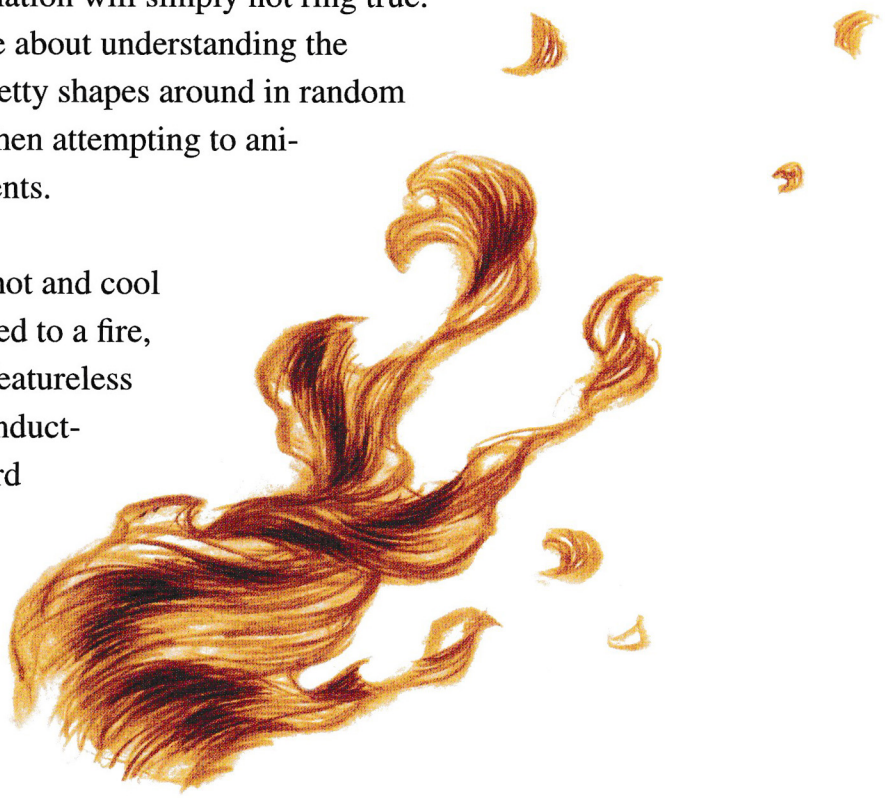
Chapter 5

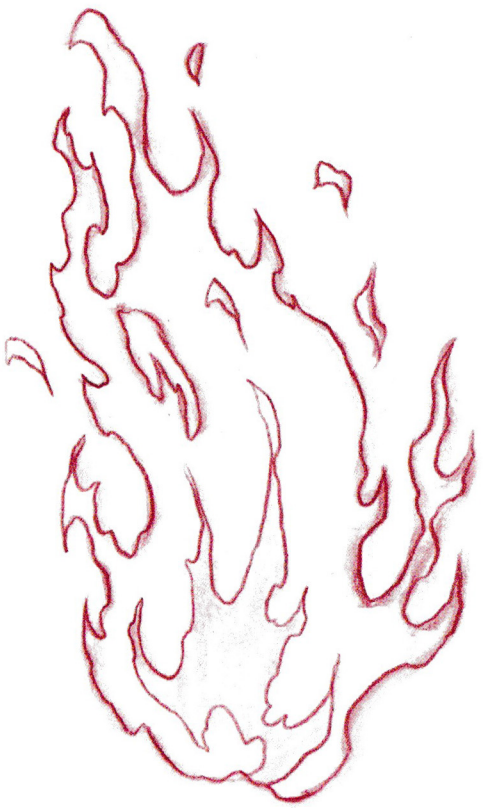
Fire, Smoke, and Explosions

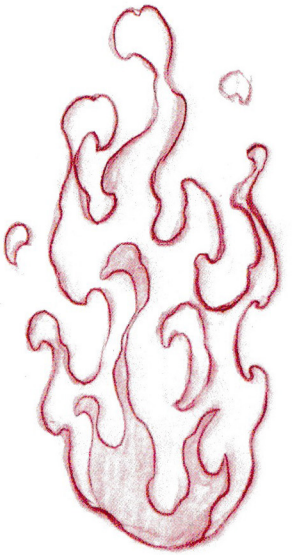
When attempting to animate fire or smoke, the importance of understanding the underlying forces of energy cannot be understated. Without this core energy, fire and smoke animation will simply not ring true. Animating fire and smoke is far more about understanding the energy that is in play than moving pretty shapes around in random ways, as we so often see artists do when attempting to animate these sublimely beautiful elements.



Without the forces of gravity, wind, hot and cool air currents, or excess fuel being added to a fire, a fire will actually burn as a perfect featureless sphere! (As was discovered when conducting experiments in zero gravity aboard a space shuttle.) When we look at a fire's flame, we are actually seeing luminous gases being released and rising quickly from their former state into the air as a given material is heated to its point of combustion.

Fire can be drawn in any number of styles. There is no right way to draw fire. What is absolutely essential though is that the drawing contain the right *energy* and *flow*!

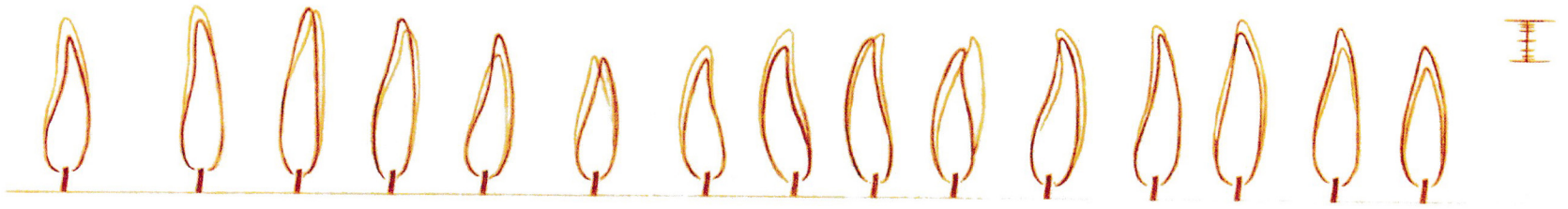




The fire on the left is drawn in a highly detailed style, slightly stylized, with a combination of smooth flowing lines and angular corners combined. The fire above is drawn with a very smooth and liquid style. Next to that we have an extremely stylized angular style of drawing fire. Finally on the right is a very smooth, swooping style of drawing fire. All of them are perfectly valid styles, depending on the style of the animated film you are working on. Anything goes, as long as the energy is in the drawing!

