mental ray fast subsurface scattering tutorial

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Chapter 1

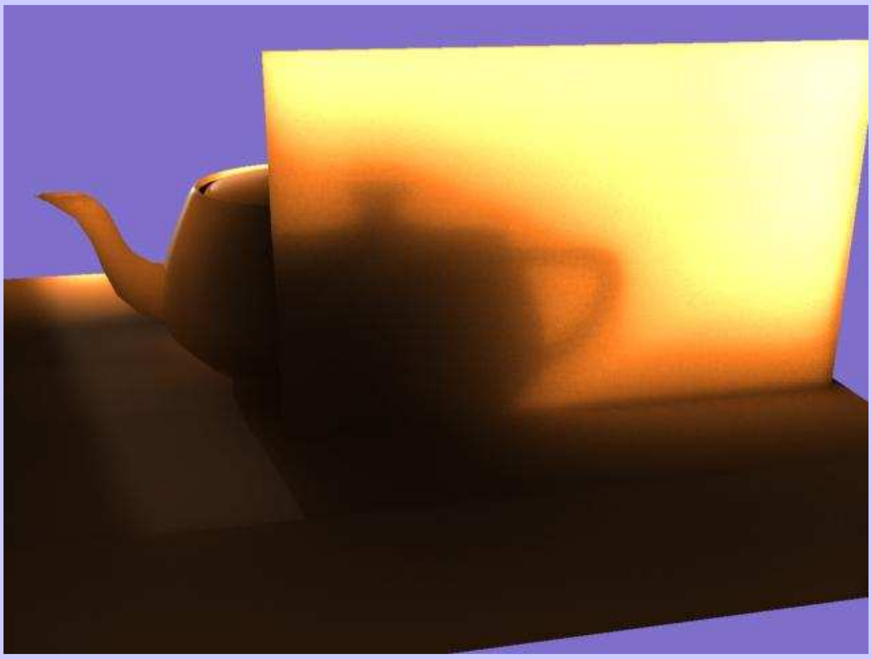
Subsurface scattering skin shader tutorial

1.1 Introduction

Welcome to the mental ray fast subsurface scattering skin shader tutorial!

Before we begin, we should talk a little about what subsurface scattering (“sss” for short) actually *is*, and what it *looks like*, and how it enhances the apparent smoothness of a surface.

Almost everyone knows about the most “obvious” effect of subsurface scattering - when light passes *through* a thin translucent object. This effect is easy to point out and easy to see.

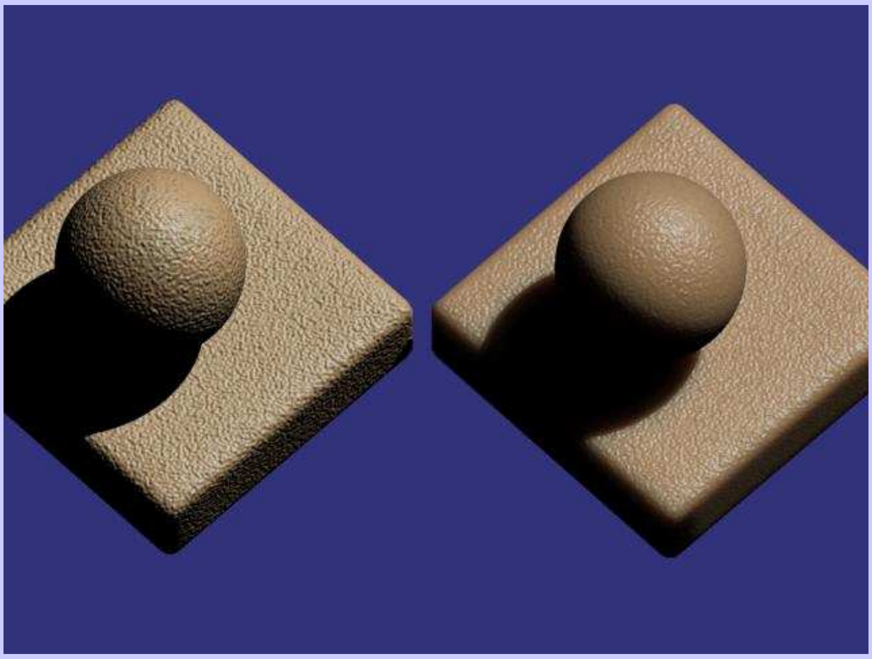


Example image of “translucency”, just one of the effects of subsurface scattering

But for *skin* this effect is secondary and of marginal importance since it only shows up in thin areas such as ears. What is of greater importance is the diffusion of light within the shallow top layer of the skin.

