NBBQ
NATIONAL BARBECUE ASSOCIATION

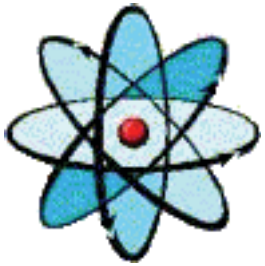
GENUINE * GENUINE * GENUINE * Ideas

# The Science of Smokers

Greg E. Blonder

genuineideas.com/food.html for more details
amazingribs.com for more recipes and advice

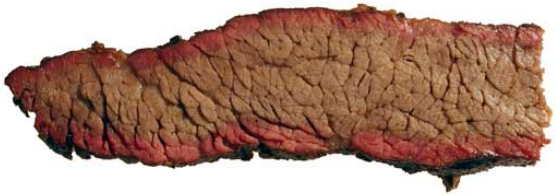
# BBQ and Science?



WE WON'T:

- ✓ Make Specific Equipment Recommendations
- ✓ Pass Value Judgment on "Best" way to smoke

- ✓ There is no Test
- ✓ There is no Math



WE WILL:

- ✓ Explain how wood burns
- ✓ How wood adds flavor
- ✓ Origin of the smoke ring
- ✓ How humidity influences cooking
- ✓ The characteristics of typical smokers
- ✓ Answer any questions you might have about BBQ Science

Opinions are my own- use at you're your own risk!

Fundamentals of Wood Combustion

↓

Fundamentals of Smoke Flavor

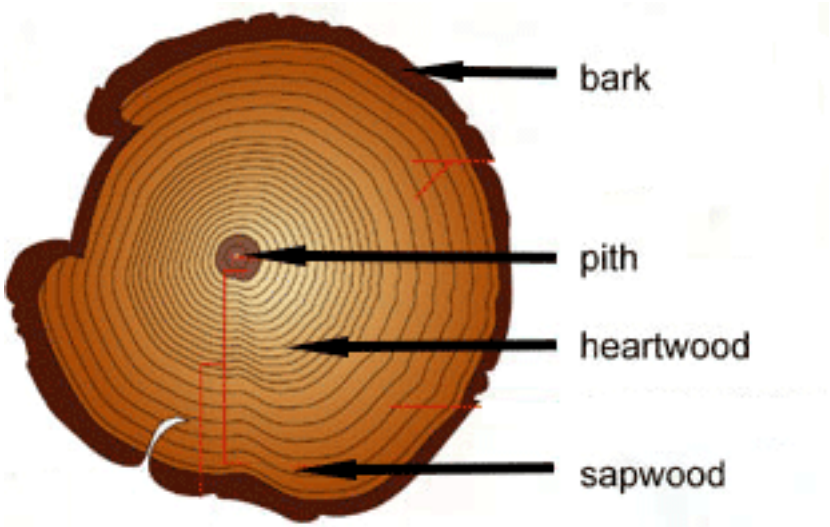
↓

Role of Humidity

↓

Compare
Smokers

# What is Wood?




| | |
|---|---|
| Cellulose | 40%-60% |
| Hemi-cellulose | 20%-30% |
| Lignin | 20%-30% |

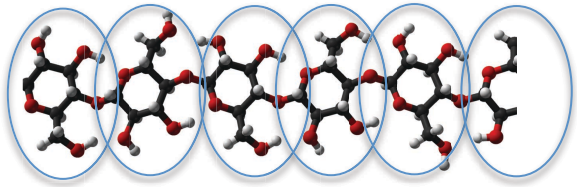
**Cellulose** are the bricks
**Lignin** is the mortar, rebar and waterproofing

# What is Wood?

Seasoned wood is 20% water, and the rest dehydrated sugar and glue!

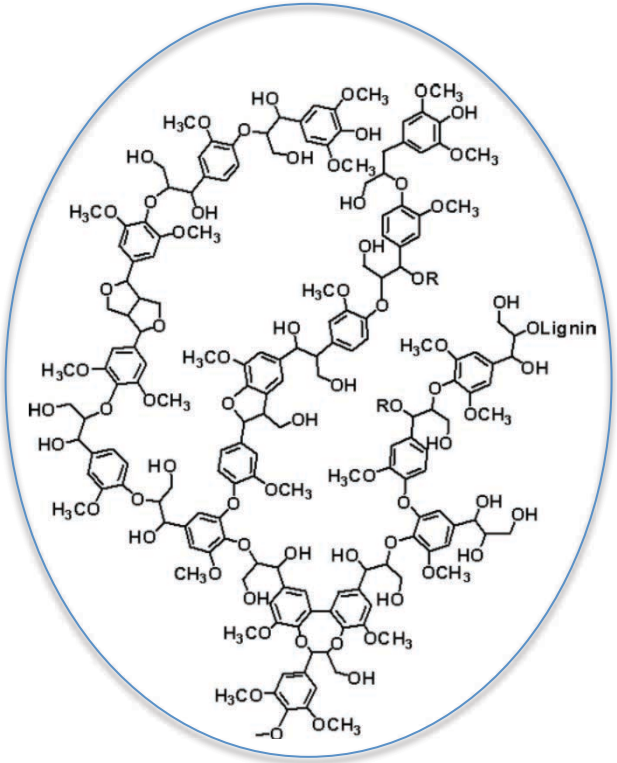
*One Cellulose Brick = Glucose - Water*

$C_6H_{10}O_5 = C_6H_{12}O_6 - H_2O$



In a fire, cellulose produces few flavor molecules - mostly burned sugar

**Lignin** is the source of BBQ flavor



# What is Smoke?

"Smoke" is the VISIBLE gaseous by-products of wood combustion.

