

An evolved hair growth mechanism in mammals, implications in human physiology.

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Abstract

There is currently no accepted theory of mammalian hair growth, that addresses the questions as any valid scientific theory is required to do.

The mechanisms of the establishment of hair growth characteristics, and changes in these is poorly understood. The body of evidence we have often seems contradictory, with no apparent common thread.

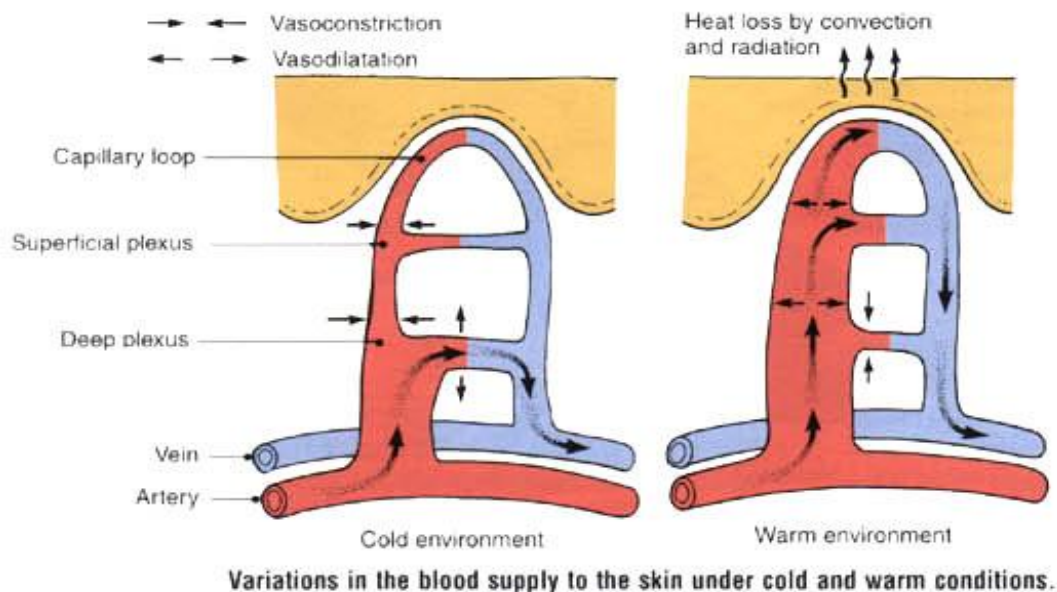
Here i offer evidence for an evolved dermal mechanism, that i consider to be the missing link in our understanding of mammalian hair growth. This mechanism makes sense of the referenced existing evidence we have, and fills in the gaps.

The fact that this mechanism can be demonstrated in modern humans, has implications in further understanding of human evolution. This includes an insight into the evolution of modern human hairlessness, changes in human hair patterns, and a link with some serious gender related conditions.

An evolved dermal system adjustment mechanism in hairy Mammals, still observable in modern humans