While the human optical subsystem is specially tuned to view other humans, the very important effects of subsurface scattering are, paradoxically, very difficult to actually *see*. Generally, these effects - unless you know what to look for - are of the variety that you do not “see” until they are absent, when it becomes obvious that “something is missing”. For this reason it is also *very easy to overdo* the effect, and to put *too strong* sss effects in one’s renderings.

Two things to look for are the apparent "softening" of bumps and small structures, and a slight "bleed" of light into shadow areas, diffusing the otherwise sharp shadow edges.



Left: No subsurface scattering vs. Right: Subsurface scattering

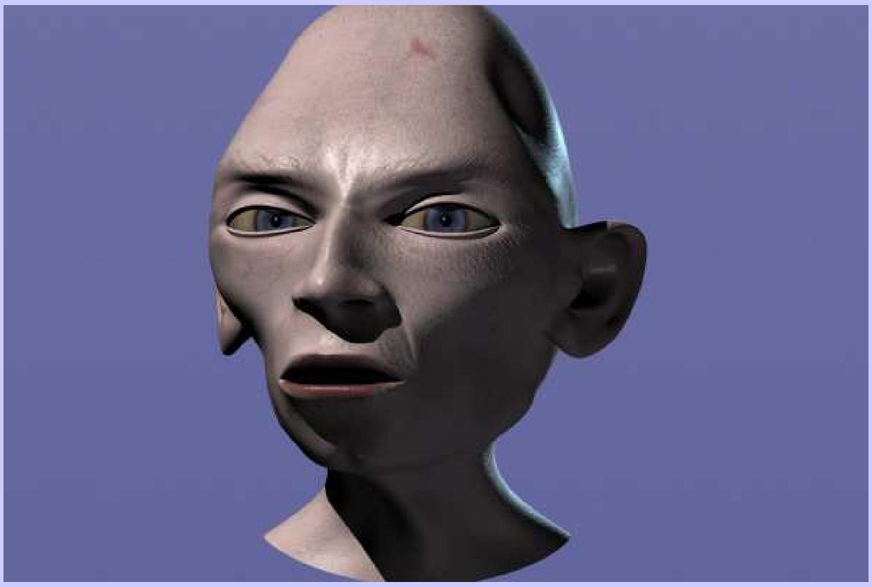
Notice how the bumps on the left object are very harsh, and how the shadow edge is completely sharp, whereas, on the right, the bumps feel softer and there is a slight color bleed into the shadow area.

1.2 Realistic skin

This tutorial will be about putting a realistic skin on our friend Globulous.

A file, `globulous-before`, is available on demand[1] which you can render. It is fully textured but uses a simple base phong material without using any subsurface scattering.

If you render you will see something like this, which looks more like plastic than human skin.



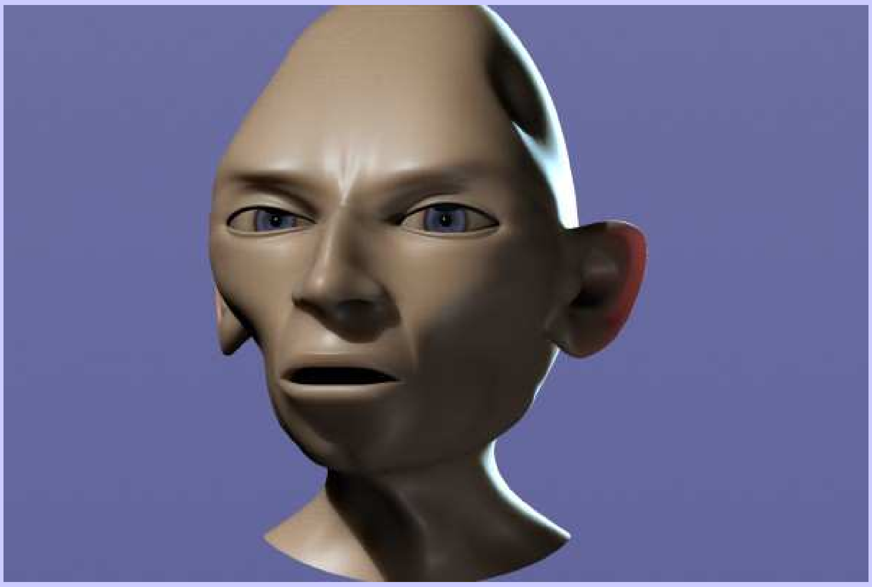
Our Friend Globulous

What we will do is replace the material with the fast sss skin material.