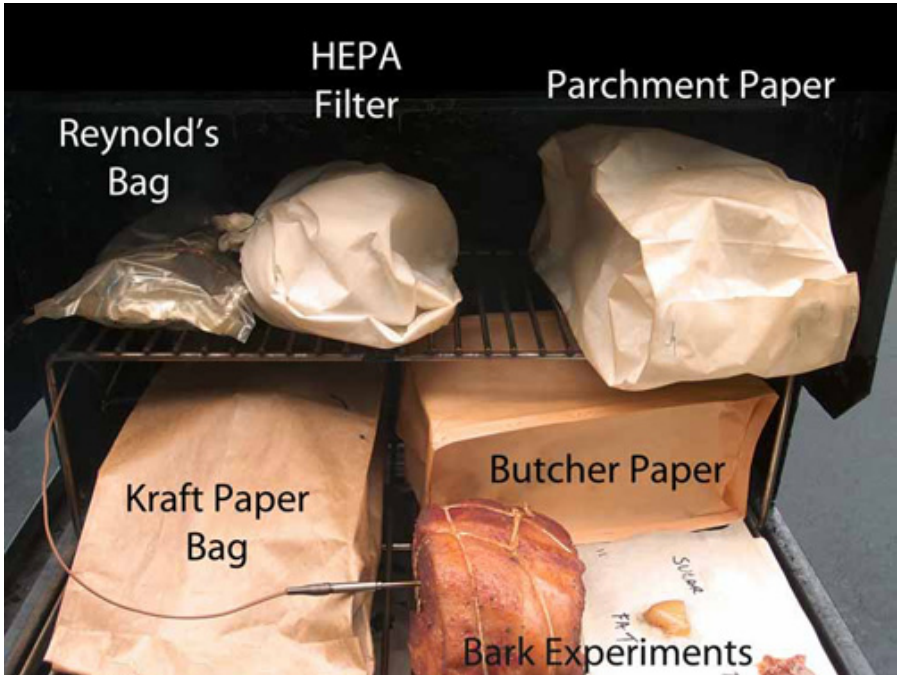
Includes particles of carbon (soot)
droplets of creosote and water
Most of the bark color comes from the visible smoke

Combustion also produces INVISIBLE gases
Most of the flavor comes from the invisible gasses!

Smoke "flavor" is a misnomer….

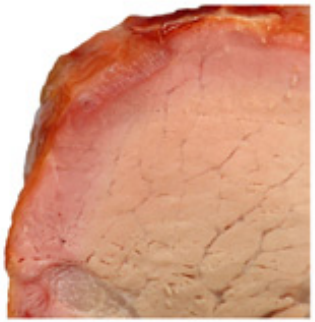
But for convenience, we'll call both "smoke".

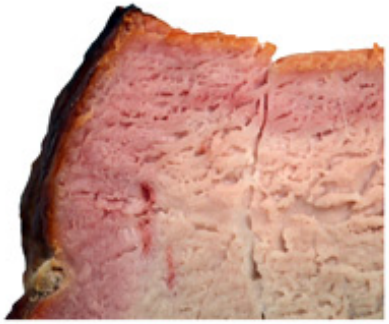
# Invisible Smoke Rules!




## Tenderloin "Smoke Ring" in Bags after Six Hours at 225F


Unwaxed Butcher Paper


Parchment Paper


HEPA Filter


Reynolds Bag, Touching

# Chemical Composition of Wood Smoke

| Chemical | avg ppm |
|---|---|
| **carbon monoxide** | **up to 100,000** |
| methane | 20,000 |
| VOCs* (C2-C7) | 15,000 |
| total particle mass | 15,000 |
| particulate organic carbon | 10,000 |
| oxygenated mono-aromatics | 5,000 |
| alkyl benzenes | 3,000 |
| aldehydes | 2,000 |
| benzene | 2,000 |
| acetic acid | 2,000 |
| oxygenated PAHs | 300 |
| substituted naphthalenes | 250 |
| **nitrogen oxides** | **200** |
| sulfur dioxide | 200 |
| naphthalenes | 200 |
| guaiacol | 150 |
| syringol | 150 |
| substituted furans | 150 |
| formic acid | 70 |
| methyl chloride | 20 |

Proportions depend on combustion Conditions and "Stuff"

Enables Smoke Ring

Smoke Flavor .01%
Smoke Aroma .01%

# A word about smoke safety

Wood smoke is toxic and carcinogenic, like cigarette smoke
-> Which is why wood stove and smoker regulations creep in

Smoked FOOD has little to no demonstrated risk
(and may provide net benefits)

Open issue: *reducing fat flare-ups and PAHs*

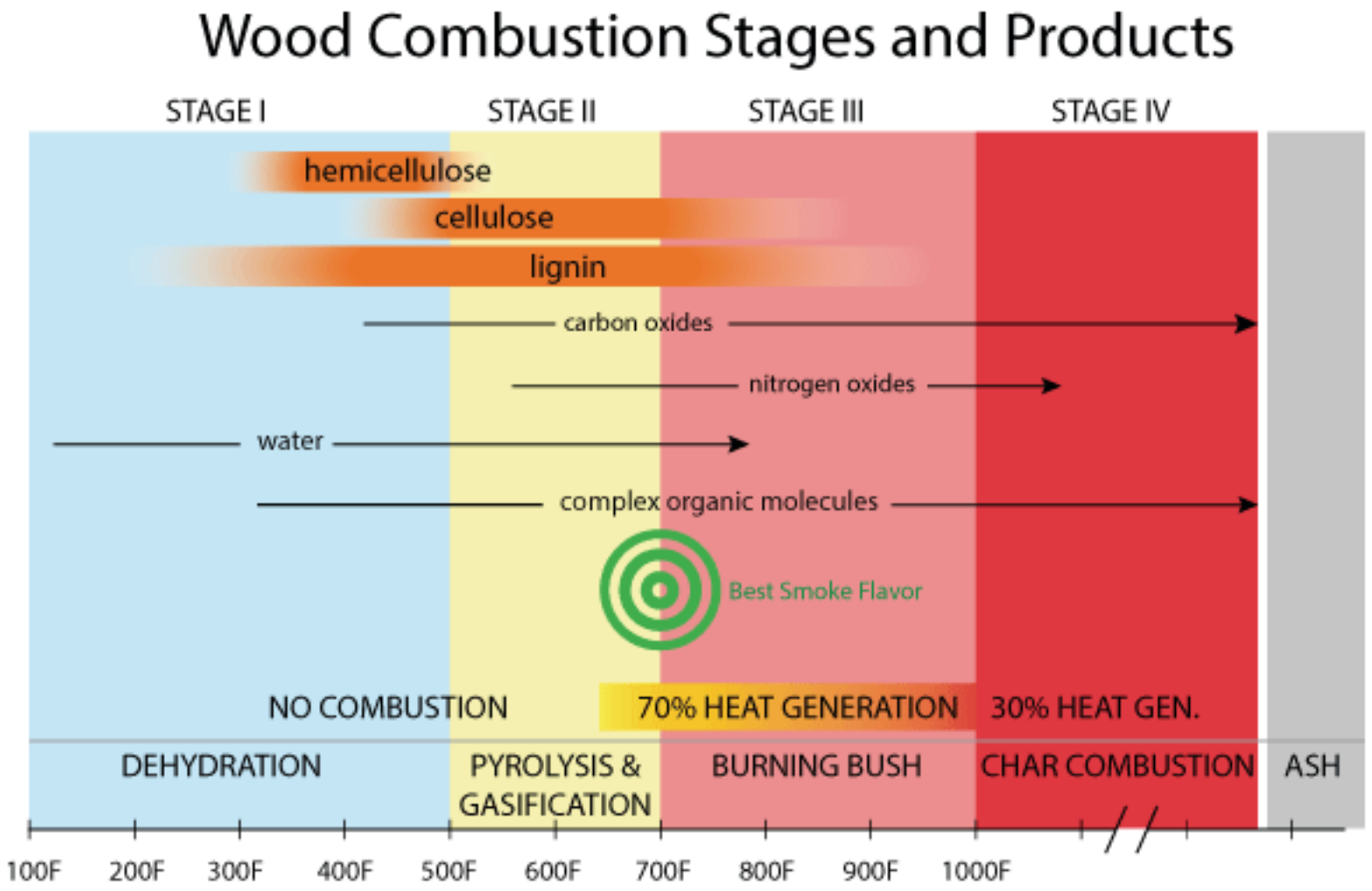
Opinions are my own- use at you're your own risk!