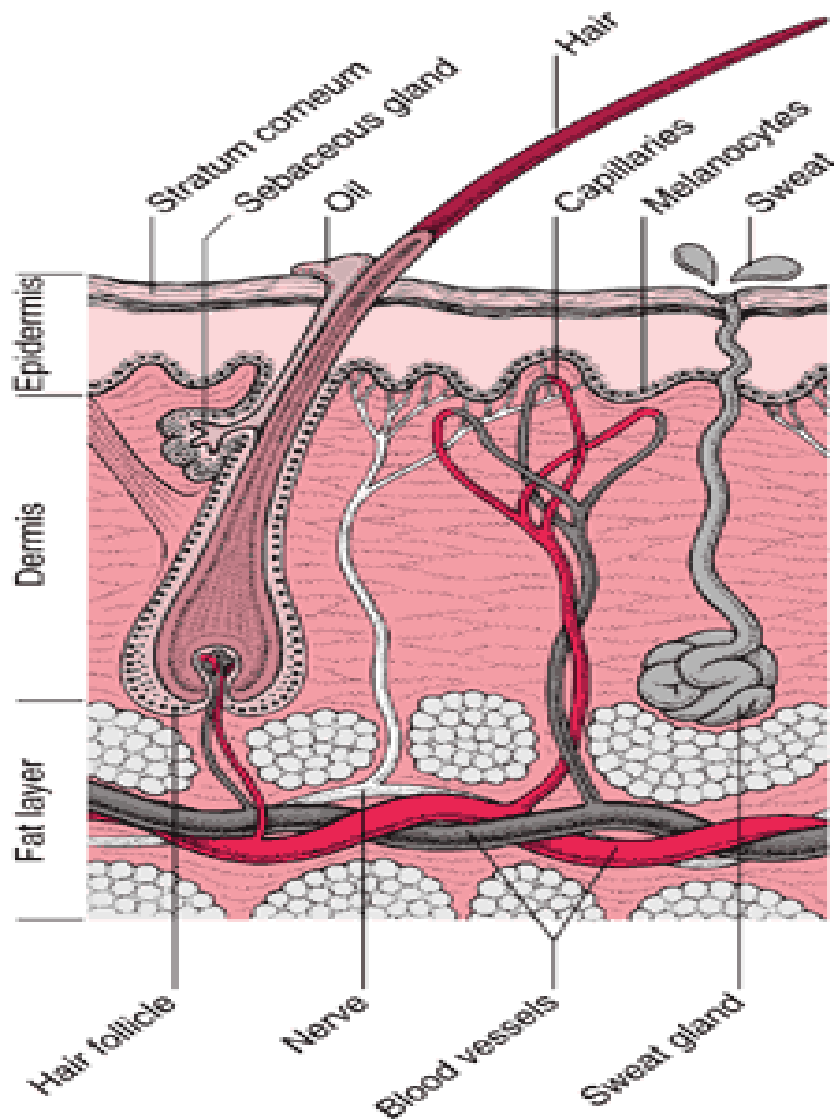
One big advantage mammals have had in evolution is the ability to live in a wide range of environmental temperatures. This is due to the ability to adjust the mammalian dermal system to increase heat retention in cold climates, and shed excess heat in hot conditions.

The primary mechanism involved is one of changes in the blood supply to the surface tissue, as described below.



A consequence of this change in blood flow, is a change in the local tissue fluid levels and pressures. Increased blood supply in response to hotter climates, increases tissue fluid levels. This ensures a good supply of fluid for the sweat glands when it's needed. Sweat glands have no pumping ability; therefore sweat secretion rate must be related to the local fluid levels and pressures. The reduced dermal blood supply in response to reduced environmental temperature conserves body heat. The reduced tissue fluid levels and pressure, reduces the sweating capacity of the tissue.

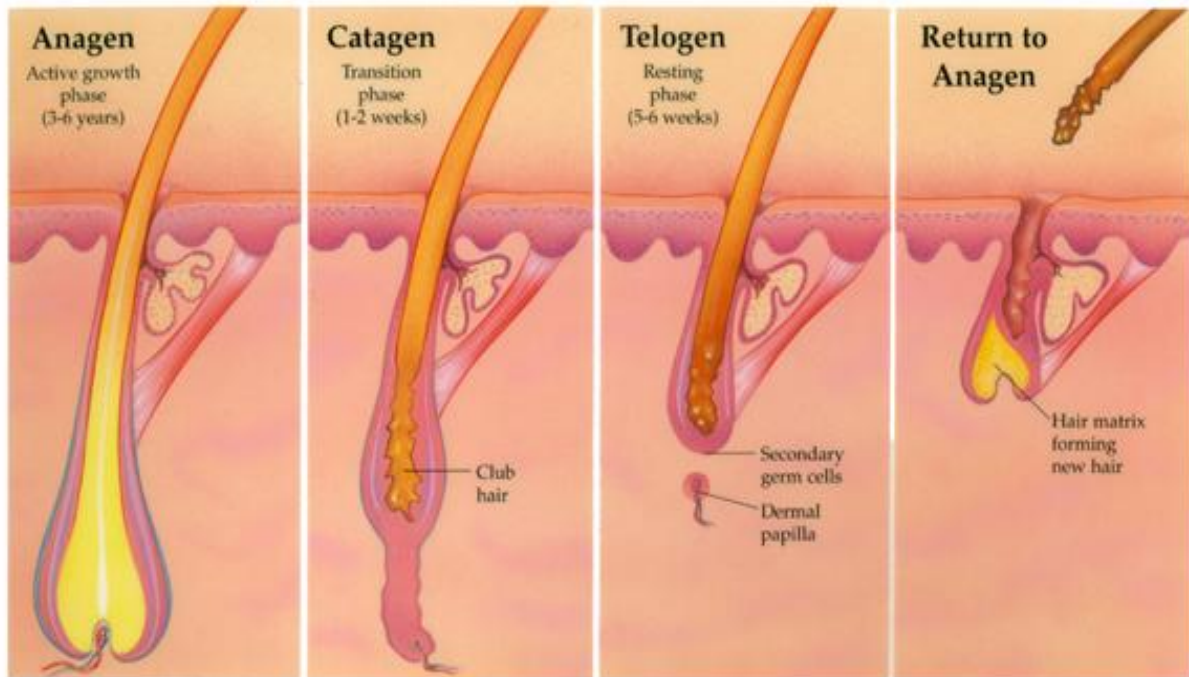
The cross section of the dermal system below shows the basics of the temperature responsive structures, variable flow blood vessels, sweat glands, and hair follicles.