> *Application specific note:*
> The method to actually apply the skin shader as a material varies between OEM integrations of mental ray. See the Technical Considerations on page 29.

[1] If no file is included for your application, you can load the geometry from `globulous.obj`, a format which can be imported by most programs. To match this tutorial you need three lights: one strong backlight of a blueish color, a key light coming from above frame left, and a weak fill light from frame right. All three lights *must* cast shadows.

Dont worry about textures, we will get to those; just apply the default material. You should be getting a rendering that looks like this:


Skin material default settings Globulous

Note: If the image does not look like this, verify the default values for the scatter radii: **Epidermal scatter radius (front_sss_radius)** should be 8mm, **Subdermal scatter radius (mid_sss_radius)** should be 25mm, **Back scatter radius (back_sss_radius)** and **Back scatter depth (back_sss_depth)** also 25mm. The Globulous model, which uses millimeters (mm) as its measurement unit, is about 300mm across, including those wingnut ears of his.

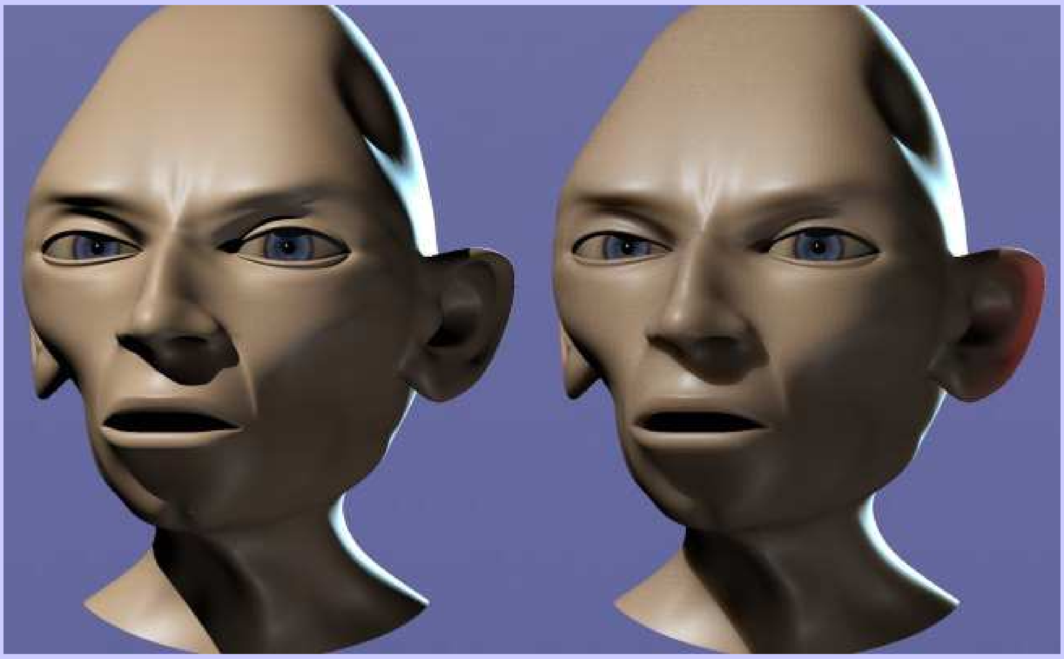
"But this doesn't look like skin" you say. No, not yet. Let's explore what the subsurface scattering is doing for us.

The fast sss shader scatters light within a certain *radius.* While we *could* change all the various scatter radii[2] in the different layers to see the effects, there is an easier way to quickly assess the effects.