# Combustion- Scientists Are Still figuring out fire chemistry

Broadly speaking, there are FOUR stages of combustion:

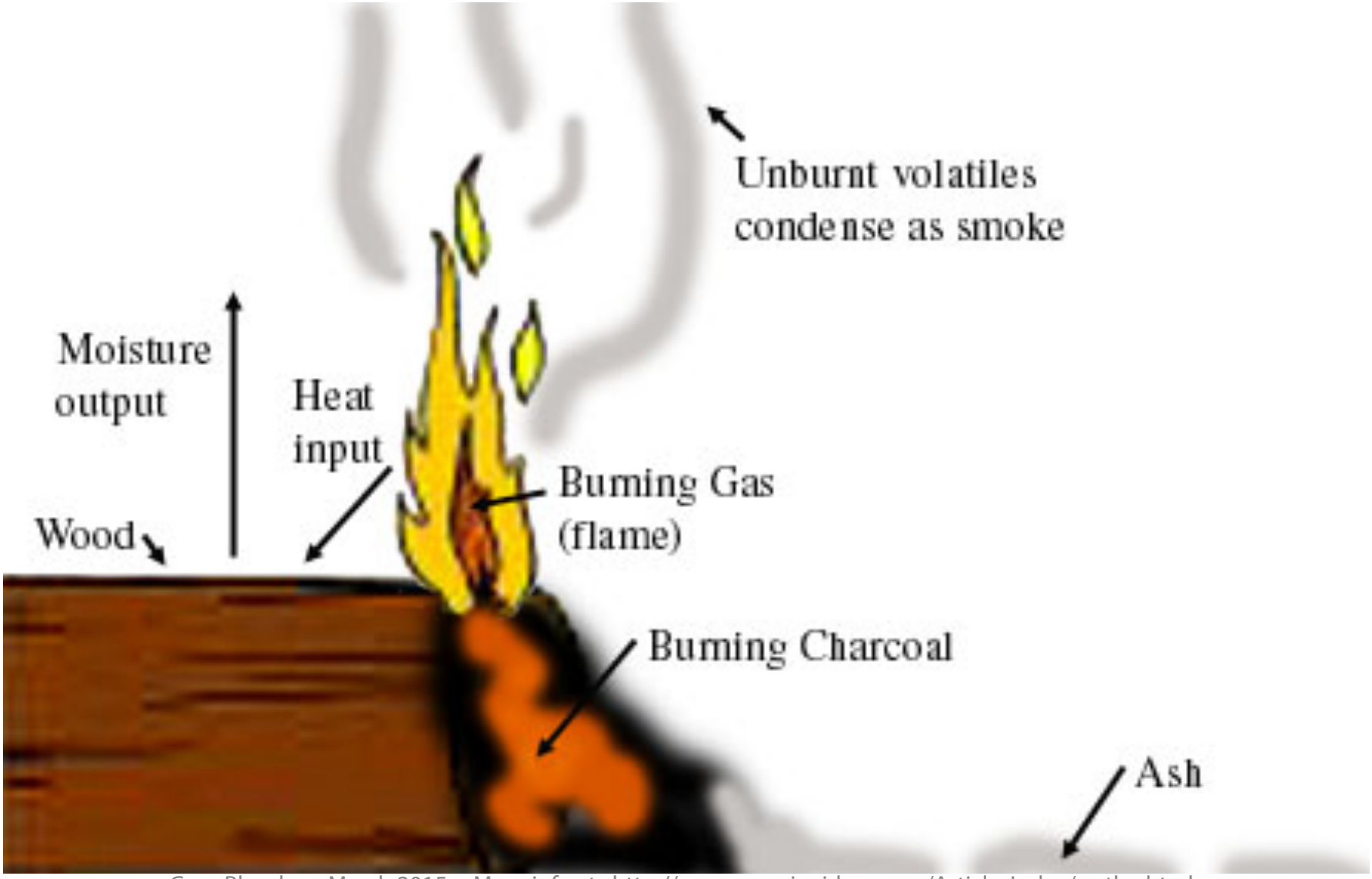
I. Dehydration- water steams out, as do some simple organic molecules
II. Pyrolysis- No flames No $O_2$, but complex gases formed and evaporate
III. Burning Bush- Gases burn, but wood is not consumed (like a candle and wick)
IV. Combustion- carbon and charcoal burn

# Flavor depends on temperature




Greg Blonder – March 2015 -- More info at http://www.genuineideas.com/ArticlesIndex/sratlas.html

# But Wood is Never at One Temp!



# "Best" Smoke flavor- according to most commercial producers and taste panels

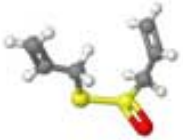
- ✓ Uniform combustion to avoid deep smoldering
- ✓ Well oxygenated fire
- ✓ A little moisture
- ✓ Temp slightly above ideal zone to avoid bitterness >1000F

We'll see how combustion conditions vary in different smokers, but how does smoke make it into the meat?

# Small Molecules Diffuse FASTER and FARTHER

Blue Dye #1

Sucrose (sugar)



Allicin (garlic)

Copper Sulfate

Water



Table Salt Ions

## Dye Diffusion Depends on Molecular Size

(36 hours, room temp, on gelatin)

Red Food Coloring

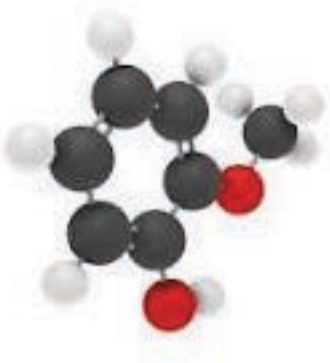
Copper Sulfate

# Smoke Molecules Are BIG

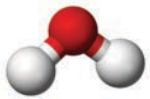
Salt – the tiniest ions, STILL takes 24 hrs
to diffuse 1” into meat in the fridge

(which is why you brine corned beef for a week and should dry rub overnight)

Smoke flavor barely gets past the surface in 24 hrs!!

