Foam On Beer (FOB)

Expectation plays a huge role in how we taste food and drink, when we approach a beer first we see it, then we smell it, last comes tasting it.
If on a hot day we are presented with a bright (not turbid - we will look at exceptions later) clear beer, the glass coated with condensation, with a firm creamy cap of foam, we will be more favourably disposed toward it and will probably enjoy it more!
The same beer too warm to form condensation, unexpectedly cloudy and without a head will probably be received much less favourably.

We don't expect a head on a glass of Champagne, or soda water, but we do expect a Cola drink to foam - however briefly, temporary foaming agents (Saponins from the bark of Quillaia or yucca trees) are added to many soft drinks.

So why do we expect a head on beer?
I think the part of the answer is probably very old, people used to drink beer rather than water because the water wasn't safe.
For a beer to have and to hold a head it has to be safe (free of bacteria and their waste products), it has to have a reasonably high level of malt and hops (be made from good tasting stuff), to have been boiled to give a reasonable level of protein and bitter acids, it also needs to be "fresh". As beer ages and yeast starts to autolyse an enzyme called Protease-A is released, which degrades head building proteins.
If a beer "looks the goods", we anticipate that it will taste great, there is probably a bit of racial memory going on to, a good looking beer is a "safe" beer...

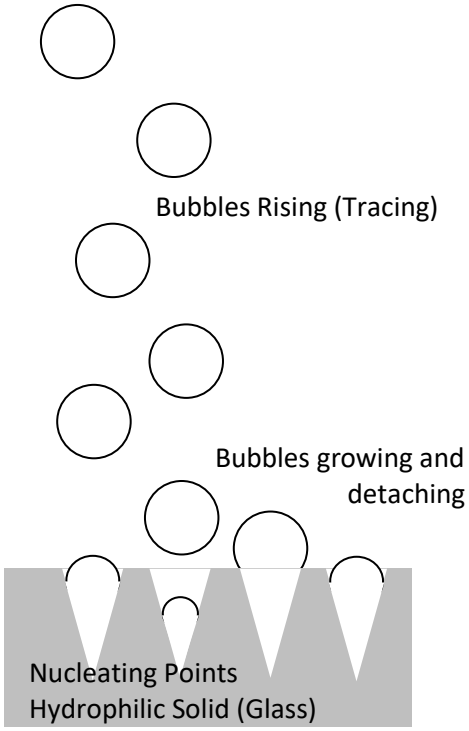
We have mentioned several carbonated drinks, what they all have in common is dissolved Carbon Dioxide (CO_2), they all form bubbles and in pretty much the same way.
Carbonated beverages have what is called a Supercritical amount of CO_2 that is to say more than would be there naturally for a given temperature; simply it's under pressure to keep the CO_2 in solution.
When we release the overpressure by opening the can/bottle or tap on a keg the CO_2 starts to come out of solution and forms bubbles. Bubbles form on Nucleating Points which are any place in the liquid where an irregularity initiates bubble growth, these include roughness on the container (deliberate or not), yeast cells, micro bubbles Calcium Oxalate crystals (beer stone) haze particles...
Where beer is different is that the bubbles don't burst on reaching the surface (well not anything like as quickly).
This introduces us to the first point where we get some control over how much foam ends up on our beer. It's not just the amount of CO_2 in solution, but also the temperature that determines the amount of bubbles that form. Different beer styles have different amounts of dissolved CO2 as part of the makeup, from as high as 9g/L in some German Wheat beers to as low as 2.5g/L in a cask conditioned UK Ale at the opposite extreme.
Worth noting that the UK ale isn't famous for its big fluffy head, the German Wheat most certainly is.

Proper control of Carbonation is critical to good head formation. This includes dissolved CO_2 and serving temperature, both should be appropriate to the beer being served. Visit http://braukaiser.com/wiki/index.php/Carbonation_Tables for more information

In a perfect world the glass would be 1-2^{o}C warmer than the temperature of the beer.
Too cold can cause gushing especially if the glass is frozen, small ice crystals provide a lot of nucleating points.

Too warm and something similar happens, lots of bubbles form in the first portion poured as the warm glass heats the beer – this reduces the solubility of CO_2, resulting in lots of bubble formation.

Bubbles and Foam are different; bubbles are a body of gas usually spherical because of surface tension, immersed in a liquid. Foam is a film of liquid with gas on both sides of the wall, where it gets interesting is that bubbles have to transition through the surface of the liquid and drag a "wall" with them.
Bubbles in soda water, wine or soft drink don't do this, but bubbles in beer do.
That raises the question of why?