The **Scale Conversion (scale_conversion)** parameter affects all the other radii as a division factor. So if we set it to, for example, 100.0, it would be the same as dividing all the radii by

[2]Plural of "radius"

100.0, effectively disabling the scattring completely. Let's try it:

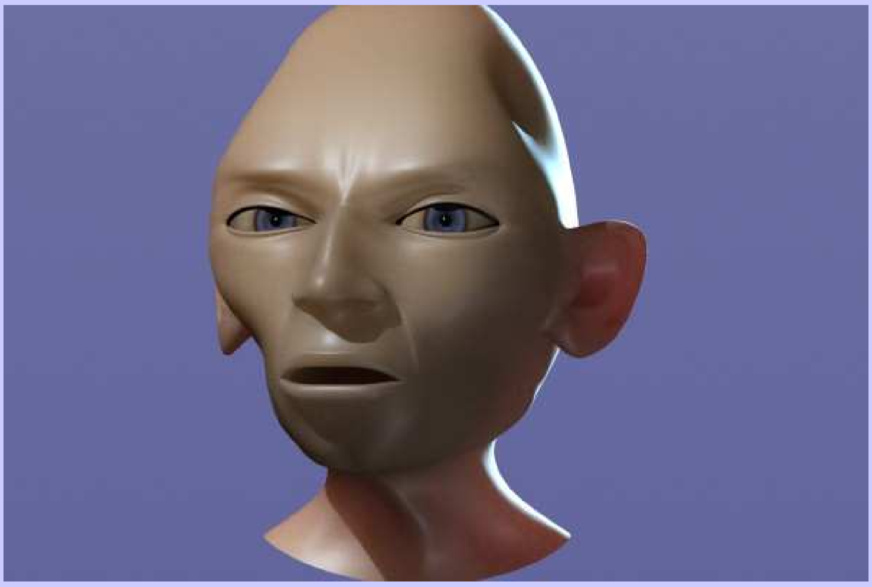


Left: Scattring disabled Right: Default scattering

The result is shown here side-by-side with the default image. In the left image, the scattering effect is completely gone. Compare with the right image - the differences are subtle. Beyond the obvious "red ear", you can see on the left image that the shadow line on the neck is completely solid and sharp, whereas on the right image, it has a slight color bleed into the shadow.

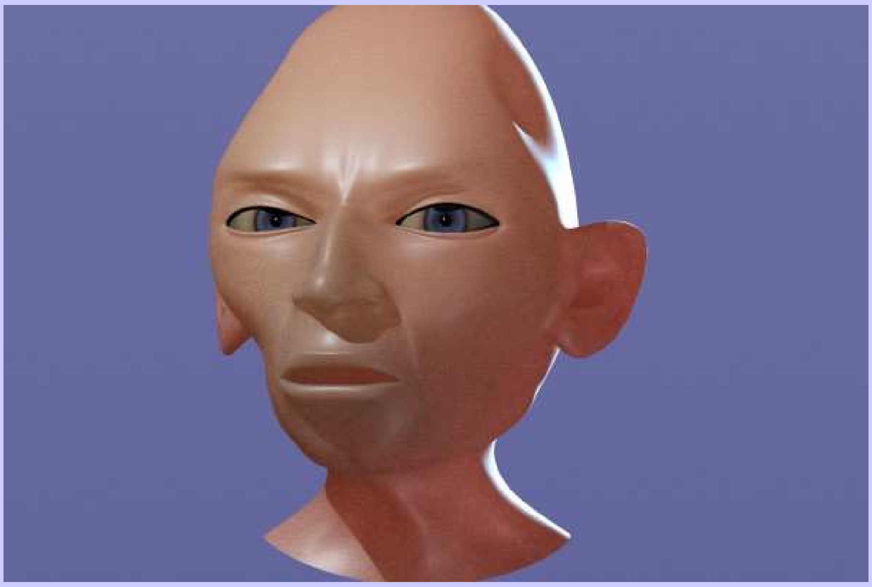
As described earlier, the difference will also become more apparent as bump maps are added.

What happens if the scattering radii are too big? Let's set **Scale Conversion (scale_conversion)** to 0.2:



Too much scattering, too big scattering radii!