Whilst it is easy to see how there is a linked temperature response with tissue fluid levels and sweat secretion, there seems no apparent integration with hair production. We know that hair production does adjust in hairy mammals in response to external temperatures. The winter coat and the summer moult testify to this.

Hair production is linked to the hair cycle described below.

Hair Growth Cycle



During the anagen expansion phase of the follicle, the follicle enlarges to form a pocket within the dermis. Hair production is all about the size of the area formed by the hair producing matrix in contact with the dermal papilla. The longer the anagen enlargement period and the larger the follicle, the larger the production area and more hair is produced. If anagen enlargement is cut short, the resulting smaller follicle produces less hair.

Hair follicles are enlarging pockets within the dermal tissue, and i considered the question of what would happen to hair follicle enlargement if the dermal tissue refused to move out of the way?

I think this is the key to understanding a masterpiece of evolutionary adaptation and simplicity, in the mammalian dermal response to the prevailing environment.

There is a basic overruling control of all normal tissue growth in multi-cellular physiology, this is contact inhibition. This turns off cell multiplication and tissue growth, if there is conflict with surrounding tissues. This ensures one tissue does not invade another. We don't know exactly how contact inhibition works at the genetic/cell level, but we do know all normal cells respond to this. Cancer cells do not respond to contact inhibition, and this is how tumours can invade other tissues.

There must be some degree of resistance that stops tissue growth in contact inhibition, and hair follicles like any normal tissue will stop enlarging at this point. If the resistance to follicle enlargement varies, then anagen follicle size becomes adjustable based upon this resistance.

The variable tissue fluid pressures in the dermal response described above, expands or shrinks the dermal tissue. The increased tissue pressure of expansion increases the resistance to the formation of any hollow space within the tissue, such as hair follicles. Reduced pressure and tissue shrinkage, will reduce the resistance to hollow structure enlargement.

A simple analogy can be made with a party balloon. Consider the balloon to be the dermal tissue. If you press a finger into this to form a pocket like a hair follicle, the resistance varies according to the pressure within it.

The overall response to shed heat is an increase in dermal blood flow to radiate heat away from the body. The increased tissue fluid levels and pressure, increases sweating capacity to also shed heat. The increased pressure and tissue expansion, reduces hair growth by reducing the size of enlarging anagen follicles by normal contact inhibition. Follicles already in full anagen size as shown in the cross section diagram above, are subject to distortion. The expanding dermal tissue moves the surface of the skin away from the dermal

papilla, pulling the follicle body with it. The hair producing matrix around the papilla begins to involute, reducing the production area and hair growth. Because tissue expansion is exponential this effect is magnified in longer follicles, and these become fully involute losing the growing connection and the hair is shed. All this adds up to a simple increase in tissue fluid pressures resulting in a moult, and reduced hair production. This is integrated with, and increases the efficiency of the bodies' heat shedding system through one simple mechanism.

