can be animated
  - Canvas objects can move: from simple bouncing balls to complex animations
- Canvas can be interactive
  - Canvas can respond to JavaScript events
  - Canvas can respond to any user action (key clicks, mouse clicks, button clicks, finger movement)
- HTML Canvas Can be Used in Games

Canvas

- The canvas is initially blank
- To display something a script needs to access the rendering context and draw on it
- The canvas element has a DOM method called getContext, used to obtain the rendering context and its drawing functions
  - getContext() takes one parameter: the type of context (2D or 3D)
  - getContext() is a built-in HTML object, with properties and methods for drawing (paths, boxes, circles, characters, images, and more)

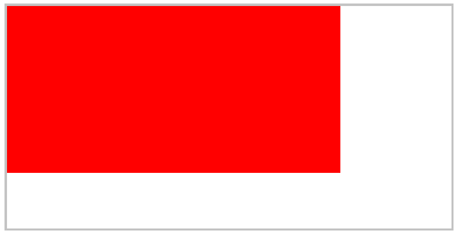
```
var canvas = document.getElementById('example');
var ctx = canvas.getContext('2d');
```

Canvas

- Skeleton template

```
<html>
  <head>
    <title>Canvas tutorial</title>
    <script type="application/javascript">
      function draw(){
        var canvas = document.getElementById('example');
        if (canvas.getContext){
          var ctx = canvas.getContext('2d'); } }
    </script>
    <style type="text/css">
      canvas { border: 1px solid black; }
    </style>
  </head>
  <body onload="draw();">
    <canvas id="example" width="150" height="150"></canvas>
  </body>
</html>
```

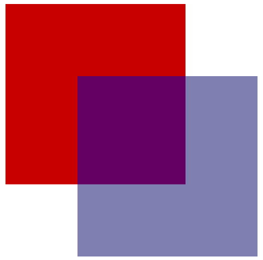
Example 1
Basic shape



- All drawing must be done in JavaScript

```
<html>
  <head>
    <script type="application/javascript">
      function draw() {
        var canvas=document.getElementById("canvas");
        if (canvas.getContext) {
          var ctx = canvas.getContext("2d");
          cxt.fillStyle="#FF0000";
          cxt.fillRect(0,0,150,75); } }
    </script>
  </head>
  <body onload="draw();">
    <canvas id="canvas" width="200" height="100">
    </canvas>
  </body>
</html>
```

Example 2

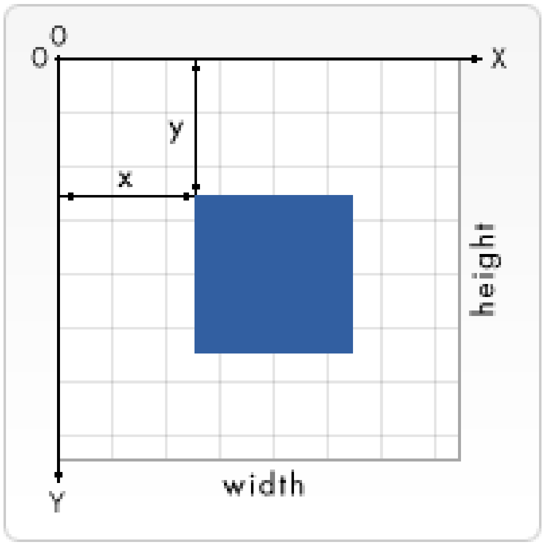


```
<html>
  <head>
    <script type="application/javascript">
      function draw() {
        var canvas=document.getElementById("canvas");
        if (canvas.getContext) {
          var ctx = canvas.getContext("2d");
          ctx.fillStyle = "rgb(200,0,0)";
          ctx.fillRect (10, 10, 55, 50);
          ctx.fillStyle = "rgba(0, 0, 200, 0.5)";
          ctx.fillRect (30, 30, 55, 50); } }
    </script>
  </head>
  <body onload="draw();">
    <canvas id="canvas" width="150" height="150">
    </canvas>
  </body>
</html>
```

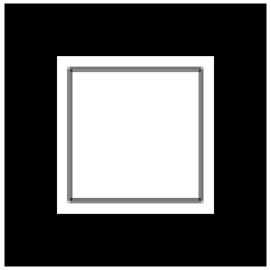
Rectangles functions

- `fillRect(x,y,width,height)`
  - draws a filled rectangle
- `strokeRect(x,y,width,height)`
  - draws a rectangular outline
- `clearRect(x,y,width,height)`
  - clears the specified area and makes it fully transparent

- Canvas coordinate space



Example 3

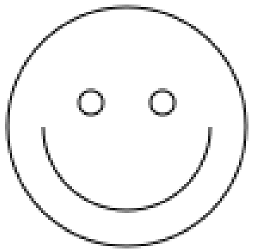


```
function drawShape()
{
  // get the canvas element using the DOM
  var canvas = document.getElementById('tutorial');

  // Make sure we don't execute when canvas isn't supported
  if (canvas.getContext){

    // use getContext to use the canvas for drawing
    var ctx = canvas.getContext('2d');

    // Draw shapes
    ctx.fillRect(25,25,100,100);
    ctx.clearRect(45,45,60,60);
    ctx.strokeRect(50,50,50,50);
  }
}
```