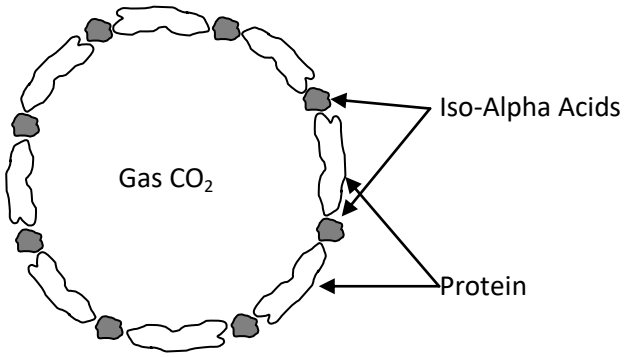
Bubbles form Foam on the top of the liquid, note that there Will be a lot more, smaller bubbles in the same height of foam

On a Schooner glass 60mm in diameter, 30mm of foam Would be made of ~1.5 million fine bubbles in ~100 layers and have a surface area of about 0.75m^2

Fine foam will last longer and be more stable than coarser foam

As the beer sits more bubbles form replenishing the head Some glasses are sand blasted or laser etched to create more nucleating points – rough glass, sharp points and floaties (haze particles) can all act as places where bubbles start to grow (nucleating points)

Bubbles in Beer as they grow and rise through the beer pick up a wall of protein and Iso-Alpha Acids, this is one reason why the head tastes bitter than the beer.



It would be nice if that was all there was to it, sorry.
It is the fate of every bubble to burst, a persistent head requires that the bubble lasts, what we call Foam Stability.
Normally there is some ongoing formation of bubbles in the glass, some glasses are even made with extra nucleating points, the bottom is often sandblasted to provide points, this is often called "Working" in the trade.

Practical Demonstration

Egg Albumen and Tetra Hop

Pouring a beer
How to get a good head
Best results are obtained if Cold Beer is poured into a glass 1-3^{o}C warmer than the beer, Avoid Dirty or Frozen glasses.
Pour about 1/3 of a glass; allow beer to rest for 1-3 minutes for the head to stabilise and for the temperature to equilibrate. Finish filling the glass, pour gently so as not to disturb the foam and so that the beer retains most of its CO_2, this will come out of solution slowly and replenish the head (work).

Practical Demonstration
Glass Cleaning Salt
Two glasses, cleaning difference
Even if your beer has great head potential, that can be undone when you serve the beer

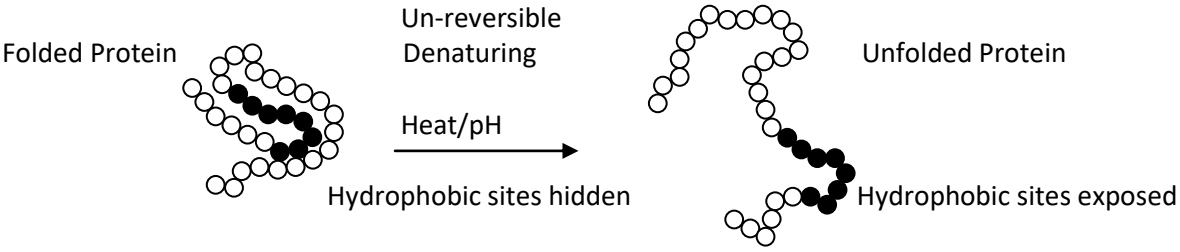
Proper cleaning is critical to good head formation and retention. Don't clean glasses with other kitchenware. Use a good non soapy cleaner (BBW). Don't use a tea-towel that has been used for anything else. Make sure Bottles, Kegs Lines and Taps are properly cleaned.

As we have seen, getting protein and Iso-Alpha into solution is critical. There is in the ingredients we use to make beer both Head Building Ingredients, there are also Head Degrading Substances. Further there are brewing processes that promote good head and processes that will harm the head forming potential of the beer.
Our job as brewers is to make sure there is enough Protein and Iso-Alpha in solution to build a good head, and not too many head negative products trying to undo our work.