The reverse situation applies with reduced environmental temperature. Blood supply to dermal tissue reduces to conserve heat. The reduced tissue fluid levels and pressures reduce sweating capacity, and shrink the dermal tissue. This allows increased anagen follicle enlargement and increased hair growth. The dermal papilla of existing follicles moves upwards into the follicle body, increasing the matrix production area. The overall result is increased hair growth and density, the mammalian winter coat.

Follicle involution and hair loss in response to increased fluid pressure has another important role in the survival of hairy mammals. A severe increase in tissue fluid pressure will involute all the local follicles, creating total hair loss in the area. Any injury will trigger an immune response and tissue swelling. Hair is shed in the area, allowing the hairy mammal to keep the wound clean. The chances of life threatening infection are much reduced. Such hair loss around injuries is noted, and referred to as shock loss.

Basic physics and common observations in humans

The basic physics of tissue expansion or shrinkage and the effect upon hair follicles are simple, and easy to understand. This mechanism does not contradict the recognised follicle changes of the normal hair cycle, rather it works with the normal hair cycle to integrate hair production to local tissue conditions. The structure of hair follicles is perfectly adapted for this purpose in evolution, as previously described.

Let's consider the proposed effect upon follicles already in the hair producing anagen state.

This mechanism claims that tissue expansion/shrinkage around these follicles, will reduce/enlarge the production area of the follicle by relative movement of follicle elements as previously described. So there are two questions here.

Firstly, can it be shown that tissue expansion/shrinkage, moves the hair production structure relative to the follicle body as suggested? Secondly, can it be shown that this movement will then change the hair production rate as the proposed mechanism predicts?

The answer to the first question lies in the common observation that hair growth seems to continue for a period after death. We know that what actually happens is the tissue around the follicle shrinks after death, causing the hair bearing structure to move upwards through the follicle body. this makes it look like continued growth(1)

Here then is confirmation of the first part of the mechanism. So can changes in hair growth follow from this relative movement?

Such movement of the hair producing structure up into the follicle body in life, would according to this mechanism increase hair production as previously described. The tissue shrinkage required to

test this in-vivo, would be difficult to achieve, but there is another way.

Instead of trying to reduce the internal tissue pressure, we could more easily increase the external pressure on the skin. Such pressure over a period of time, would compress the tissue causing the same relative movement of the follicle elements, increasing hair production according to this mechanism.

It seems that this experiment has already been performed many times in clinical medicine. When a plaster cast has been used to firmly support broken bones, one consistent effect is increased hair growth under the cast. Here is just one of many references to this effect (2). This is clear confirmation of this pressure/hair growth relationship in humans.

There is one other factor that is important. This is the natural toughness or weakness of the tissue around hair follicles. Tough tissue will in itself resist anagen enlargement reducing follicle size, whilst weak tissue will allow larger follicles to develop. Any given change in tissue fluid pressure will have more effect on expansion/shrinkage in weak tissue than tough tissue, hence more effect upon hair growth.

These factors should be kept in mind when considering this dermal mechanism in terms of known physiology.