Path functions

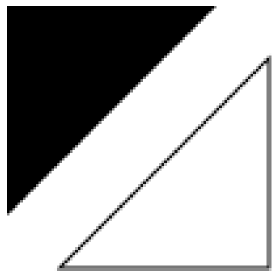
- `beginPath()`: creates a path (list of lines, arcs, ...)
- `closePath()`: closes the path by drawing a straight line from the current point to the start
- `stroke()`: draws an outlined shape
- `fill()`: paints a solid shape
- `moveTo(x,y)`: move the pencil to the x and y coordinates
- `lineTo(x,y)`: draws a straight line to the specified ending point
- `arc(x, y, radius, startAngle, endAngle, anticlockwise)`: draws an arc using a center point (x, y), a radius, a start and end angle (in radians), and a direction flag (false for clockwise, true for counter-clockwise
- To convert degrees to radians:
  - `var radians = (Math.PI/180)*degrees`

Example 4
Path



```
function drawShape() {
  var canvas = document.getElementById('tutorial');
  if (canvas.getContext){
    // use getContext to use the canvas for drawing
    var ctx = canvas.getContext('2d');
    // Draw shapes
    ctx.beginPath();
    ctx.arc(75,75,50,0,Math.PI*2,true);
    ctx.moveTo(110,75);
    ctx.arc(75,75,35,0,Math.PI,false);
    ctx.moveTo(65,65);
    ctx.arc(60,65,5,0,Math.PI*2,true);
    ctx.moveTo(95,65);
    ctx.arc(90,65,5,0,Math.PI*2,true);
    ctx.stroke(); }
  else { ... }
}
```

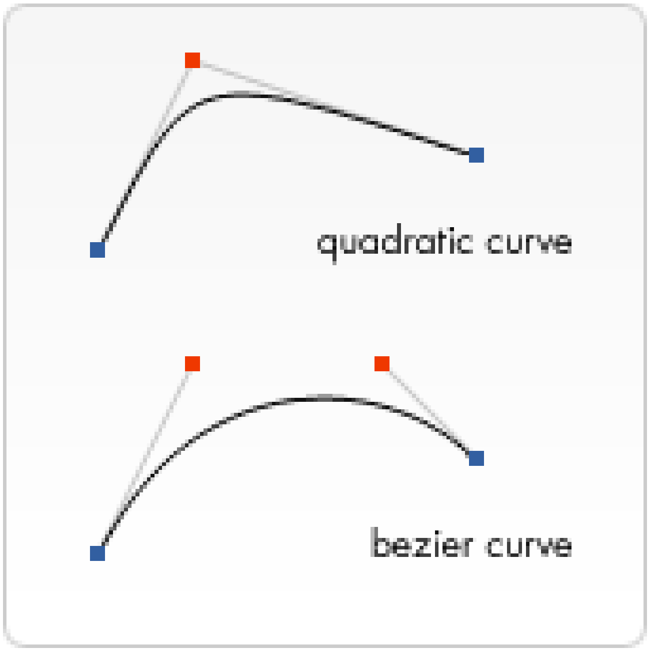
Example 5
Path



```
function fdrawShape(){
  document.getElementById('tutorial');
  if (canvas.getContext){
    var ctx = canvas.getContext('2d');
    // Filled triangle
    ctx.beginPath();
    ctx.moveTo(25,25);
    ctx.lineTo(105,25);
    ctx.lineTo(25,105);
    ctx.fill();
    // Stroked triangle
    ctx.beginPath();
    ctx.moveTo(125,125);
    ctx.lineTo(125,45);
    ctx.lineTo(45,125);
    ctx.closePath();
    ctx.stroke();
  }
  else { ... } }
```

Bezier and quadratic curves

- `quadraticCurveTo(cp1x, cp1y, x, y)`
  - one control point
- `bezierCurveTo(cp1x, cp1y, cp2x, cp2y, x, y)`
  - two control points

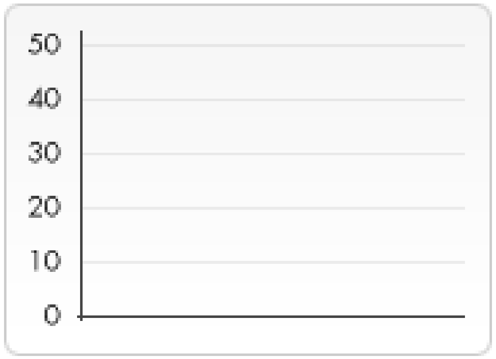


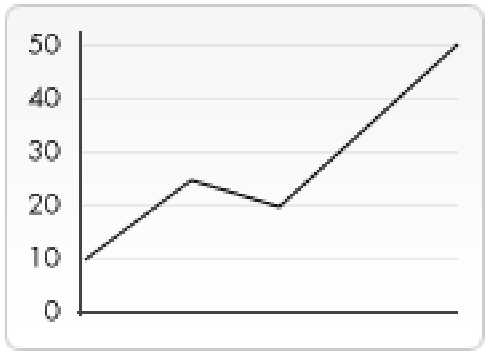
Example 6
Images

```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  var img = new Image();
  img.src = "img_flwr.png";
  img.onload = function(){
    ctx.drawImage(img,0,0);
  }
}
```