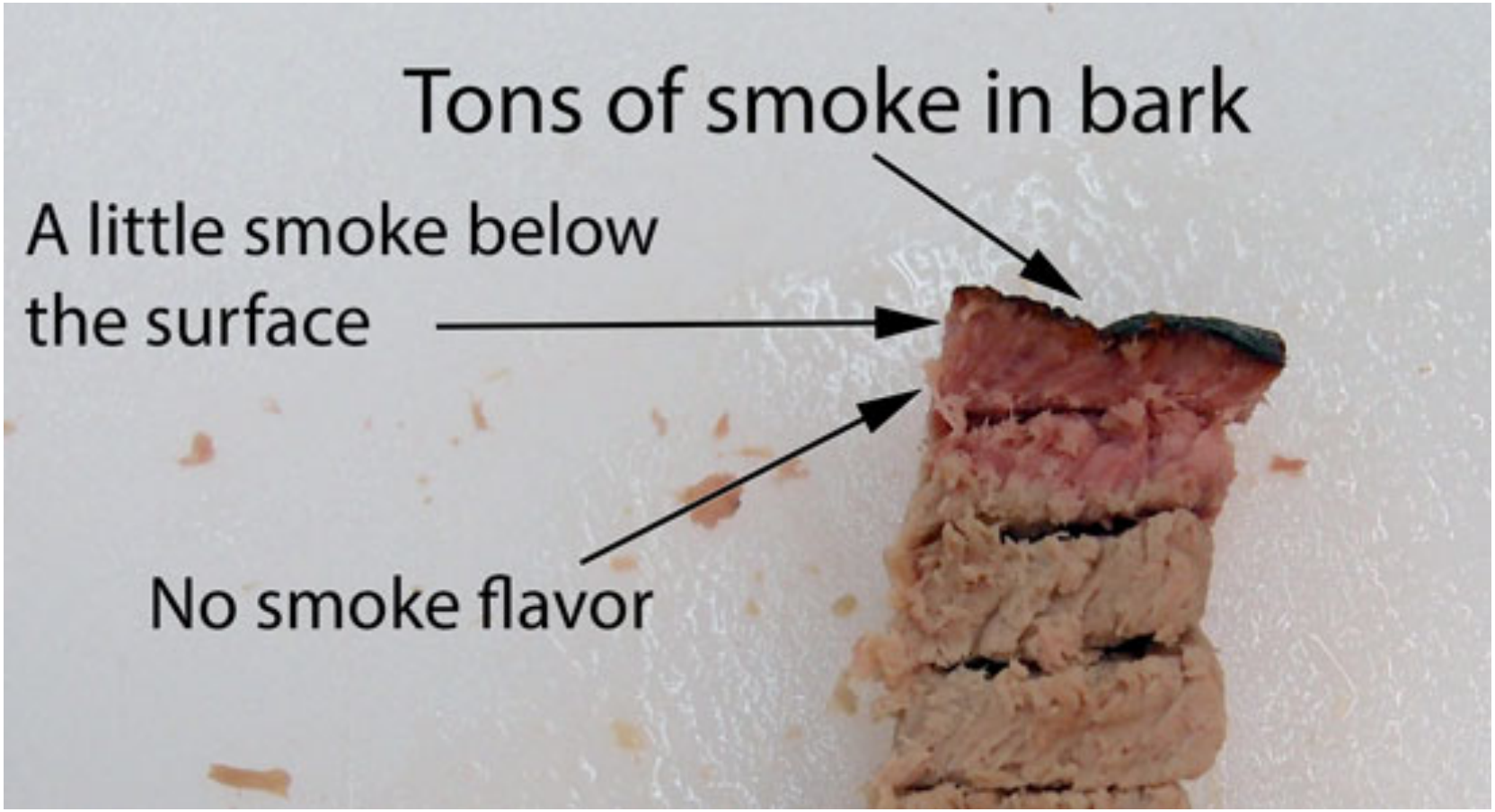


guaiacol



water

# Smoke Flavor is only on the surface and can be washed off




Smoke flavor generally SHALLOWER than ring depth!

# More Smoke Flavor

Cold Meat attracts smoke
Moist surface attracts smoke
Turbulence brings smoke to the meat
Meat must be in airflow- Ferris wheel or convection fan
Avoid washing off smoke flavor with heavy mop or braise

# Does the wood matter?

Combustion and flavor:

- ✓Wood Species
- ✓Bark
- ✓Soil
- ✓Harvest time
- ✓Seasoning

# Does the wood matter?

If your customers can tell the difference
If you don't drown the smoke in BBQ sauce
If you don't wash off the smoke flavor
If you don't mismanage the combustion conditions

then, YES



# Does wood seasoning matter?

Moisture content MATTERS!
Too wet: waste energy boiling off water, and tilts combustion products towards acrid
Too dry: cannot supply enough air to burn completely- tilts combustion towards soot

## IDEAL MCDW ~18%-25%

Live tree- Moisture Content water weight/Dry Wood weight (MCDW) up to 150%
e.g. 3 lbs of water in 2 lbs of dry wood=150% MCDW

Liquid water in pores wrings out quickly,
leaving ~30% MCDW chemically absorbed water
With outdoor seasoning, 30% declines below 25%
But each log in the pile is different…


Can tell MCDW by heft of split log, cracking, or sound banging together
But a moisture meter is more accurate and consistent
Providing you follow manufacturer's directions

# Smoke Flavor

- >100 Chemicals in smoke
- Some smoke components have weak aromas, others intense
- Three dominate, guaiacol, syringol and caramels
- Some flavors evaporate in minutes (which is why reheating is such a challenge)
- Some morph and muddy with steaming or crisping on flat-top