To really drive it home, let's do more:

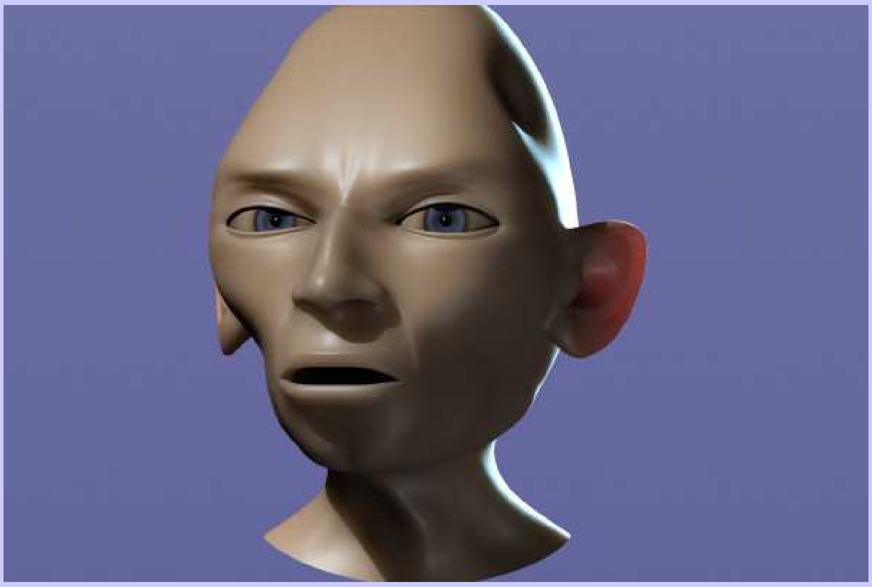


WAY too large scattering radii

See how the entire head looks like a balloon filled with red gas? Also note the graininess that appeared. The current sample count (64, in this case, the default) is simply too little for such a gigantic scatter radius as we have here.

So, if you have an existing model (that is perhaps not made to scale or not in real world units) and apply the skin shader, and the result is a red blob with noise in it, the reason is your scattering radii are way too big. If the result looks like hard plastic, the scattering radii are too small. Tweak with **Scale Conversion (scale_conversion)** or by tweaking the radii separately.

Let's change it to something more sensible ... but to be able to see the effect, we stick **Scale Conversion (scale_conversion)** at 0.5 to be able to "see" the effect a bit more.



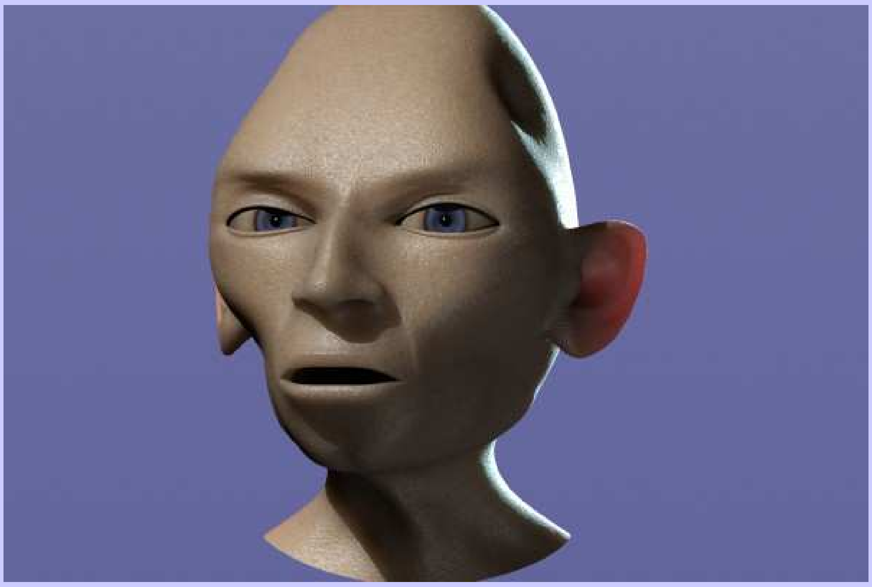
Globulous w. a sensible scale for scatter radii

But it still doesn't look like skin, does it? Sure, it has a bit of a waxy quality due to the scattering, but the surface is way too shiny and smooth. Let's add some bump mapping and see where that leads us.

We will add a simple perlin **noise** map for bumps.