- `drawImage(image, x, y)`
  - **renders an image**

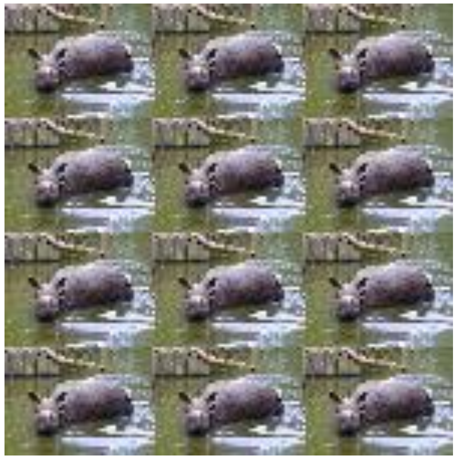
Example 7
Images





```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  var img = new Image();
  img.src = 'images/backdrop.png';
  img.onload = function(){
    ctx.drawImage(img,0,0);
    ctx.beginPath();
    ctx.moveTo(30,96);
    ctx.lineTo(70,66);
    ctx.lineTo(103,76);
    ctx.lineTo(170,15);
    ctx.stroke();
  }
}
```

Example 8
Images

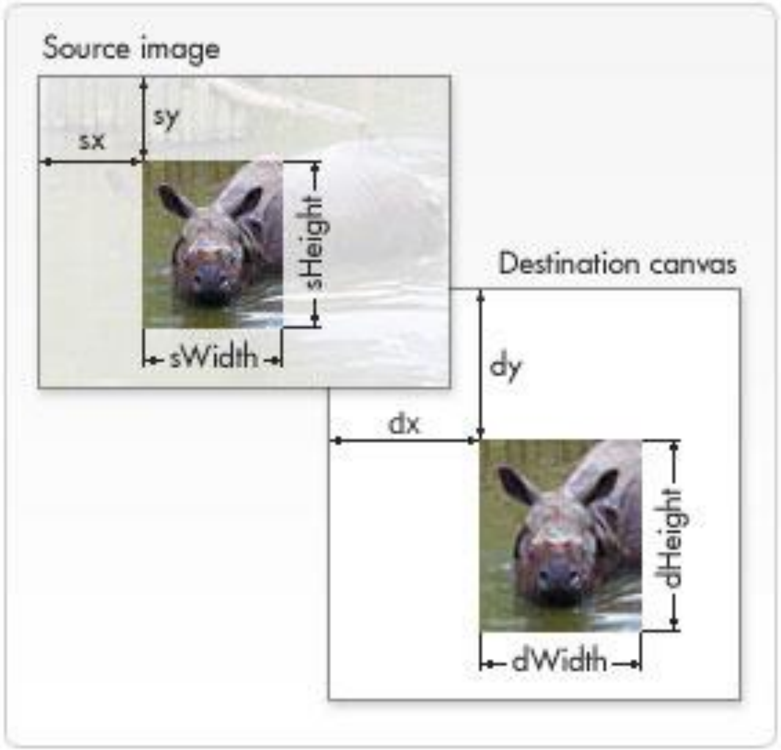


```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  var img = new Image();
  img.src = 'images/rhino.jpg';
  img.onload = function(){
    for (i=0;i<4;i++) {
      for (j=0;j<3;j++) {
        ctx.drawImage(img,j*50,i*38,50,38);
      }
    }
  }
}
```

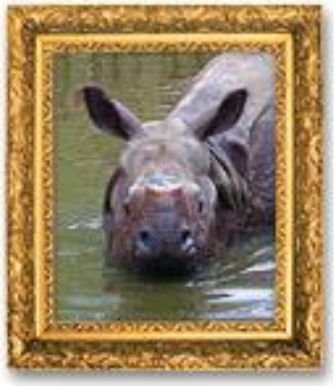
- `drawImage(image, x, y, width, height)`
  - images can be scaled

Images

- `drawImage(image,sx,sy,sWidth,sHeight,`
  `dx,dy,dWidth,dHeight)`
  - images can be sliced



Example 9
Images



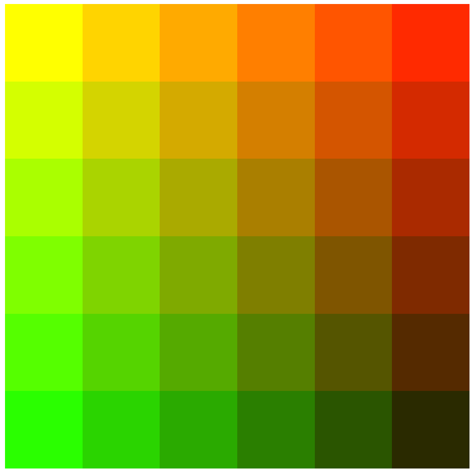
```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  ctx.drawImage(document.getElementById('source'),
                33,71,104,124,21,20,87,104);
  ctx.drawImage(document.getElementById('frame'),0,0);
}
```

Colors

- `fillStyle = color`
- `strokeStyle = color`

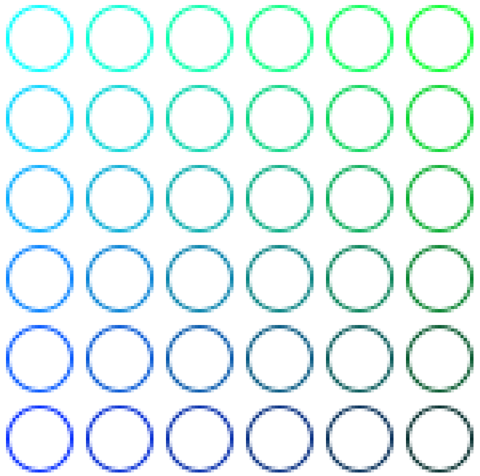
```
// these all set the fillStyle to 'orange'
ctx.fillStyle = "orange";
ctx.fillStyle = "#FFA500";
ctx.fillStyle = "rgb(255,165,0)";
ctx.fillStyle = "rgba(255,165,0,1)";
```