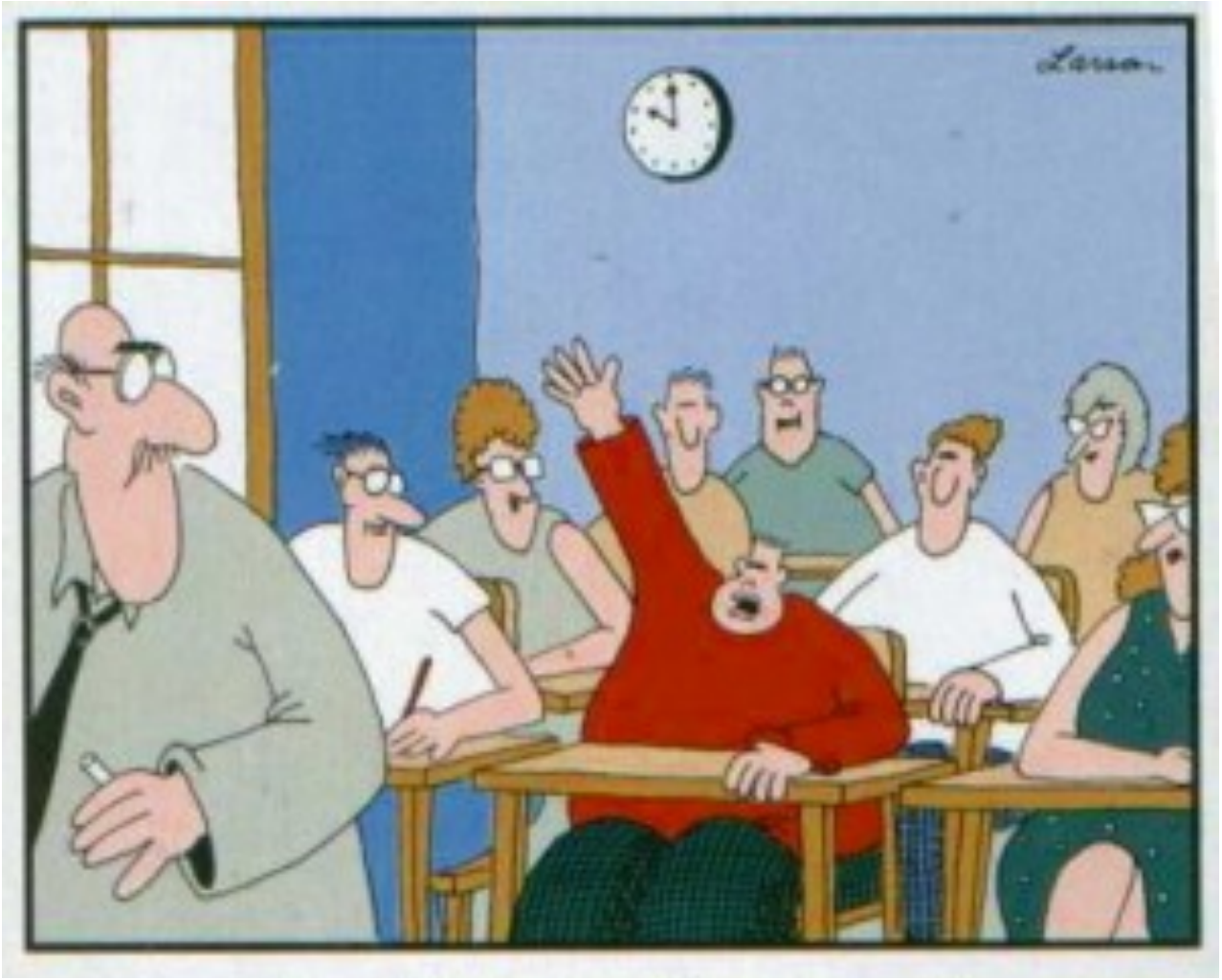
The CHALLENGE:

Can taste and smell 100 part per trillion-

small amounts of bitter flavors can dominate

Biggest mistake- controlling temp by damping fire, best to control quantity of fuel or separate heating from smoke generation

**Pitmasters rule!**

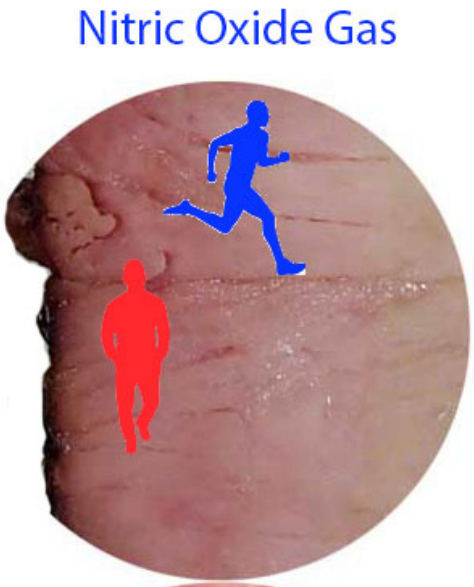


Mr. Osborn, may I be excused?
My brain is full.

# Smoke Ring Overview

- Meat is pink due to MYOGLOBIN, not blood
- Myoglobin breaks down and turns gray between 140F and 175F (depending on species, slaughtering conditions, pH, ..)
- Nitric Oxide (NO) is produced during CLEAN wood combustion
- NO acts like a photographic “fixer”, and converts myoglobin to a heat-stable pink compound.
- IF it arrives at the meat before the temperature is too high.

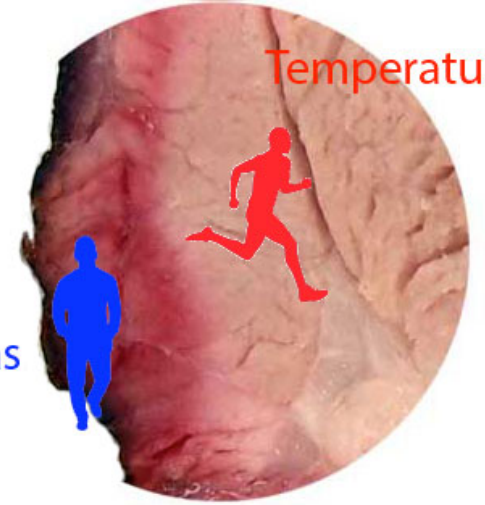
# The ring stops growing when Myoglobin is destroyed by heat




**Wide Pink Ring**

* Low slow heating
* Moist surface
* High NO combustion

*NO arrives before temp turns myoglobin gray*




**Dark, Narrow Ring**

* High temp cook
* Dry surface
* Low NO combustion

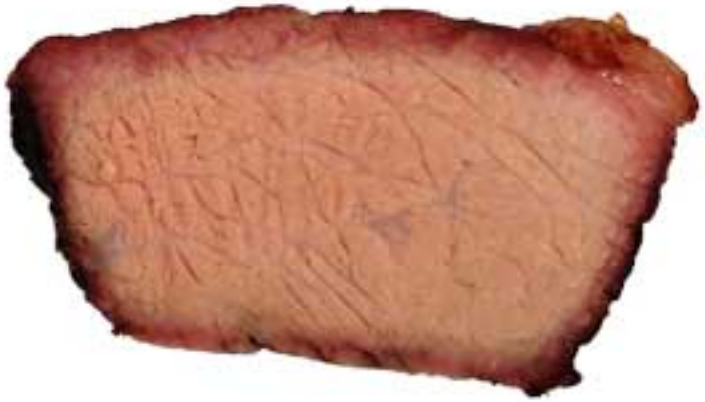
*Temp rises quickly, turning myoglobin gray before NO arrives*