First let us analyze a small flame like we might find on a candle or match. Its shape is a simple tapering affair, fatter at the base and tapering off to a dull point. In a sheltered setting, with little or no wind, its movement will be a subtle stretching and squashing.

There should be no extra shapes emanating off of or breaking away from a flame this small and simple. To add detail would suggest a much larger fire. In a relatively calm setting, the small flame throbs and bobs gently as it subtly gains on and then loses against the cooler air surrounding it.



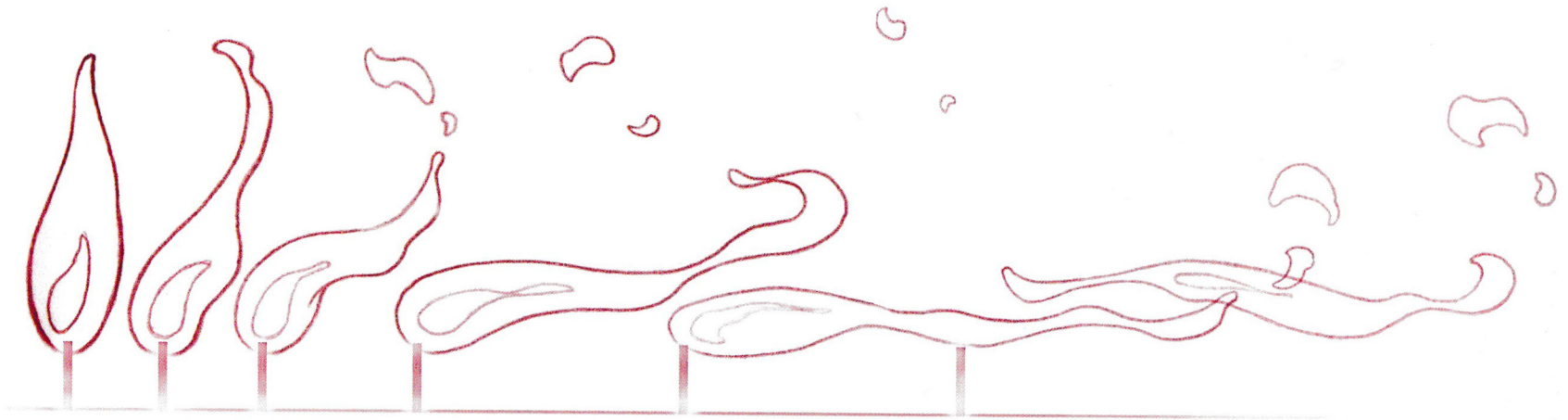
In the series of drawings above, I have animated a candle flame behaving as if it is in a room with very little turbulence in the air. The flame simply grows taller, and then shorter, weaving with an extremely subtle wave action as it stretches and contracts. The simple graph on the right shows the highest and lowest points of the tip of the flame. There should be a slowing-in cushion as it reaches its highest and lowest points, with the drawings being much closer together. The lighter part of the drawing is the subsequent position, to illustrate the movement more clearly.

I am always on the lookout with my camera for good special effects reference material. It is one of the greatest ways to observe and keep engaged with the effects learning experience.