Example 10
Colors



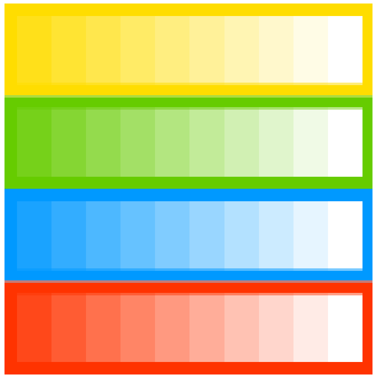
```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  for (i=0;i<6;i++){
    for (j=0;j<6;j++){
      ctx.fillStyle = 'rgb(' + Math.floor(255-42.5*i) + ',' +
                               Math.floor(255-42.5*j) + ',0)';
      ctx.fillRect(j*25,i*25,25,25);
    }
  }
}
```

Example 11
Colors



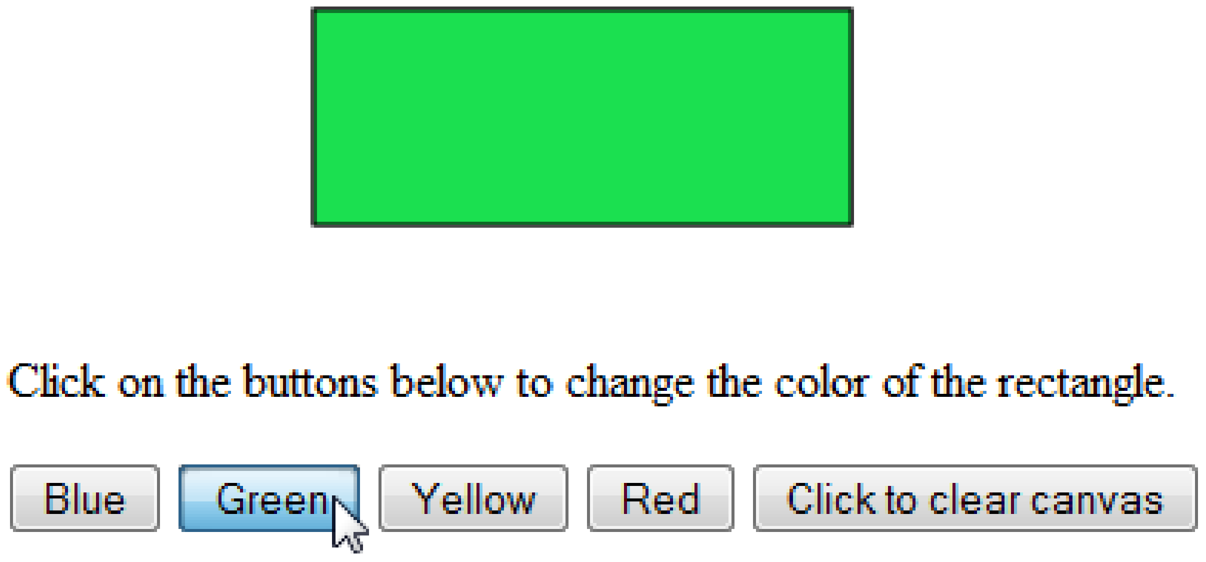
```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  for (i=0;i<6;i++){
    for (j=0;j<6;j++){
      ctx.strokeStyle = 'rgb(0,' + Math.floor(255-42.5*i) +
                        ',' + Math.floor(255-42.5*j) + ')';
      ctx.beginPath();
      ctx.arc(12.5+j*25,12.5+i*25,10,0,Math.PI*2,true);
      ctx.stroke();
    }
  }
}
```

Example 12
Transparency



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  // Draw background
  ctx.fillStyle = 'rgb(255,221,0)';
  ctx.fillRect(0,0,150,37.5);
  ctx.fillStyle = 'rgb(102,204,0)';
  ctx.fillRect(0,37.5,150,37.5);
  ctx.fillStyle = 'rgb(0,153,255)';
  ctx.fillRect(0,75,150,37.5);
  ctx.fillStyle = 'rgb(255,51,0)';
  ctx.fillRect(0,112.5,150,37.5);
  // Draw semi transparent rectangles
  for (i=0;i<10;i++){
    ctx.fillStyle = 'rgba(255,255,255,'+(i+1)/10+')';
    for (j=0;j<4;j++){
      ctx.fillRect(5+i*14,5+j*37.5,14,27.5) } } }
```

Example: colors and interaction


Click on the buttons below to change the color of the rectangle.

Example: colors and interaction

```
<body>
  <canvas id="drawing" style="" > </canvas>
  <p>Click on the buttons below to change the color of the
     rectangle. </p>