# Nitrogen is Rare in Wood

| | |
|---|---|
| Oak leaves | 2% |
| Oak bark | 0.5% |
| Sapwood | 0.2% |
| Heartwood | 0.1% |

# NO from air makes a weak ring

Propane Gas
smoke ring from
residual 20 ppm NO

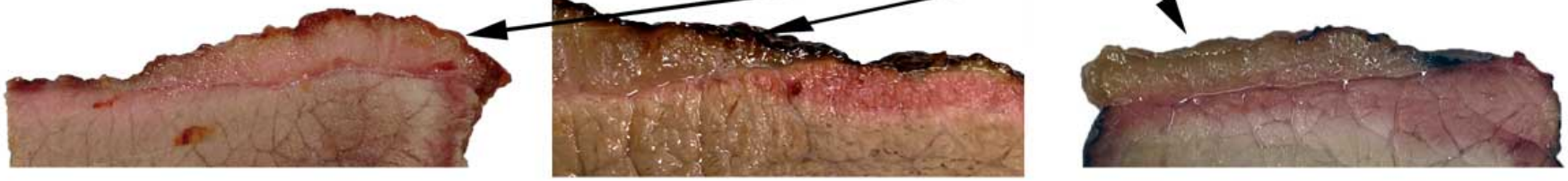


# And Nitric Oxide Concentration Depends on Wood and Combustion

| Fuel | NO in exhaust |
|---|---|
| Savannah Grass Fire, near surface | 250 ppm |
| Roaring Charcoal Briquettes | 100-200 ppm |
| Roaring wood fire (depends on wood) | 50-200 ppm |
| Pellet Smoker | 25-50 ppm |
| Roaring Lump Charcoal (depends on wood) | 10-70 ppm |
| Charcoal briquettes- long slow cook | <20 ppm |
| Propane Smoker- hot flame | <20 ppm |
| Smokenator (briquettes in Weber) | <10 ppm |
| Electric smoker with wood lumps | <2 ppm |
| Propane Grill | <2 ppm |

# NO easily penetrates FAT

## Smoke ring forms UNDER Fat

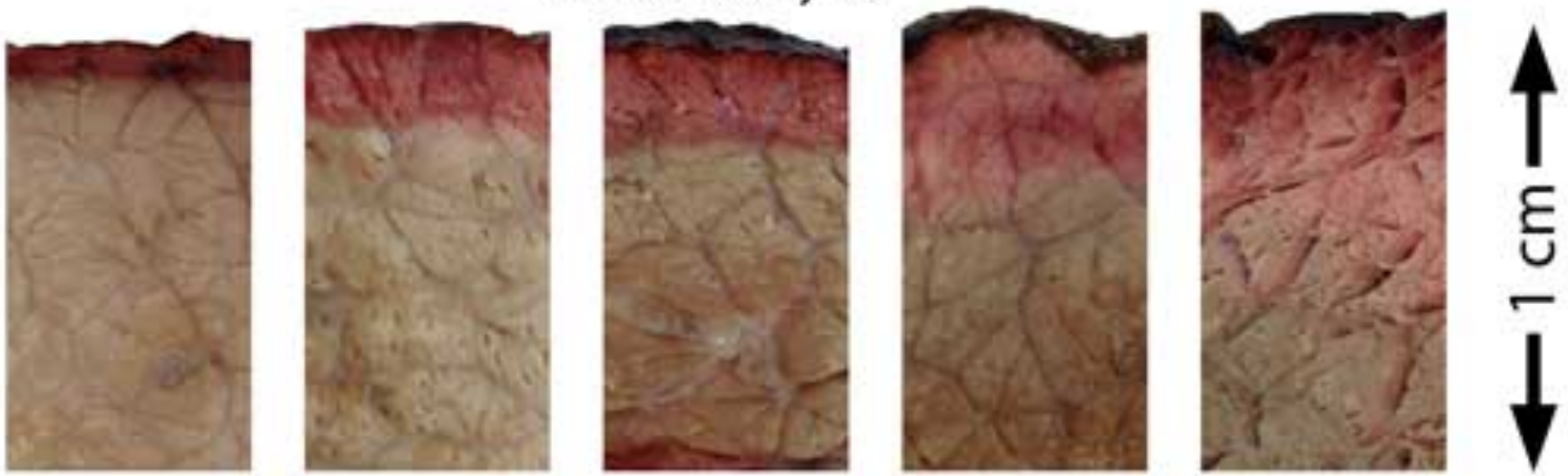


3% carbon monoxide  Pellet Smoker  Sodium Nitrite

But if the fat is thicker than the ring
NO RING!

# pH Affects Smoke Ring

brisket 1% by wt




Weak Acid (Vitamin C)

Salt

Plain

Weak Base $Ca(OH)_2$

(Baking Soda)

# Ways to Increase Smoke Ring

- Remove or thin the fat.
- Start with cold meat.
- Keep the meat's surface moist (but not dripping wet).
- Use fuel with high nitrogen content.
- Keep the fuel dry-- no wet wood hunks!
- Start off with a vigorous fire, then drop down to slow and low.
- Drop the cook temperature.
- Protect from intense air currents.
- Knock the ashes off the briquettes or coals.
- Use less salt in the rub- keep it under 1/2 tsp of table salt/lb
- Increase the pH of the meat.
- Avoid an acidic rub or marinade early in the smoke.

# Role of Humidity

Humidity helps collagen break down and tenderizes meat
Humidity improves yield and profit- less shrink
Humidity increases smoke flavor
Sometimes speeds up cooking

But some smokers are as dry as the desert,
due to high airflow and ineffective moisture systems