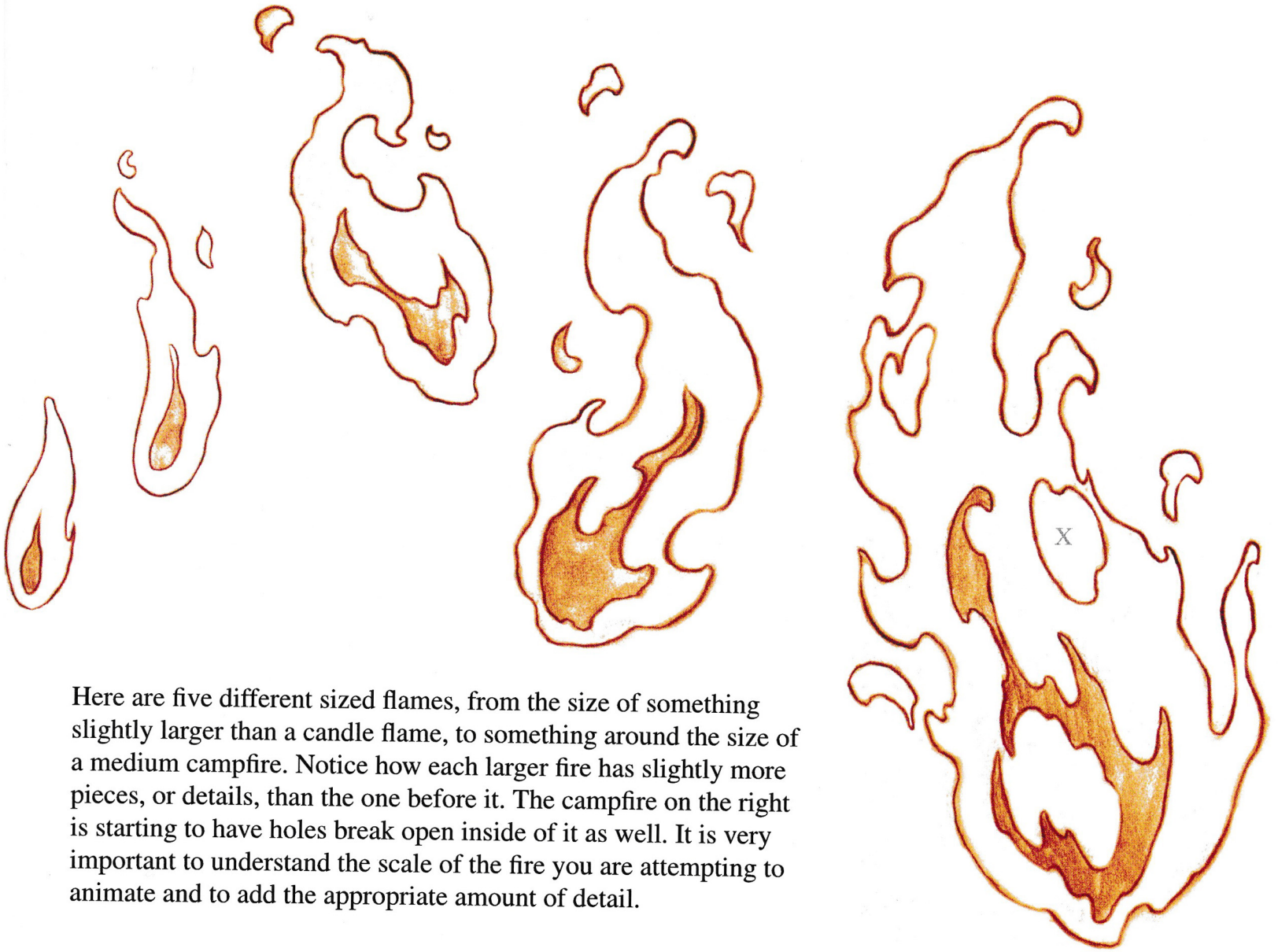
If we add a small amount of wind to the scenario, which also adds oxygen, or fuel to the fire, our candle flame will stretch out in the direction of the wind, and pieces may break off at this point. It becomes slightly more violent and reactionary to the outside forces. Extremely subtle turbulence occurs, introducing opposing curves, billows and flickers.

If the wind gets any stronger, a candle flame is quite easily extinguished. In its last dying breath, the flame may momentarily flare out with a burst of oxygen, become larger for one or two frames, stretching out to maybe three times its normal length, and then snapping off a little flicker before ultimately dying. This will usually be followed by a small puff of linear smoke, which appears two to six frames after the flame is extinguished, and is generally very short-lived, maybe a second or two at the most.

Remember those imitation flames made out of flimsy fabric in Chapter 2 with a fan blowing straight up from underneath them? This is a perfect example of how fire animates. Hot and cool air colliding causes the wind and turbulence that creates the shapes we see in a real fire, which is why this illusion works so well.