  <input type="button" value="Blue" id="blue" onclick="BlueRect()" />
  <input type="button" value="Green" id="green" onclick="GreenRect()" />
  <input type="button" value="Yellow" id="yellow" onclick="YellRect()" />
  <input type="button" value="Red" id="red" onclick="RedRect()" />
  <input type="button" value="Click to clear canvas" id="clear"
         onclick="ImgClr()" />
</body>
```

Example: colors and interaction

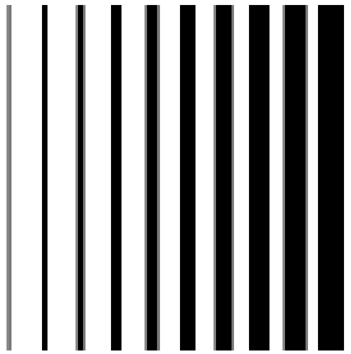
```
<script type="text/javascript">
  var canvas=null;
  var context=null;

  window.onload = function() {
        canvas=document.getElementById("drawing");
        context=canvas.getContext("2d");
        // Border
        context.beginPath();    //This initiates the border
        context.rect(100,60,175,70);
        context.fillStyle="#ffffff";
        context.fill();
        // Border width
        context.lineWidth=1; //This sets the width of the border
        // Border color
        context.strokeStyle="#000000";
        context.stroke();
  }
  ...
```

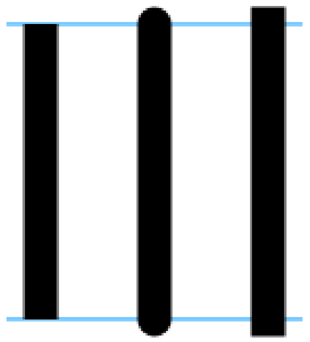
Example: colors and interaction

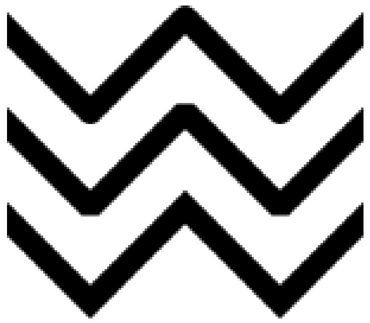
```
   ...
   function BlueRect () {
        context.fillStyle="#701be0"; // Changes the rectangle to blue
        context.fill();
        context.strokeStyle="#000000";
        context.stroke();
   }

   function GreenRect () {
        ...
   }

   function ImgClr () {
        context.clearRect(0,0, canvas.width, canvas.height);
        // Clears the whole canvas area

   }

</script>
```

Lines

- Several properties to style lines
  - `lineWidth = value`
  - `lineCap = type`
  - `lineJoin = type`
  - `miterLimit = value`





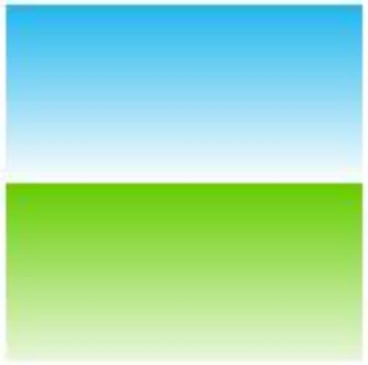


Gradients

- `createLinearGradient(x1,y1,x2,y2)`
  - starting point (x1,y1) and end point (x2,y2) of the gradient
- `createRadialGradient(x1,y1,r1,x2,y2,r2)`
  - starting circle (x1,y1, r1) and end circle (x2,y2, r2)
- `addColorStop(position,color)`
  - position: a number between 0.0 and 1.0 that defines the relative position of the color in the gradient
  - color: string

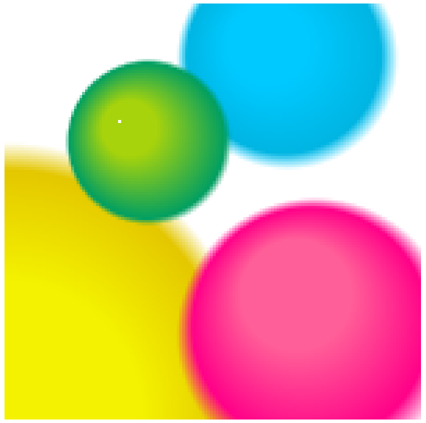
```
var lineargradient = ctx.createLinearGradient(0,0,150,150);
lineargradient.addColorStop(0,'red');
lineargradient.addColorStop(1,'green');
```

Example 13
Linear gradients



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  // Create gradient
  var lingrad = ctx.createLinearGradient(0,0,0,150);
  lingrad.addColorStop(0, '#00ABEB');
  lingrad.addColorStop(0.5, '#fff');
  lingrad.addColorStop(0.5, '#66CC00');
  lingrad.addColorStop(1, '#fff');
  // assign gradients to fill style
  ctx.fillStyle = lingrad;
  // draw shape
  ctx.fillRect(10,10,130,130);
}
```

Example 14
Radial gradients



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');

  // Create gradients
  var radgrad = ctx.createRadialGradient(45,45,10,52,50,30);
  radgrad.addColorStop(0, '#A7D30C');
  radgrad.addColorStop(0.9, '#019F62');
  radgrad.addColorStop(1, 'rgba(1,159,98,0)');

  var radgrad2 = ctx.createRadialGradient(105,105,20,112,120,50);
  radgrad2.addColorStop(0, '#FF5F98');
  radgrad2.addColorStop(0.75, '#FF0188');
  radgrad2.addColorStop(1, 'rgba(255,1,136,0)');
  ...
```

Example 14
Radial gradients

```
...
var radgrad3 = ctx.createRadialGradient(95,15,15,102,20,40);
radgrad3.addColorStop(0, '#00C9FF');
radgrad3.addColorStop(0.8, '#00B5E2');
radgrad3.addColorStop(1, 'rgba(0,201,255,0)');

var radgrad4 = ctx.createRadialGradient(0,150,50,0,140,90);
radgrad4.addColorStop(0, '#F4F201');
radgrad4.addColorStop(0.8, '#E4C700');
radgrad4.addColorStop(1, 'rgba(228,199,0,0)');