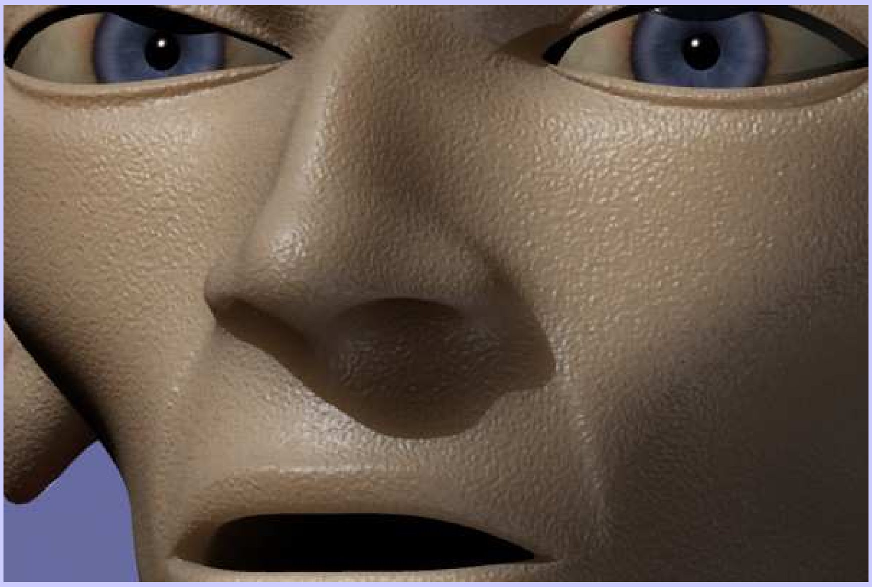
Application specific note:
Consult your application specific documentation about how to do it.

This is the result:



Globulous with simple "Nosie" bumps

Notice how this gives it a more "skin"-like quality. Of course, the skin is that of a silicon mask or the rubber alien from planet Zod, but it gets a distinctly more "skin-like" feel the moment bumps are added. Let's look at a closeup:



Closeup of bumps

Now this isn't pretty, but it illustrates a point: The scattering "fills in" the tiny crevices between bumps and makes bumpmapping less "harsh". Feel free to turn **Scale Conversion (scale_conversion)** back to 100 temporarily and see the difference. Without scattering, all the bumps would be very harsh, with shading as dark as that of Globulous's cheek.

1.3 Tuning scattering "on your own"

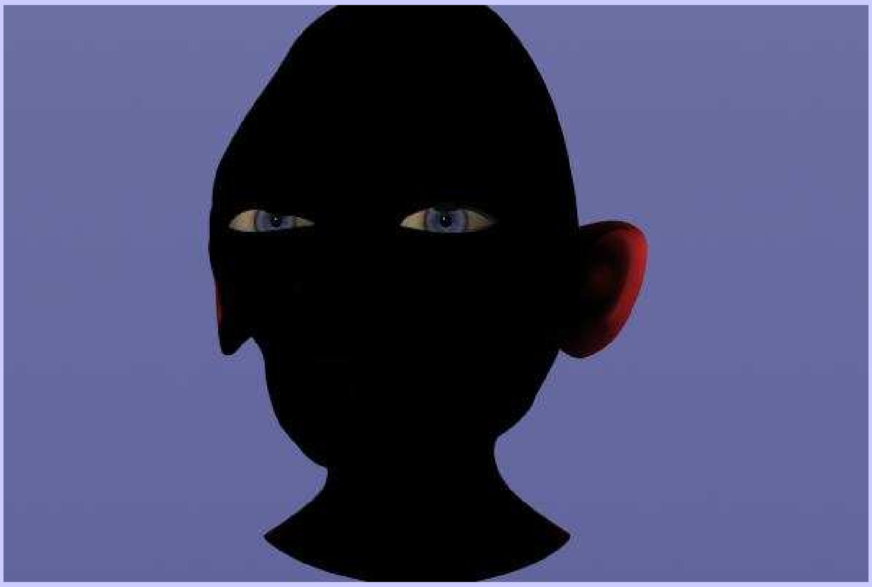
1.3.1 "Subdermal" scattering - the meaty stuff

So far, we have been using the standard settings. But let's look at how we can arrive at a result independently.