Implications in modern humans

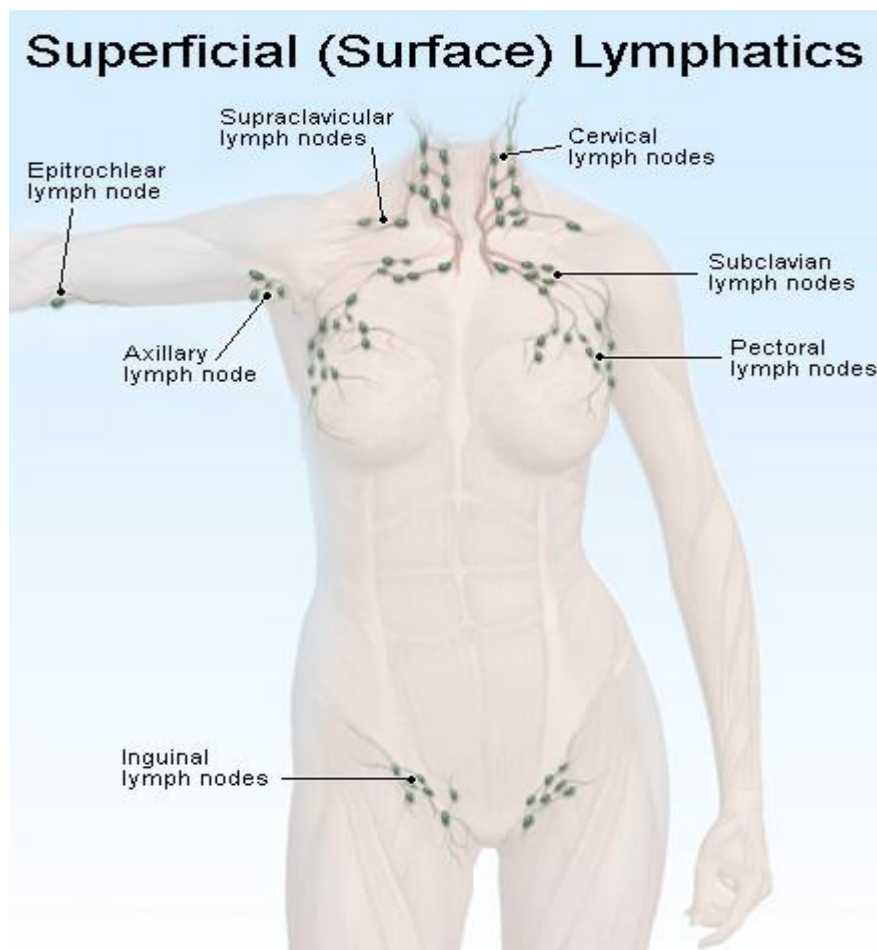
This dermal mechanism makes a link with changes in tissue fluid pressures, hair growth and the capacity of the tissue to produce sweat. Where hair growth is increased, sweating capacity is reduced. Where hair growth is reduced, sweating capacity is increased.

There has been a study “Beards, Baldness, and Sweat Secretion” that has confirmed this relationship in modern humans (3) This study

clearly demonstrates the predicted hair/ sweating relationship of this dermal mechanism in modern humans.

The study involves changes in human hair growth related to androgens. The secondary hair growth changes in both sexes are known to be related to an action of androgens. The areas of increased growth are the pubic and armpit areas, and in men the higher levels of androgens affect the beard and chest areas.

The other common factor in these areas is increased levels of lymphatic vessels in the dermal tissue.



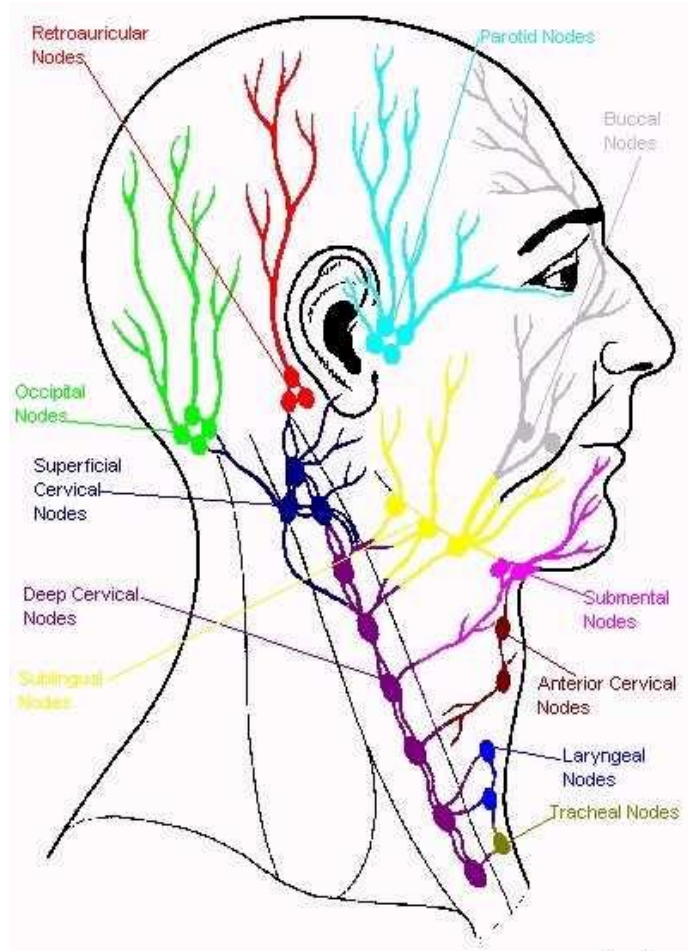
This dermal mechanism suggests that androgens are increasing lymphatic drainage efficiency, reducing the local tissue fluid pressures and increasing local hair growth.