// draw shapes
ctx.fillStyle = radgrad4;
ctx.fillRect(0,0,150,150);
ctx.fillStyle = radgrad3;
ctx.fillRect(0,0,150,150);
ctx.fillStyle = radgrad2;
ctx.fillRect(0,0,150,150);
ctx.fillStyle = radgrad;
ctx.fillRect(0,0,150,150); }
```

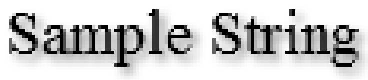
Example 15
Pattern

- `createPattern(image,type)`
  - **type: repeat, repeat-x, repeat-y, no-repeat**

```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  // create new image object to use as pattern
  var img = new Image();
  img.src = 'images/wallpaper.png';
  img.onload = function(){
    // create pattern
    var ptrn = ctx.createPattern(img,'repeat');
    ctx.fillStyle = ptrn;
    ctx.fillRect(0,0,150,150);
  }
}
```

Text and shadows

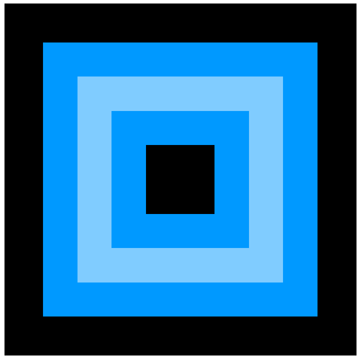
- `fillText()`
  - draws the actual text



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  ctx.shadowOffsetX = 2;
  ctx.shadowOffsetY = 2;
  ctx.shadowBlur = 2;
  ctx.shadowColor = "rgba(0, 0, 0, 0.5)";

  ctx.font = "20px Times New Roman";
  ctx.fillStyle = "Black";
  ctx.fillText("Sample String", 5, 30);
}
```

Save and restore

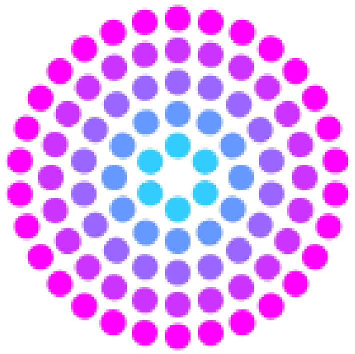
- Canvas states are stored on a stack
- Methods `save()` and `restore()`



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  ctx.fillRect(0,0,150,150); // default settings
  ctx.save(); // Save the default state
  ctx.fillStyle = '#09F' // Make changes to the settings
  ctx.fillRect(15,15,120,120); // Draw with new settings
  ctx.save(); // Save the current state
  ctx.fillStyle = '#FFF' // Make changes to the settings
  ctx.globalAlpha = 0.5;
  ctx.fillRect(30,30,90,90); // Draw with new settings
  ctx.restore(); // Restore previous state
  ctx.fillRect(45,45,60,60); // Draw with restored settings
  ctx.restore(); // Restore original state
  ctx.fillRect(60,60,30,30); // Draw with restored settings
}
```

Example 15 Trasformations

- translate(x,y)
- rotate(angle)
- scale(x,y)
- transform(m11,m12,m21,m22,dx,dy)

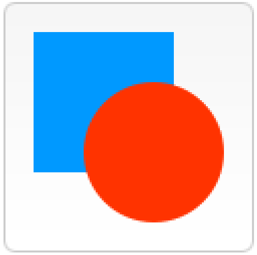