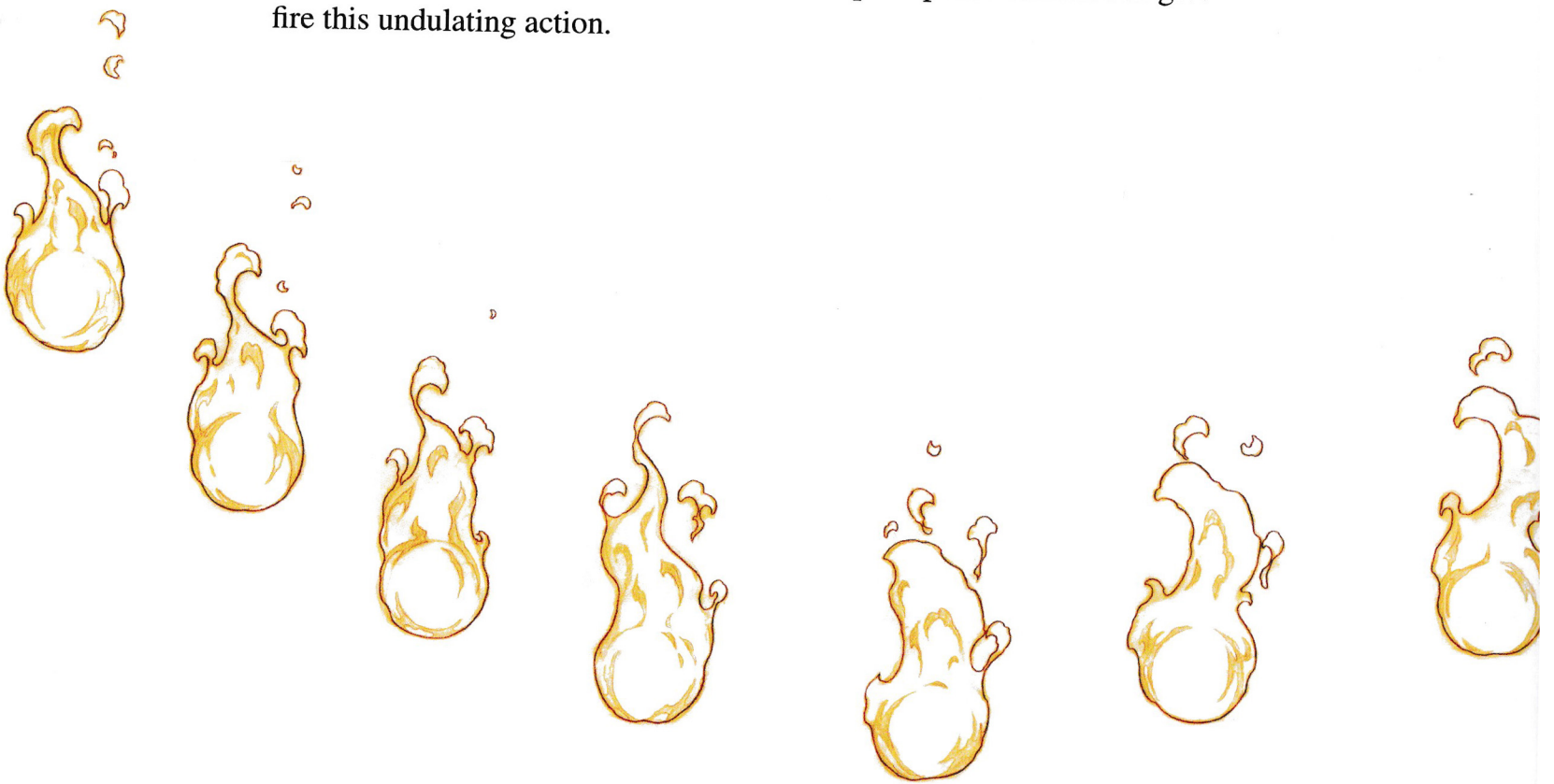


In this sequence of drawings, we see a candle flame being blown out. It doesn't take a very big breeze, or blow, to extinguish a candle flame, except of course when it's your birthday and you're trying to blow out a lot of them at the same time! Interestingly, before actually getting blown out, a flame will actually expand in volume a little bit, fueled by the oxygen in the wind, as we can see in the second, third and forth drawings. When animating a flame being blown out, it is a good idea to stretch it much further than you might expect it to actually stretch in reality. Remember, exaggeration is our friend, and it makes our animation more punchy and believable! It would be feasible to add one more drawing perhaps of the dissipating pieces of the flame, but it works well if it simply vanishes quickly!

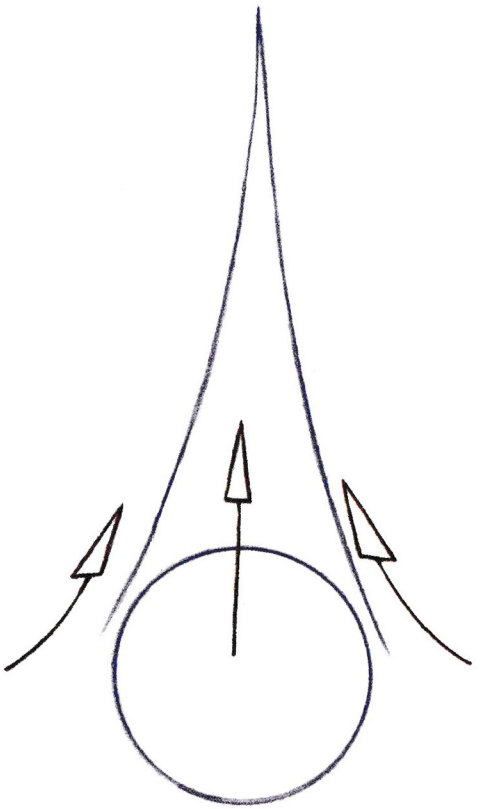


Here are five different sized flames, from the size of something slightly larger than a candle flame, to something around the size of a medium campfire. Notice how each larger fire has slightly more pieces, or details, than the one before it. The campfire on the right is starting to have holes break open inside of it as well. It is very important to understand the scale of the fire you are attempting to animate and to add the appropriate amount of detail.

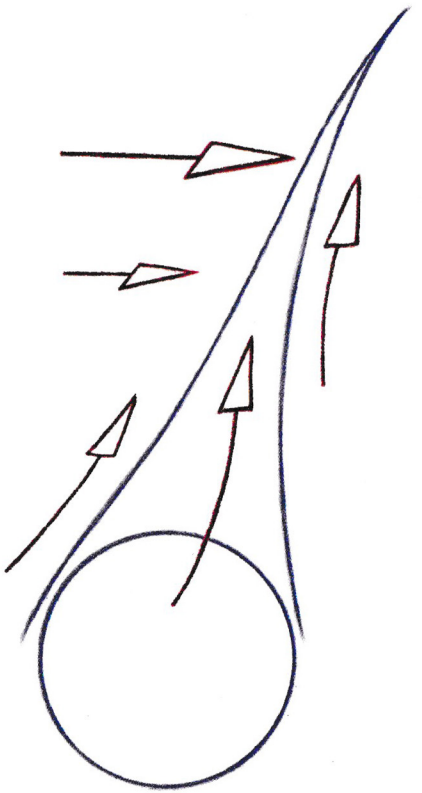
As we advance to a larger fire, as in a campfire or a burning torch, the bobbing motion will become more pronounced, as will the reversing internal arcs, which undulate from side-to-side. This motion is caused by one side of the fire cooling faster than the other; the hotter side will then rise faster, rolling upward and over, causing a flame shape to break off of the main silhouette. This series of events repeats itself as forces interact with it, especially wind—even an imperceptible current can give fire this undulating action.



Before any interior details can be considered, it is best to construct the basic flow, or gesture, of the fire. On the second pass, the primary interior shapes can be conceived as sections of spherical masses moving upwards, which then diminish in size. We build the silhouette with sharper edges, connecting these spherical masses. The over arching idea of a fire is a triangular shape, or a series of triangular shapes feeding one another. These quickly unite into larger silhouettes, depending on the severity and frequency of the forces (wind, gravity, pressure) and the amount of available fuel from the material that has been ignited (paper, straw, wood, gasoline, etc.).