Such an effect of androgens upon lymphatic efficiency makes perfect sense in terms of androgens being performance and growth enhancing. The increased tissue fluid turnover will increase nutrient supply and waste removal in tissues, enhancing the other performance/growth effects of androgens.

This also means a significant gender difference in lymphatic transport efficiency. In my opinion, this is fully in line with known gender differences in immune function and some serious auto-immune conditions. Immune component levels in tissues, tissue exposure times and traffic through lymph nodes, are all related to lymphatic drainage efficiency.

According to this mechanism, weak tissue will allow larger follicles and increased hair growth, and I suggest an example of this in modern humans. If you compare the feel of the tissue beneath the eyebrows compared to the tissue around, you can note the difference. Eyebrows grow from a strip of tissue that is noticeably softer than the tissue around them.

The combination of tissue weakness and reduced local tissue fluid pressures, also account for the human scalp hair growth pattern in my opinion. Below is a diagram of the superficial lymphatics of the human head. It can be seen that the base of the scalp growth area matches the point where the lymphatic's start to go deeper. The relevance of lymph vessels to the beard area is also seen.



The most studied area of human hair growth is male pattern baldness, and any valid mechanism has to answer the questions here.

The proposed hair growth mechanism in male pattern baldness

The proposed dermal system mechanism as it relates to hair growth makes sense of the often puzzling results of studies in human hair loss. It explains the recognised conditions in the bald scalp in MPB, and why particular treatments have positive effects. It also explains why some transplantation procedures work whilst others fail, and why these procedures have evolved into the form they are today.

Basic observations

According to this mechanism, the prime mover in human MPB is an increase in the local tissue fluid levels and pressure. There are basic observations anyone can make here. Why do people refer to a shiny bald head? Why does the skin shine? Because it is smooth and taut due to the expansion of the tissue. Elastosis and tissue thickening have been noted in bald scalp compared to hairy scalp (4). When you know what to look for, you can see the point on the forehead where the swelling starts. The pitting edema test is used as a rough guide to the fluid levels in tissues. In this a finger tip is pressed hard into the tissue, and held for around 15-20 seconds. This pushes excess fluid away, and when the finger is removed a “pit” remains for a few seconds until the fluid returns. If a pit is formed there is increased fluid in the tissue, the deeper the pit the greater the fluid level. People with MPB will find it interesting to try this simple test starting low on the forehead, then moving upwards.

Evidence in the literature

The conditions in the balding scalp are recognised as including fibrotic tissue development, and increased inflammatory activity. (5) (6). These are the same conditions recognised in edemous tissue. (7). The much increased sweating capacity of the scalp in MPB predicted by this dermal mechanism, is confirmed in a clinical study (3)

Treatments that increase hair growth are recognised as having effects upon the bodies “Hydraulic” characteristics. There are two FDA approved treatments for MPB, Finasteride and Minoxidil.

Finasteride (Propecia) reduces levels of Dihydrotestosterone (DHT), the primary male hormone implicated in changes in hair growth. The

known effects include reduced prostate swelling, erectile dysfunction, reduced ejaculate, and breast swelling and tenderness. (8).

Minoxidil was initially developed to treat high blood pressure, and causes a significant change in the fluid dynamics described as “a shift of blood to the central blood volume”. That is away from the hair follicles, and in line with the proposed hair growth adjustment mechanism (9) People complain that Minoxidil causes wrinkles.

It has recently been discovered that a drug developed to treat glaucoma by reducing fluid pressure, increased eyelash growth. This drug Latanoprost has now been shown to increase hair growth in MPB models (10).