```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  ctx.translate(75,75);
  for (i=1;i<6;i++){
    ctx.save();
    ctx.fillStyle = 'rgb('+(51*i)+','+(255-51*i)+',255)';
    for (j=0;j<i*6;j++){
      ctx.rotate(Math.PI*2/(i*6));
      ctx.beginPath();
      ctx.arc(0,i*12.5,5,0,Math.PI*2,true);
      ctx.fill(); }
    ctx.restore(); }
}
```

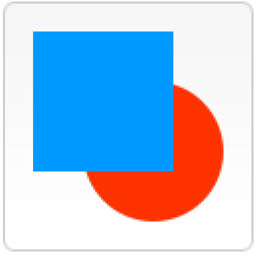
Compositing

`globalCompositeOperation = type`

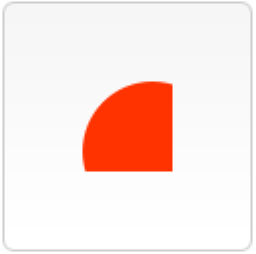
- `source-over` **(default)**
  - draws new shapes on top of the existing canvas content



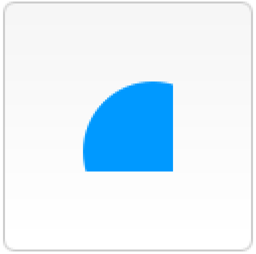
- `destination-over`
  - new shapes are drawn behind the existing canvas content



- `source-in`
  - the new shape is drawn only where both the new shape and the destination canvas overlap; everything else is transparent



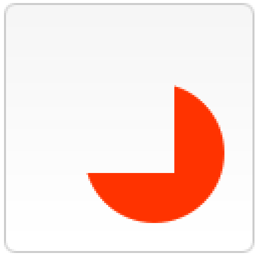
- `destination-in`
  - the existing canvas content is kept where both the new shape and existing canvas content overlap; everything else is transparent



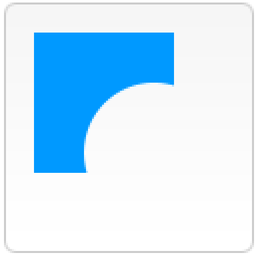
Compositing

`globalCompositeOperation = type`

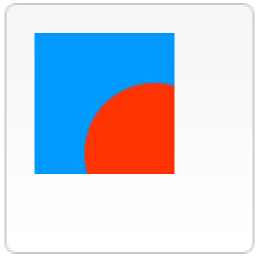
- `source-out`
  - the new shape is drawn where it doesn't overlap the existing canvas content



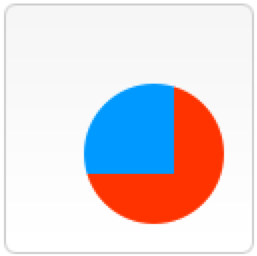
- `destination-out`
  - the existing content is kept where it doesn't overlap the new shape



- `source-atop`
  The new shape is only drawn where it overlaps the existing canvas content



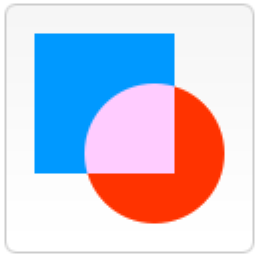
- `destination-atop`
  - the existing canvas is only kept where it overlaps the new shape; the new shape is drawn behind the canvas content



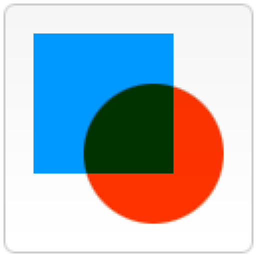
Compositing

`globalCompositeOperation = type`

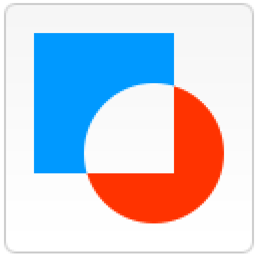
- `lighter`
  - where both shapes overlap the color is determined by adding color values



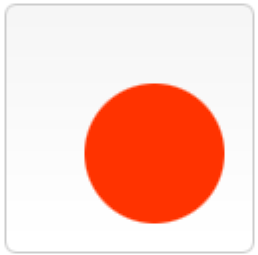
- `darker` (unimplemented)
  - where both shapes overlap the color is determined by subtracting color values



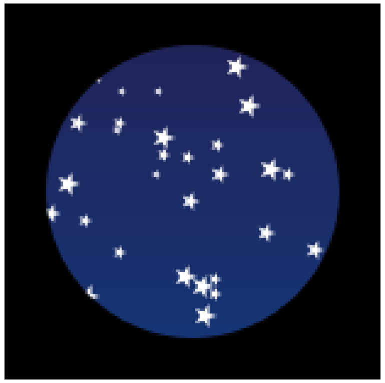
- `xor`
  - shapes are made transparent where both overlap and drawn normal everywhere else



- `copy`
  - only draws the new shape and removes everything else



Example 16
Clipping path



```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  ...

  // Create a circular clipping path
  ctx.beginPath();
  ctx.arc(0,0,60,0,Math.PI*2,true);
  ctx.clip();

  ...
```

Canvas pixel manipulation

- It is possible to access the individual pixels of a canvas, by using an ImageData object
- The ImageData object has three properties: width, height and data
  - The width and height properties contain the width and height of the graphical data area
  - The data property is a byte array containing the pixel values
- The 2D context API provides three methods to draw pixel-by-pixel
  - `createImageData()`
  - `getImageData()`
  - `putImageData()`

Pixel manipulation

- Example: create a 100 x 100 pixels ImageData object

```
var canvas = document.getElementById("ex1");
var context = canvas.getContext("2d");
var width = 100;
var height = 100;
var imageData = context.createImageData(width, height);
```

- Each pixel in the data array consists of 4 bytes values: one value for the red color, green color and blue color, and a value for the alpha channel
  - Each of the red, green, blue and alpha values can take values between 0 and 255
- Example: sets the color and alpha values of the first pixel

```
var pixelIndex = 0;
imageData.data[pixelIndex ] = 255; // red color
imageData.data[pixelIndex + 1] = 0; // green color
imageData.data[pixelIndex + 2] = 0; // blue color
imageData.data[pixelIndex + 3] = 255; // alpha
```

Pixel manipulation

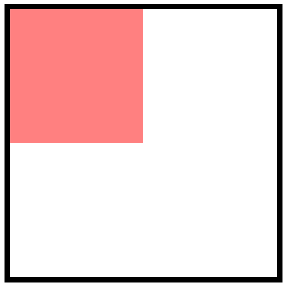
- Once you have finished manipulating the pixels, you can copy them onto the canvas using the function putImageData()