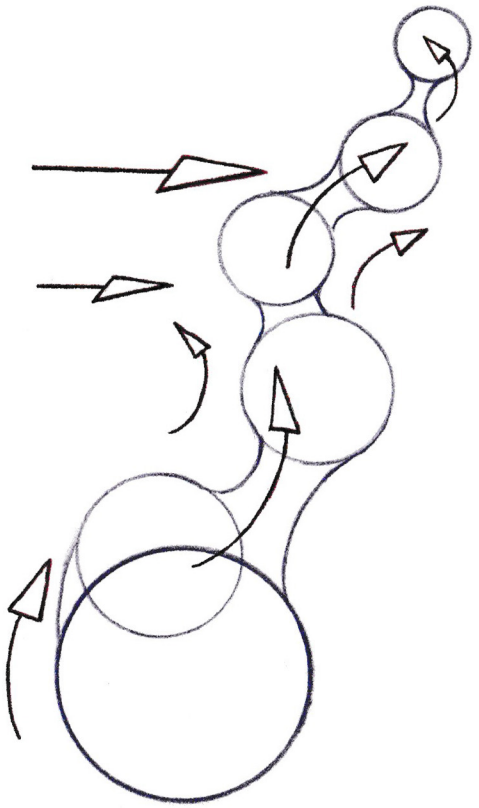


1. Hot air rises from a fuel source, drawing in cooler air in from the bottom.



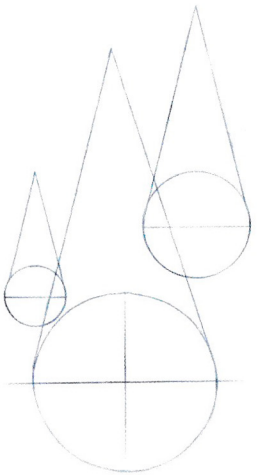
2. Add a small breeze, pushing the flame to the side. It begins to arc.

This simple yet effective formula for animating a medium-size fire was originally designed by a colleague of mine at Walt Disney, David Tidgwell. I have never found a better explanation!



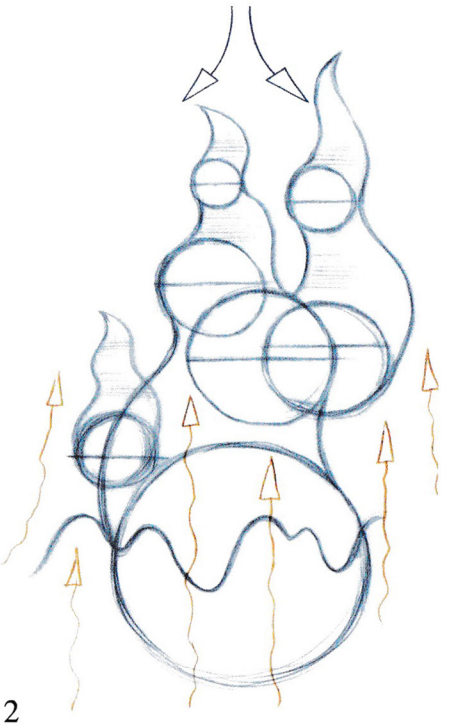
3. Add turbulence. As the cooler air interacts with the rising hot air, it creates alternating eddies of swirling air.

4. Add details. The energy pattern is simply and clearly described within the details.



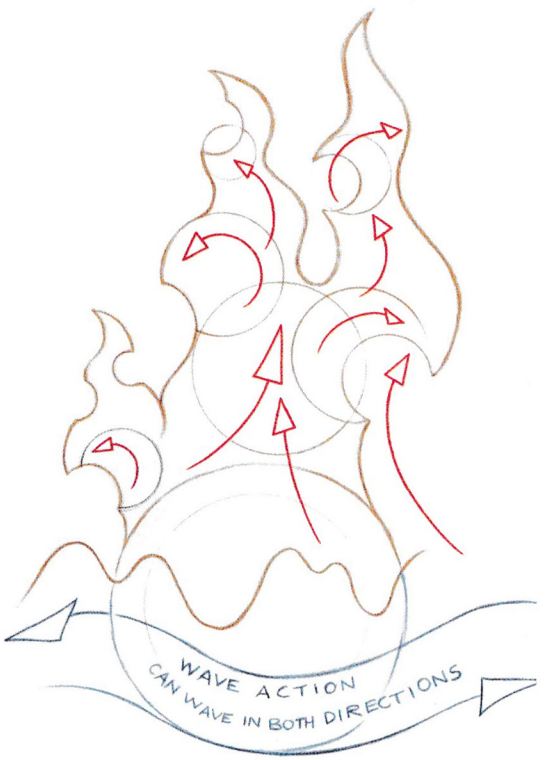
1

Here is another approach to "building" a fire. I have started with basic triangles—note that they are different sizes. Because of the repetitive nature of fire shapes, it is important to always vary your shape sizes.



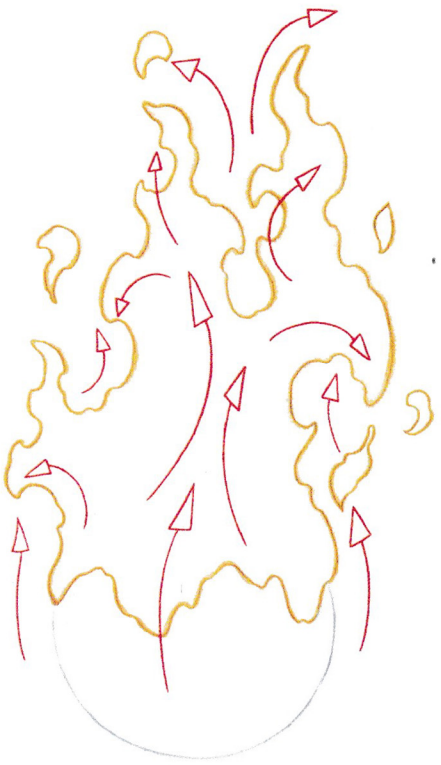
2

Now I have treated each of the individual triangles as if they are flags being blown from below. I have added the curving bottom line shape of the fire, and indicated the directional flow of the air currents causing the flags to flutter and wave. Note that there is cooler air pushing down from above the fire as well, that causes additional turbulence.