The black art of hair transplantation.

Two early landmark studies in human hair transplantation are referenced (11) (12). These resulted in the notion of “donor dominance”. That is the transplanted hair maintained its original growth characteristics in the new location. The Nordstrom study referenced used 4mm diameter grafts, and studied the growth effects up to 21 months. Nordstrom concludes that the results are either because of a factor within the follicles themselves, or an effect “very close to the follicles”. It is important to note the methods and conclusions of Nordstrom and others here.

We then move on to the commercial use of these techniques in MPB, by the developing transplantation industry. Because of the commercial interests, we have little in the way of unbiased follow up studies of long term results of the early procedures. However we now have clinics that specialise in the repair of problems caused by these early procedures (13).

One recognised effect in the old larger grafts is described as doughnutting. This is where hair is lost in the centre of the grafts, leaving only hair growing around the edges. It is accepted as common, and

some claim inevitable in grafts of 2mm and larger. The explanation for this hair loss in transplanted grafts is hypoxia. The claim is that the larger the graft, the harder it is for oxygen to get to the centre during the healing process. This causes loss of the follicles.

The big problem here is no such effect was ever noted in any of the reputable early studies of large grafts. If hypoxia was killing follicles in large grafts early on, this would certainly have been picked up during the period of the early studies. These ran up to two years in some studies. Transplants are done in sessions over months, and i am pretty sure the customers would have complained about this.

The hair loss referred to as dough-nutting is a longer term effect, suspiciously like the original balding process in this area of the scalp. Transplants are sold as using “genetically different” follicles that are resistant to balding? Hair transplantation in MPB, has now evolved into a form that uses very small grafts containing one to four or so follicles. These do not suffer from central hair loss (13).

According to the proposed hair growth adjustment mechanism, the accepted follicle miniaturisation in MPB is caused by increased local tissue fluid pressure. The expansion of tissue around the follicles puts the squeeze on follicles, restricting their anagen enlargement through normal contact inhibition.

In modern transplantation, large anagen follicles in a small piece of tissue are transplanted to the bald scalp. The subsequent healing process creates fibrotic scar tissue in the area. I think what happens is these large follicles act as a template or mould, in the development of what becomes a fibrotic matrix around them. This then protects this large follicle space from the influence of the surrounding tissue upon future anagen enlargement. Tissue engineering aims at creating such “scaffolds” for in-vivo tissue development and growth (14).

The conditions in bald scalp in particular are recognised as promoting fibrosis. The development of such a protective matrix explains why the only follicles producing terminal hair long term in the old large grafts, are those around the edge. That is close to, or in the transplantation scar. I think this is the effect “very close to the follicles” that Nordstrom accepted the possibility of.

More recent studies have questioned the old donor dominance idea, with experiments in transplanting follicles to various areas of the body. The results demonstrate that hair growth does in some cases tend to adjust to the surrounding tissue (15). I think it depends upon the extent of the scarring matrix that is formed, and if this completely protects the follicle from the surrounding influence. Theoretically if no scar tissue was formed at all, the transplanted follicles would be free to adjust their size to the local pressure conditions.

I suggest there is a recent study that demonstrates this principle (16) People were surprised by the results of this study, as miniaturised human MPB follicles enlarged considerably when transplanted onto immune deficient mice. This obviously points towards an influence of the immune system. I suggest that the immune status of these mice prevented fibrotic scar formation, allowing the follicles to enlarge in the lower pressure conditions.

A suggested transplantation experiment

I suggest a simple study that would test both the genetic difference assumption, and the external scaffold idea in transplantation.

This would be a repeat of the original transplant technique of taking 4mm grafts from the “resistant” back of the head, to the bald MPB area. The growth of these to be properly monitored scientifically over

time. If these then suffer the hair loss pattern called dough-nutting over a timescale that rules out hypoxia, the genetic difference assumption would be in trouble.

The final nail in the coffin of this assumption would be to then place a single modern mini graft in the centre of the dough-nutted grafts. If this hair grew as usual, it would rule out any influence of hypoxia or bad blood supply as the cause of hair loss in large grafts. This only leaves a continuation of MPB as being the cause, and the genetic difference notion would finally be refuted. Such a result would also strongly support the tissue scaffold idea in the growth of transplanted follicles.