```
var canvasX = 25;
var canvasY = 25;
context.putImageData(imageData, canvasX, canvasY);
```

- It is also possible to grab a rectangle of pixels from a canvas into an ImageData object, by using the getImageData() function
  - x and y: coordinates of the upper left corner of the rectangle to grab from the canvas
  - width and height: width and height of the rectangle to grab from the canvas

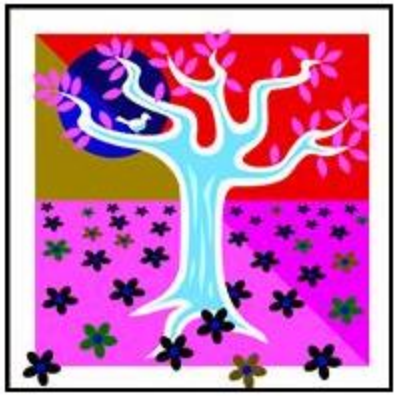
```
var x = 25;
var y = 25;
var width = 100;
var height = 100;
var imageData2 = context.getImageData(x, y, width, height);
```

Example 17
Pixel manipulation



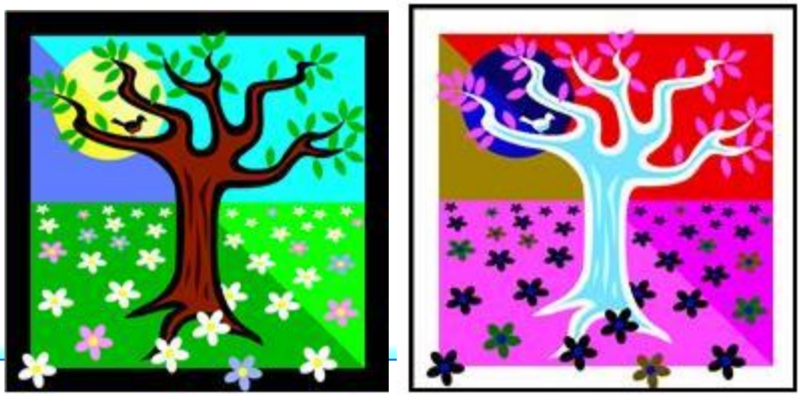
```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  var imgd = false;
  var w = 50, var h = 50, x = 0, y = 0;

  imgd = ctx.createImageData(w, h);
  var pix = imgd.data;

  // Loop over each pixel
  for (var i = 0, n = pix.length; i < n; i += 4) {
    pix[i  ] = 255; // the red channel
    pix[i+3] = 127; // the alpha channel
  }

  // Draw the ImageData object.
  ctx.putImageData(imgd, x, y);
}
```

Example 18
Pixel manipulation



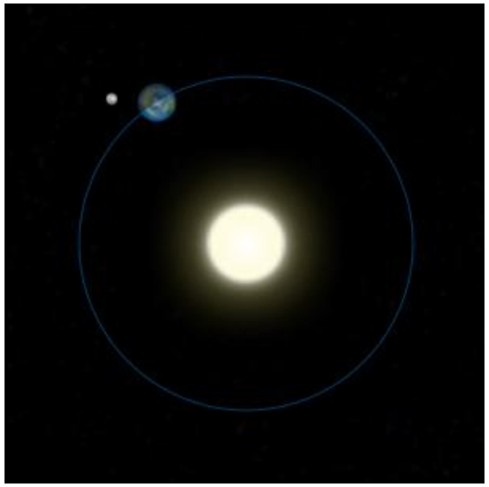
```
function draw() {
  var ctx = document.getElementById('canvas').getContext('2d');
  var x = 0, y = 0;

  // Create a new image
  var img = new Image();
  img.src = 'tree.jpg';

  // Draw the image on canvas
  img.onload = function(){
    ctx.drawImage(img,0,0);

  // Get the pixels
  var imgd = ctx.getImageData(x, y, this.width, this.height);
  var pix = imgd.data;

  ...
```

Example 18
Pixel manipulation



```
  ...

  // Loop over each pixel and invert the color.
  for (var i = 0, n = pix.length; i < n; i += 4) {
    pix[i  ] = 255 - pix[i  ]; // red
    pix[i+1] = 255 - pix[i+1]; // green
    pix[i+2] = 255 - pix[i+2]; // blue
    // i+3 is alpha (the fourth element)
  }

  // Draw the ImageData object
  ctx.putImageData(imgd, x, y);
}
```

Animations



- Since scripts can control canvas elements, it's easy to make animations
- Unfortunately there are limitations: once a shape gets drawn it stays that way
    - To move it we have to redraw it and everything that was drawn before it
- It takes a lot of time to redraw complex frames and the performance depends highly on the speed of the computer it's running on

Basic animation steps

- Clear the canvas
  - Unless the shapes you'll be drawing fill the complete canvas (for instance a backdrop image), you need to clear any shapes that have been drawn previously
  - The easiest way to do this is using the clearRect method
- Save the canvas state
  - If you're changing any setting (styles, transformations, etc) which affect the canvas state and want to make sure the original state is used each time a frame is drawn, you need to save it
- Draw animated shapes
  - The step where you do the actual frame rendering
- Restore the canvas state
  - If you've saved the state, restore it before drawing a new frame

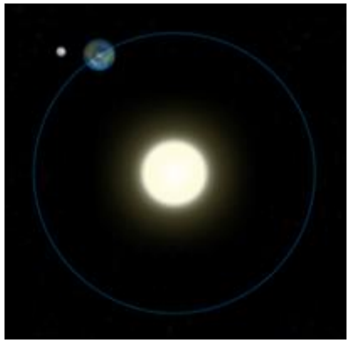
Controlling animations

- Two ways
  - Execute the drawing functions over a period of time

```
// execute every 500 milliseconds
setInterval(animateShape,500);

// execute once after 500 milliseconds
setTimeout(animateShape,500);
```

  - User input: by setting eventListeners to catch user interaction

- Examples



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