*Texas crutch is an alternative,*
*but affects bark and washes smoke into jus*

# Range of Humidities

Kitchen Oven @225F < 1% RH

Pellet Smoker <3%

With proper water bath ~15%

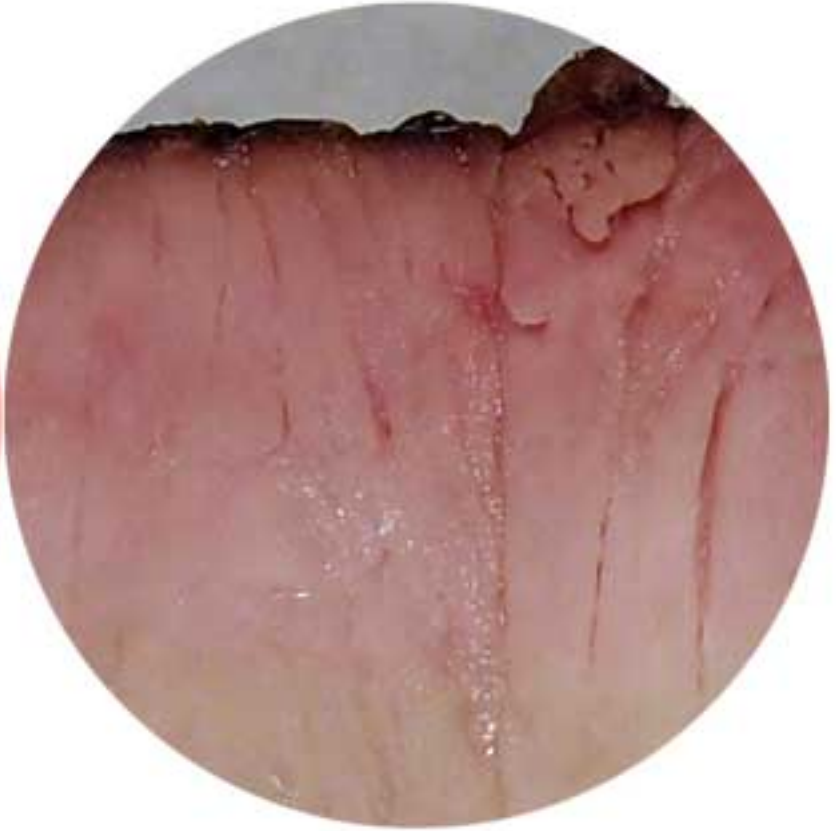
Example:
5% without lavastones
15% with lavastones

Propane combustion and meat juices also contribute moisture to air

# 3% vs 15% RH Smokers

Pellet Smoker

Humid Smoker



# Humidity

Need to KNOW the humidity in your smoker
Should be in the range of 10-20%

Armed with Science , now on to comparing smokers:

# Three Kinds of Smokers

- Smoke from wood + HEAT from combusting wood
- Smoke from wood + secondary (flavorless) fuel for heat
- Faux Smoke from chemical treatment

# Wood-Fired, Wood-Heated Smokers

- Open pit
- Stick Burner
- Pellet Fired Smoker

# Open Pit and Burn Barrel

# Open Pit Smoker

**Advantages**

- Great ‘cue
- “Authentic”
- Uniform combustion with burn barrel
- Bitter flavors evaporated in burn barrel
- Smoke, and sometimes drip flavors

**Issues**

- High fuel costs
- Fire hazard->fires->high insurance->meet modern standards-> close pit
- Rarely automated
- Highly dependent on skill of pitmaster
- Tough life

# Stick Burner


# Stick Burner Smoker

**Advantages**

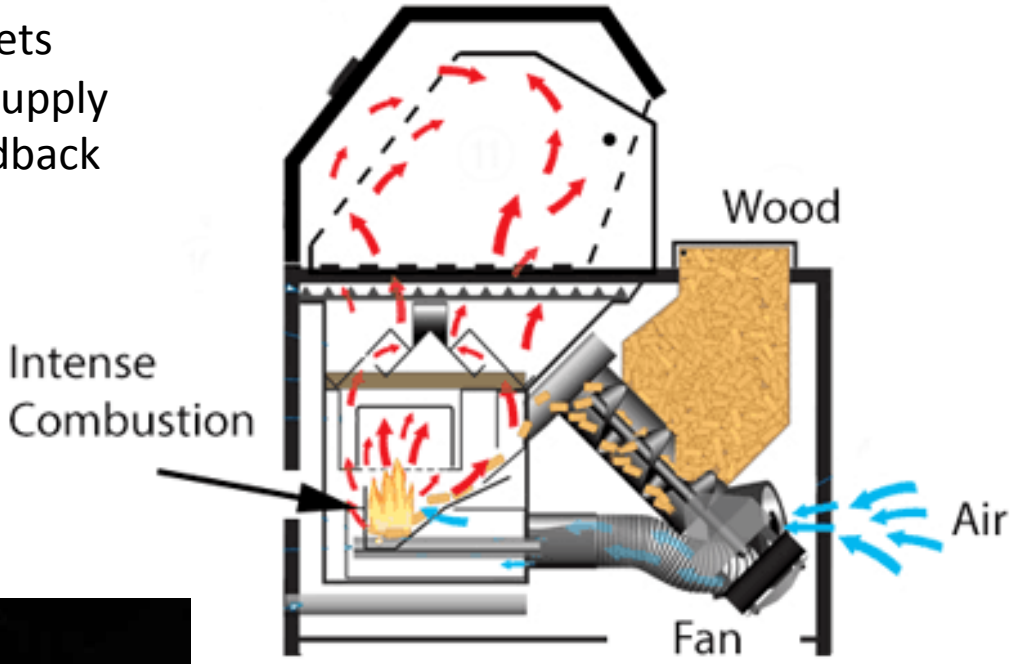
- Clean smoke flavor
- Simple,  no moving parts, low maintenance
- Traditional

**Issues**

- Fuel Costs
- Sometimes erratic results
- Uniformity
- Temperature control
- 200 air exchanges an hour
- Small stick burners can be dry

# Pellet Fired Smoker

Hardwood pellets screw-fed to combustion chamber
Forced-air fully and uniformly burns pellets
Temperature adjusted by cycling wood supply
Generally full electronic control and feedback




Firepot tornado

# Pellet Fired Smoker

**Advantages**

- Small fire, large air "miniature burn barrel"
- Clean smoke
- Little ash
- Set it and forget it
- Easy to blend wood species, even grasses and herbs
- Consistent

**Issues**

- Less smoke flavor at high temps
- Often dead air spots with low smoke exposure
- High air exchange often dries out meat surface
- Generally low humidity
- Some pellets deliver too little heat, and too much creosote.

# Heat Assisted Smokers

- Electric Smoker
- Gas Smoker
- Sawdust Smoker
  (Pellet Smoker)
- Friction Smoker
- Charcoal Smoker
- Two-step

# Electric smoker

Power often limited 20 A circuit  2 KW at home, 6 KW commercial
Under 10 air exchanges an hour to preserve heat
Smoke from heated wood or pellet tray
Thermostatically and often computer controlled

# Electric Smoker

**Advantages**

- Very low cost of ownership
- Tightly sealed and High humidity
- Simple ventilation
- No skill required to operate
- Set and forget
- Holds low temps very well
- Can cold smoke

**Issues**

- Poor combustion- too little heat and air
- Too little NO for smoke ring
- Sometimes bitter and black bark
- Hard to smoke at high temps

# Gas Assisted



Wood Burning
(Fireplace-size logs)

Wood Burning!
We're Not Just Blowing
Ordinary Hot Air.