Implications of this mechanism in human evolution

According to this mechanism, the relative hairlessness of modern humans came about by a general increase in dermal tissue toughness. This increases resistance to follicle enlargement as previously described. This offers an opportunity to compare tissue samples from the eyebrow area with samples from hairless areas and other primates, to establish the actual physical difference. This would then offer an important insight into the reason for tissue toughening in human evolution. In my opinion, the reduced hair growth response to heat, could in a long term exposure make reduced hair growth permanent through increased tissue rigidity.

In long term edema, tissue fibrosis is a recognised effect.(7) Conditions in the bald scalp are also comparable to changes caused by solar elastosis (4). These changes in tissue increase its toughness. The retention of weaker tissue in the scalp and eyebrow areas, are in line with sun and sweat protective hair growth in bipedalism, in a hot savannah. Bipedalism itself will encourage scalp fluid drainage and increased hair growth. This mechanism therefore supports the theory of modern humans evolving in a hot savannah area.

This mechanism demonstrates that humans are not a special case in terms of hair growth. Our hair patterns and growth changes, are the result of the normal follicle response to surrounding tissue, just as hair follicles evolved to do in their original function in mammals.

The mechanism also demonstrates a principle that the creationist intelligent design argument cannot explain. The creationist argument has to assign particular purpose to physiology. They try to do this with human hair patterns making various claims of purpose. However this mechanism demonstrates that modern human hair growth has no real purpose, and is a side effect of something else that does. For example, secondary growth at puberty (beard armpits groin) is a side effect of increased lymphatic efficiency evolved to support adult growth. It could be said that such hair growth “then” became a sexual signal of maturity, but that is not an explanation of why it exists.

Further Discussion

This dermal system mechanism raises some interesting questions, and avenues for further research. The development of excess scalp hair length in humans, would not have been a good idea in terms of survival. Hair hanging over the eyes and ears would be dangerous, unless by the time this developed we had also developed the sense to cut or tie it.? The complex “plumbing” system that evolved to service the human brain, could logically connect the two things by promoting good scalp drainage.

The indicated involvement of contact inhibition in hair follicle size, would indicate that manipulating contact inhibition could increase hair growth. However this would be a bad idea in my opinion.

The prominent hair researcher Elaine Fuchs did a study with mice involving changes in the B-catenin/ Wnt’s pathway. This pathway has been linked to the contact inhibition pathway (17) Hair growth was significantly increased, but so was tumour development (18).

There is currently no accepted theory of hair growth that addresses all the questions as a valid scientific theory is required to do. This lack of clarity has encouraged what is probably the last real area for quacks and charlatans to thrive. Many young men who are desperate to treat MPB, are prey to all kinds of ineffective, and sometimes dangerous expensive potions. Whilst this mechanism does not offer a quick fix, it does indicate a clear path for future research into effective treatments of MPB. At least at this time, the mechanism does indicate what will not work and what is to be avoided.

There are many medical conditions that include hair loss. Tissue edema is also a recognised feature here, as in radiation exposure and chemotherapy. If the hair loss in a particular condition is due to local tissue expansion, this would be reflected in the shape of the hair that is shed. The peripheral reduction in the hair production area in response to tissue expansion as previously described, would produce a club hair shape. This club hair shape is noted in cases of hair loss, and in my opinion this confirms tissue expansion as the mechanism of shedding.

This mechanism also offers some insight into the evolutionary order of developments. The development of larger more specialised sweat/scent glands in areas of secondary body hair growth, and changes in sebaceous glands could also be a consequence of this mechanism in the long term. This possible relationship would however require further discussion.

The most important implications of this mechanism are in gender related auto-immune conditions. These can be debilitating and sometimes fatal. It is accepted that sex hormones must play a role here, and research continues to identify the hormonal link.(19).

In implicating the male hormone Dihydrotestosterone (DHT) as increasing lymphatic drainage efficiency, this hair growth mechanism

suggests DHT as a major player in protecting men from autoimmune conditions.

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