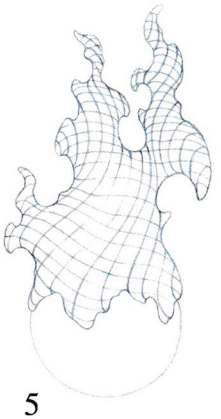
3

Now things start to get a lot more dynamic, as turbulenc is added to the picture. This turbulent energy creates small spiraling eddies of air that twist, pull, and squeeze the triangular shapes, causing the familiar arcing shapes that we see so frequently in fire. Note that on the left sid of the fire the twisting currents rotate counter-clockwise, while those on the right revolve in a clockwise direction. Opposing arcs become very apparent at this stage, and are an outstanding feature of almost all good, elemental effects design.



4

At this stage in the drawing, the same air currents and turbulence that came into play in Figure 3 are now used to add the more detailed, wavy, wiggly shapes that really start to describe this shape as a fire. Opposing arcs are always a very important aspect of these designs. As always, make sure that the size and positioning of these shapes avoid being overly repetitive.



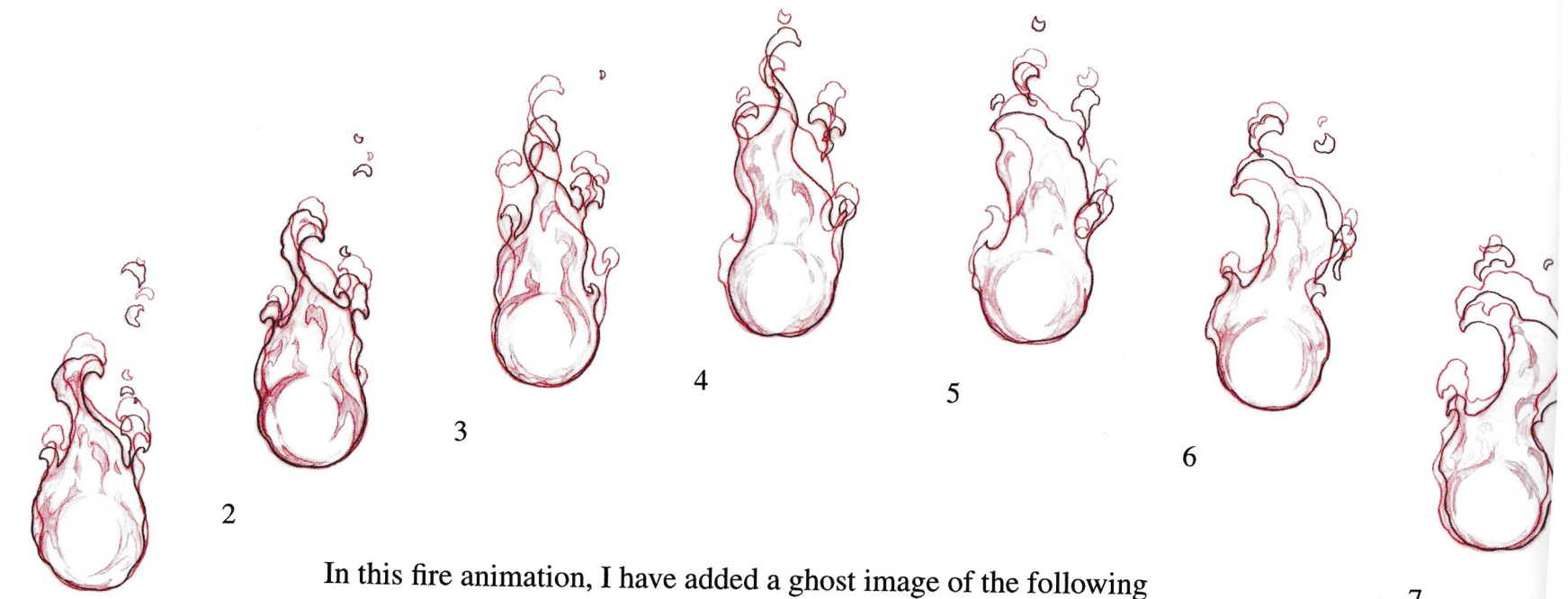
5

6

At this point, we must think of our two-dimensional diagram as a three-dimensional object. I have illustrated, first with an overly technical wire-frame drawing, one way of approaching this stage in our drawing. We can then add our interior shapes which do much to describe the volume and directional energy of the fire. With more experience, one would generally begin a fire drawing with a very volumetric sketchy approach, skipping the more technical process shown here in the first four examples. But this is an excellent foundation for beginning to understand the principles at play in a fire.