# Gas Assisted Smoker

**Advantages**

- Low cost of ownership
- Can generate sweet smoke
- "Gassy" taste a myth
- Generally humid
- Large Capacity
- Some fully computer controlled
- Transitional option from competition to restaurant

**Issues**

- Can generate weak smoke
- Can generate bitter smoke
- High airflow sometimes dries meat

# Sawdust Smoker

Smoldering sawdust
(sometimes pressed disks or pellets)
Low exhaust requirements
Runs from simple to computer controlled

# Sawdust Smoker

**Advantages**

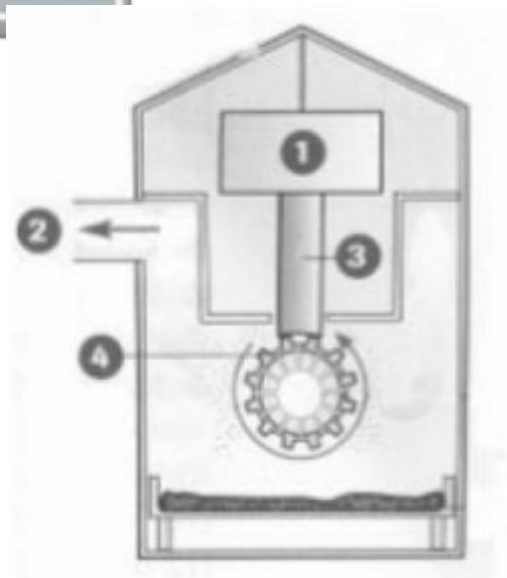
- Copious smoke
- Inexpensive fuel
- Good for cold smoking
- Low ventilation requirements
- Separate humidity system
- Agitated sawdust best

**Issues**

- Smolders
- Smoke can be heavy or acrid
- Sawdust may be contaminated

# Friction Smoker

Where there is smoke, there's fire- NOT!
Lumber feeds against friction wheel
Rubbing two sticks together reaches 700F to 800F in seconds
Auto and manual feeders




# Friction Smoker

**Advantages**

- On-demand smoke
- Combustion temperature in ideal zone (~700F)
- Low vent requirements
- Very predictable

**Issues**

- Auxiliary humidity control
- Mechanically complex with potential maintenance issues
- Specialized fuel rods
- “Inauthentic”

# Charcoal is "wood" that starts at Stage 4

Coconut Shell
Extruded charcoal

Lump hardwood

Briquettes- wood+ coal + other additives

Almost pure carbon
Should add only heat, and little to no flavor
Poorly controlled lump may crackle and produce creosote
Briquettes additives may contribute slight flavor, especially oxygen starved
Briquettes consistent heat source

# Charcoal-heated Wood Smoker

Charcoal provides consistent heat and very little flavor
Wood hunks provide flavor
Styles- gravity fed, tray, minion, ..

# Charcoal Heated Smoker

**Advantages**

- Briquettes a predictable heat source
- Medium cost of fuel
- Traditional
- Reliable and simple
- Wood addition controls smoke level
- Sufficient heat to steam water tray

**Issues**

- Wood hunks often under oxygenated and smolder (note- can't "oversmoke" with too much wood!)
- Charcoal sometimes adds bitter flavors
- Generally manual control, but can be automated

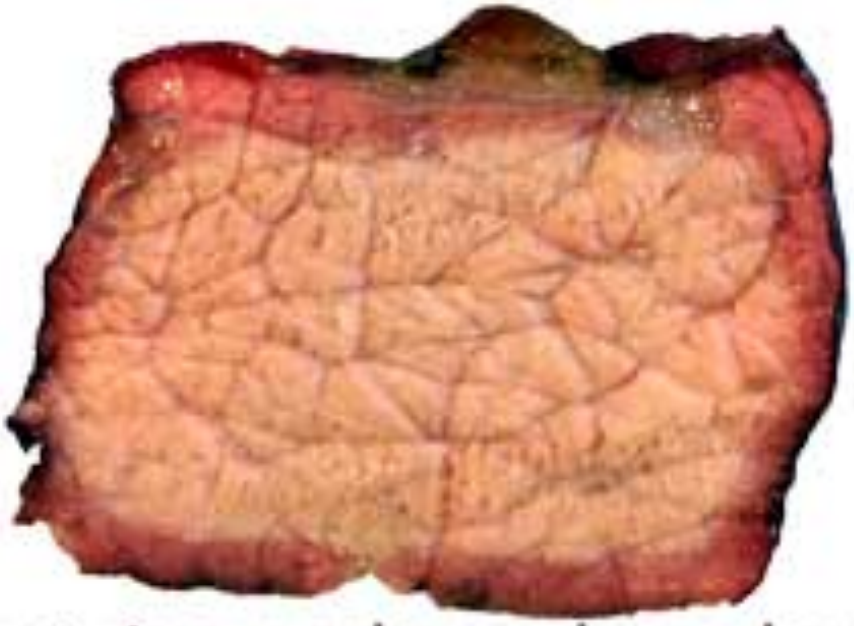
# Two-Step, Two-Machine Cooking: Smoke, then Steam

- A little bit of fully combusted wood goes a long way
- Smoke for 15 minutes to a few hours
- Then tenderize in high humidity oven

+

# The Power of Smoke

15 mins in pellet smoker,
then finished in kitchen oven



brisket ring and good smoke flavor

# Two-Step Smoker

**Advantages**

- Re-use existing equipment
- Optimize each step
- Helps hold meat til service
- Looks traditional

**Issues**

- Bark suffers
- Less complex flavors

# “Exotic” Smokers

- Supercritical Steam 650F-800F
  (sand blasting sawdust with water)
- Laser or Flash lamp to ignite wood

## Steam smoke generators

The steam smoke is particularly suitable for the industrial production of boiled sausage. In the smoke generator the steam is superheated to about 400° and can be operated with both wood chips and sawdust. It is characterized by extremely short smoking times and intense smoke flavour.

# Chemical "Smoke"

Used for some cheeses, bacons, mall restaurants

- Liquid Smoke
- Sodium Nitrite Ring
- Bed of Nails injection
  - with TSP, gums, binders, MSG

Pyrolized fat droppings


Needle-head: Needle quantity 968pcs

# Summary

- Wood Combustion Creates Heat and Aromatics
- The Aromatics taste GREAT if you can avoid "contamination" by other smoke ingredients
- Combustion conditions are critical variables
- Humidity control improves smoke flavor and yield
- Almost any smoker can be made to work, but some are easier to operate, and more consistent

# Five Biggest Mistakes in BBQ

1. Burning too much fuel with too little air
2. Salting meat too late
3. Too little humidity
4. Ruining good ‘cue by improper storage and reheating
5. Resuscitating bad ‘cue by drowning in sauce