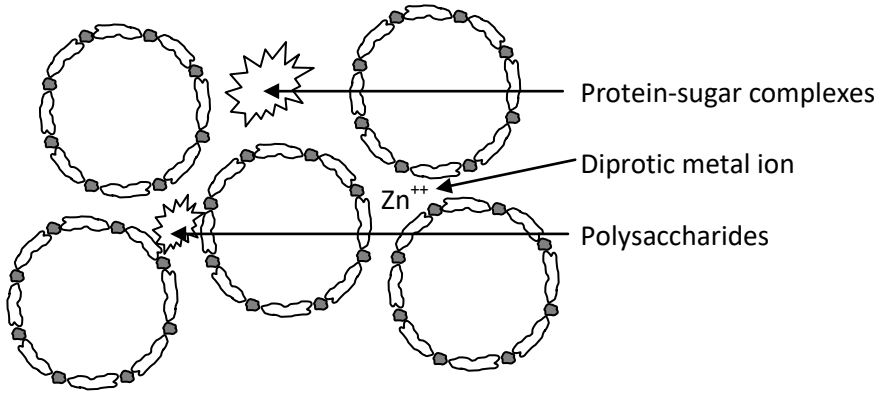
First the head Building Ingredients
Protein is one of the parameters that is given on every COA, not just Total Protein, but Soluble Protein is also given.
Protein Chemistry is a science in its own right, there are 22 Amino Acids, of these about 20 are used to build living things, they combine in groups to form Peptides, Polly Peptides and Protein. There are so many possible proteins that we rarely look at them as other than groups and we look at the molecular weight of the group.
Soluble wort proteins range in size up to 100,000MU. There are two that get talked about they are Protein Z (40,000MU) and LTP Protein (10,000MU), most of the research on head formation has focused on these two proteins. The fact that they are the most abundant proteins in beer no doubt plays a part in this

Researchers have found that neither of these proteins when extracted from malt are particularly good at head building, but when extracted from wort they are very powerful head builders.
What has changed during the boil is that the protein has become "Denatured" we have all heard how mash enzymes become inactive at certain temperatures, Enzymes are proteins and the same thing is happening to other proteins during mashing and wort boiling.
Soluble proteins tend to have Hydrophobic and Hydrophilic (literally water hating and loving) sites, in their natural state the hydrophobic sites are wrapped up inside the protein – away from water, when the protein is denatured they are exposed. Given the chance they will avoid water by chumming up with a bubble.

Denaturing of Protein



In the head on top of the beer there is a bit more going on.
Foam is a matrix of gas bubbles, between then is a liquid layer



The liquid slowly drains down, back into the beer. When the walls get thin enough the bubbles burst. One of the factors that determine the rate of drainage is the viscosity of the beer. Polysaccharides and Protein-sugar complexes (intermediates in the milliard darkening reaction) make the beer locally thicker and reduce the rate of drainage.
Ale and darker beer can be expected to have better head retention because of the darkening products
Zinc is a very powerful head stabiliser in rates of around 1ppm
NB this is too high for fermentation so it must be a post ferment addition.

We get the protein from our grist. Before we go any further, yes wheat malt contains more of the head positive proteins so wheat can be used to improve the amount of head building material in the wort. No sensible brewer would choose high protein malt for its head building potential (see 6 row malt) what is important is having enough of the right sized soluble protein.

There are also head negative components in the grist, mostly Lipids. Lipids are a bit of a catch all name given to fats and oils; they act much like the oily addition to the glass we looked at earlier.
A normal all grain grist should have plenty of head building ingredients to form good dead on most beers, if your grist is supplemented with a lot of sugar (0% protein) or contains a lot of unmalted adjunct, we have every reason to expect good head on the beer. Unless we apply poor processes that either reduces head positive ingredients or increase head negative components.

Just a couple of points on processes that affect head
With modern well modified malt there is no need for a "Protein Rest" about all it will do is chop up useful protein and make it too small to build head.

Mashing in above 62^{o}C and at lower than traditional pH's (lower than 5.2) will inactivate an enzyme known as LOX (Lipoxygenase) which will lead to an increase in water soluble oxidised lipids that are head negative and contribute to staling.

Not mashing for longer than necessary will reduce the lipids extracted into the wort. I suspect that around 45 minutes is a real lower limit, remember that 60 minute mashes are a part of modern fast mashing and are predicated on very well made malt. Long, over 120 minute, or god forbid overnight mashes will be detrimental.

Over extracting, over sparging or too hot a sparge will increase the lipid content of the wort – don't be greedy.

Quality Malt and Good Brewing Practice should provide adequate head building material and minimise the amount of head negative matter in the beer.

On wort Boiling
One of the main reasons for boiling a wort is to reduce unwanted protein. What we are referring to are large proteins that if not removed will form haze and reduce flavour stability. We as above want to denature the useful protein so it is more head active. We also want to add Iso-Alpha Acid (not just for its head building properties). Luckily big proteins will precipitate about twice as fast as will the smaller beneficial proteins, this is especially the case when hop polyphenols are present (we want them gone to, for different reasons).
Fortunately we can achieve all the desired outcomes if we boil hard and long enough to evaporate about 8-10% of the wort volume. Again a 60 minute boil is part of the modern fast brewing process, go back to the 1960's and 400minutes (6 hours) was regarded as a standard brewing cycle from mash in to knockout.
Very long boils (over 3 hours) can reduce the head positive protein content of the wort; somewhere in the 60-120 minute range is good.

High gravity worts will not have as much head building potential, match this with the fact that Alcohol is head negative and it makes getting a good head on a barley wine hard work.