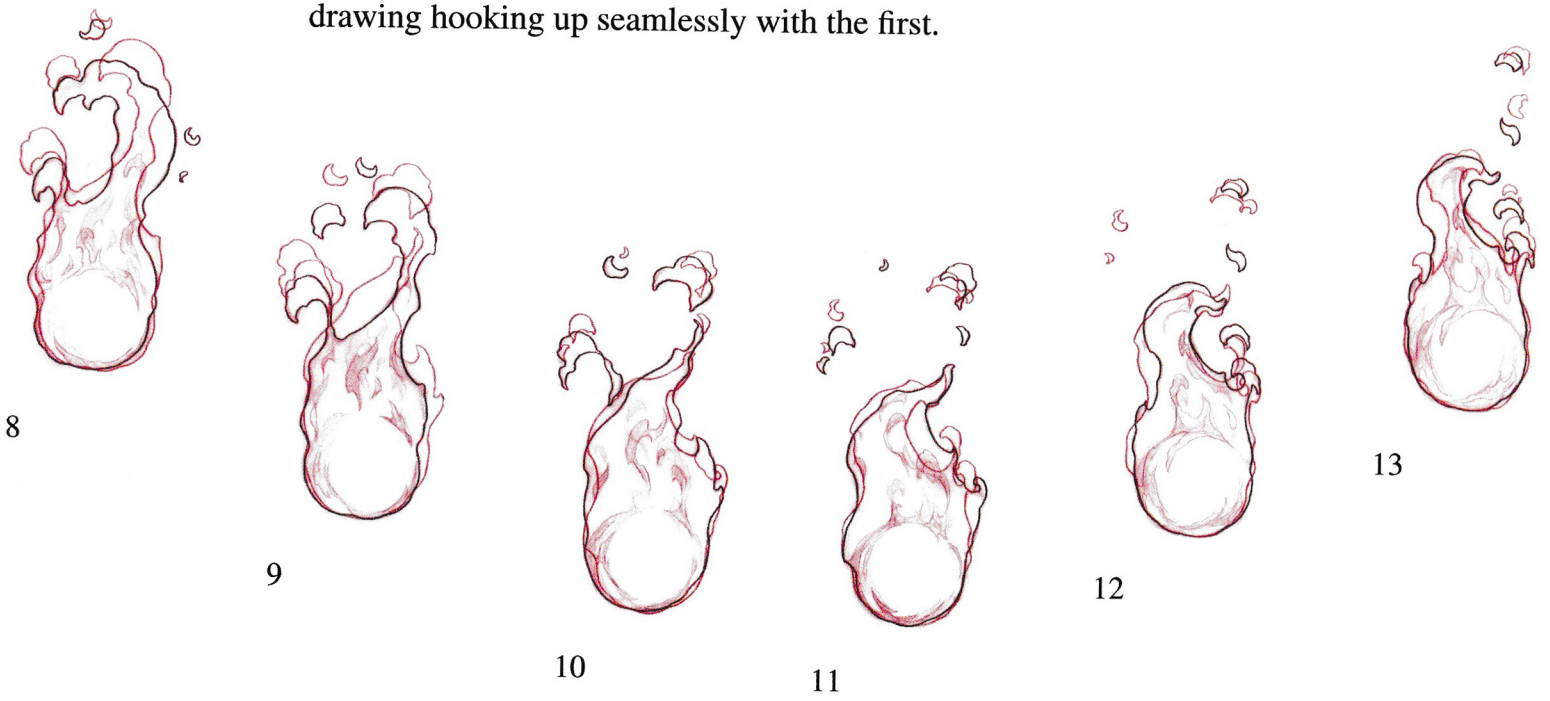
7

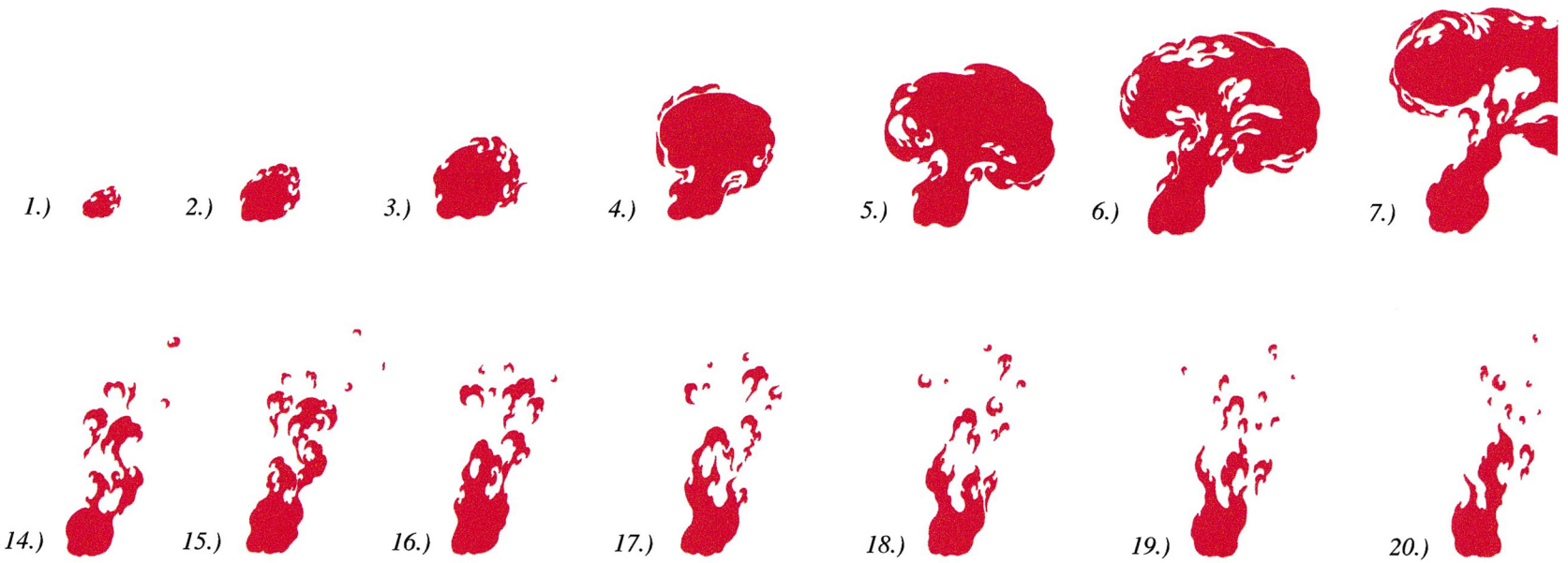
Finally, we can add our elegant touches to the fire design, tweaking and pushing our design to make it as dynamic as possible. The final outline, combined with the interior shapes, makes for a pleasing (in this case relatively simplified and stylized) rendition of a typical campfire-size fire.



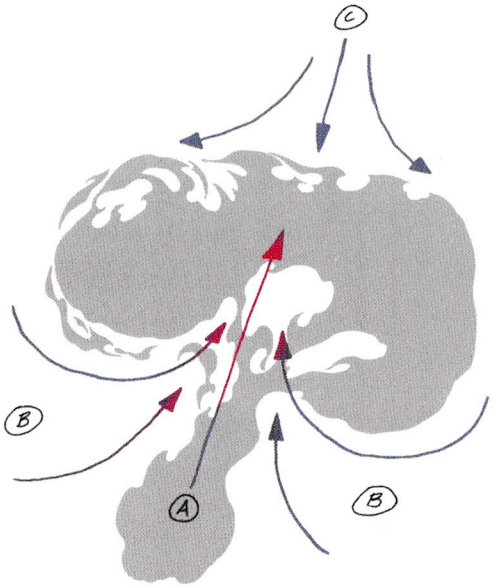
In this fire animation, I have added a ghost image of the following drawing, so that you can see clearly how the motion progresses. As the overall shape of the fire undulates with the familiar, whip/wave motion, smaller pieces emerge from the bottom sides of the fire and react to the turbulence being created by the hot and cool air currents colliding as the fire sucks in cooler air from around it, in order to fuel itself with oxygen. This animation also shows clearly how large pieces of the fire are pinched, or squeezed by the cooler air as they rise, causing them to break off as they rise. Note that the small shapes that break off from the main body of the fire do not last more that two or three drawings. Larger pieces may last longer.

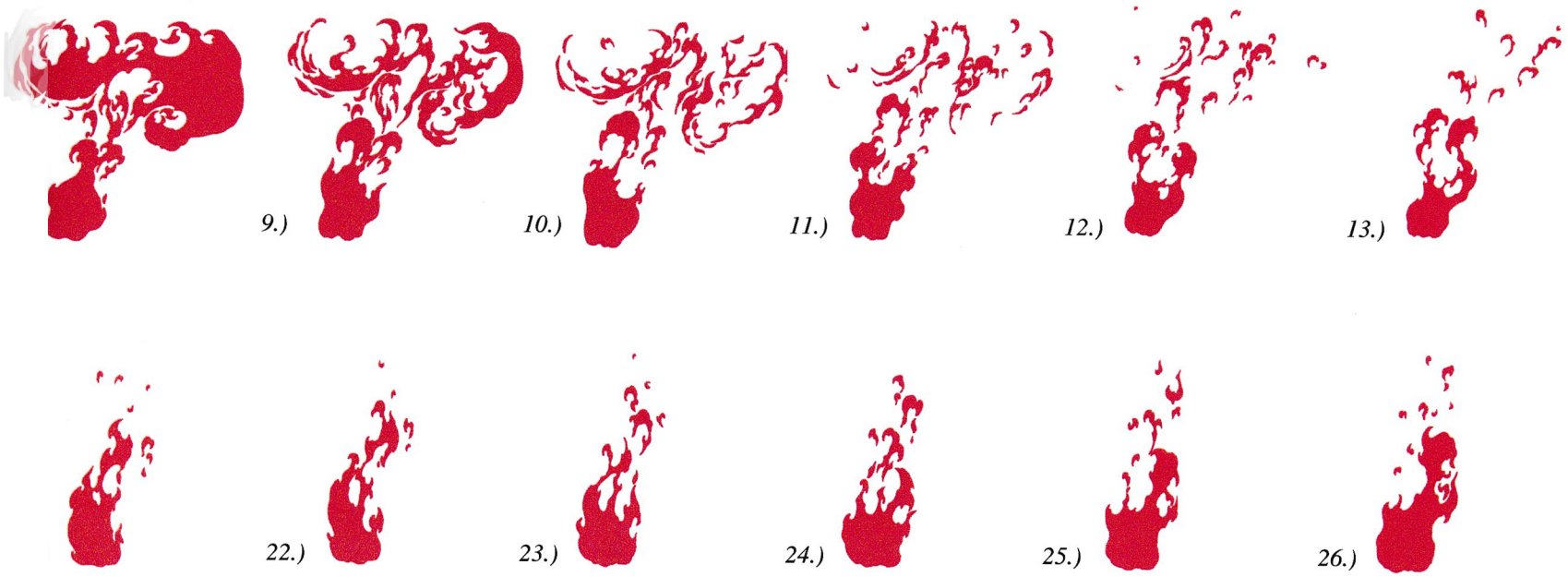
Another fire animation trick, clearly illustrated here, is how a curling shape that is breaking off and rising quickly away from the main body of the fire will invert its curved shape from one drawing to the next. This gives these little pieces of flame the appearance of flickering and behaving like a real fire. I animated this fire as if it is a well-fueled "ball of fire" so the shape of the base of the fire is much more stable and static than a camp fire would be. Note too, how the secondary inside shapes enhance the overall shape and volume of the fire, working as a sort of shading tool. This animation is a cycle of thirteen drawings, with the last drawing hooking up seamlessly with the first.





Here I have animated what a fire might look like igniting, as if from a pool of a highly flammable substance like gasoline. Initially, in #1 through 3, the fire simply blossoms quickly upward and outward. It is well fueled with a flammable substance and plenty of oxygen. Outside forces have not yet come into play, but immediately in #4 and onward, we see the familiar mushroom phenomenon beginning to take shape. In this clearly illustrated enlarged view of #7. we see the force of the initial ignition still shooting upward. (A) As the cooler air surrounding the fire pushes it down from above, (C) and the hot fire sucks cool, oxygen-filled air into itself from the air surrounding it, (B) it pulls the cooler air inward and upward, and the collision of these forces creates the mushroom shape.





As the fire continues to rise, the intense heat, with no place to go but up, has to push its way through the layers of varying temperatures of cooler air around it. As the hot and cool air interact, spiraling eddies and twisting currents of air are formed, which give the fire its distinct shapes. Every smaller shape of the fire that is created (as outside forces tear it to pieces) takes on a somewhat similar form, as the cooler air above it, and its natural trajectory upward continue to create fascinating and beautifully shaped air currents. Keep in mind always fire is pure energy being expended—and seems to have a life of its own. Its shapes are created by hot and cool air reacting to each other. If the physics of your fire animation don't follow these natural laws of nature, it will look unnatural and strange.