To do this, we will look at all scattering contributions *separately.* So:

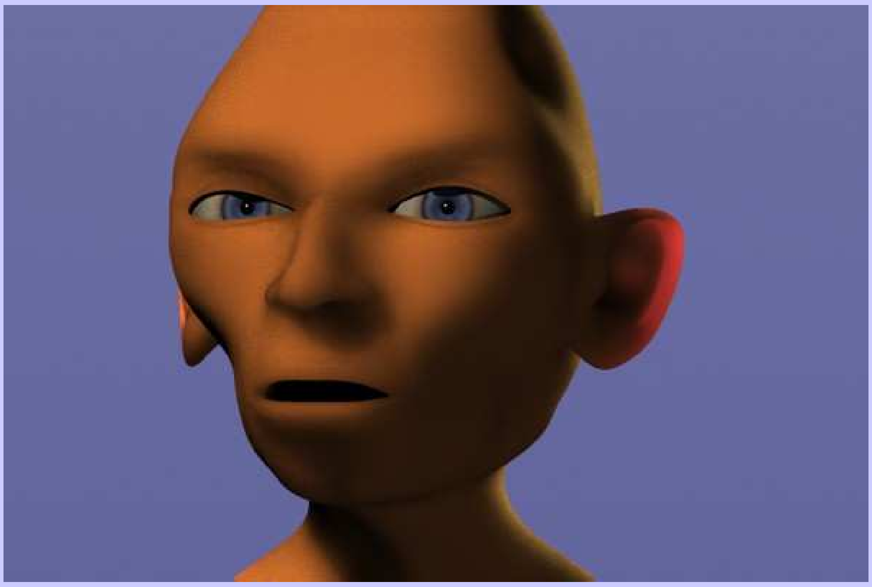
- Set **Scale Conversion (scale_conversion)** back to 1.0
- Set **Unscattered diffuse weight (diffuse_weight)** to 0.0
- Set **Epidermal scatter weight (front_sss_weight)** to 0.0
- Set **Subdermal scatter weight (mid_sss_weight)** to 0.0
- Set **Back scatter weight (back_sss_weight)** to **1.0**
- Set **Overall specular weight (overall_weight)** to 0.0
- Remove the "noise" bump map we added

This turns *everything* off, except the back scattering light - the stuff most people think about when you say “subsurface scattering”. As you can see, it’s not really much to look at:



Globulous with back surface (through) scattering only

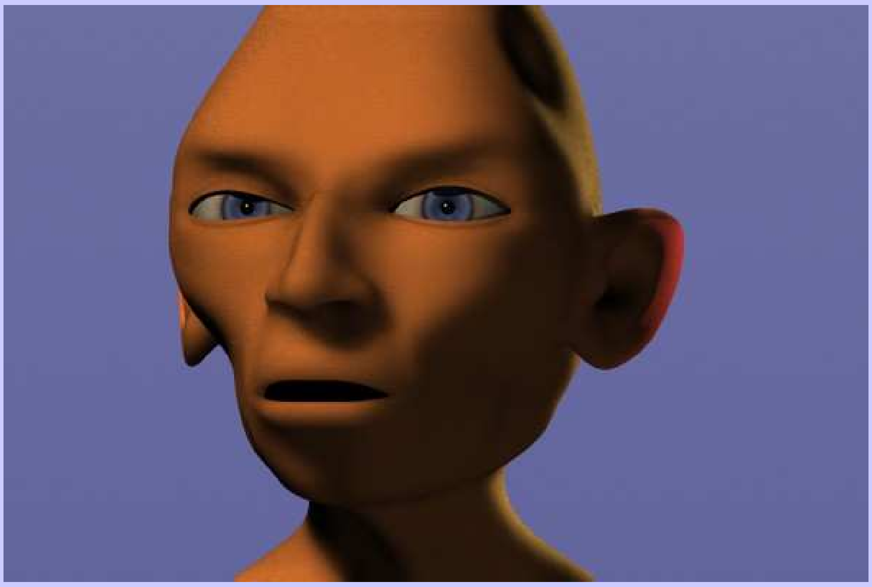
Now set **Subdermal scatter weight (mid_sss_weight)** to **1.0** as well, to turn on the subdermal scattering. What we call here the “subdermal” or “middle” layer is all the meaty stuff under the top layer of the skin, which contributes the famous red glow effects. Your render should now look like this:



Globulous with a default subdermal scatter radius of 25mm

This is the default setting of a 25mm scatter radius. We see a reddish-orange diffused area (plus the translucent ear bit). Note how “blurry” the shadow of the nose is.

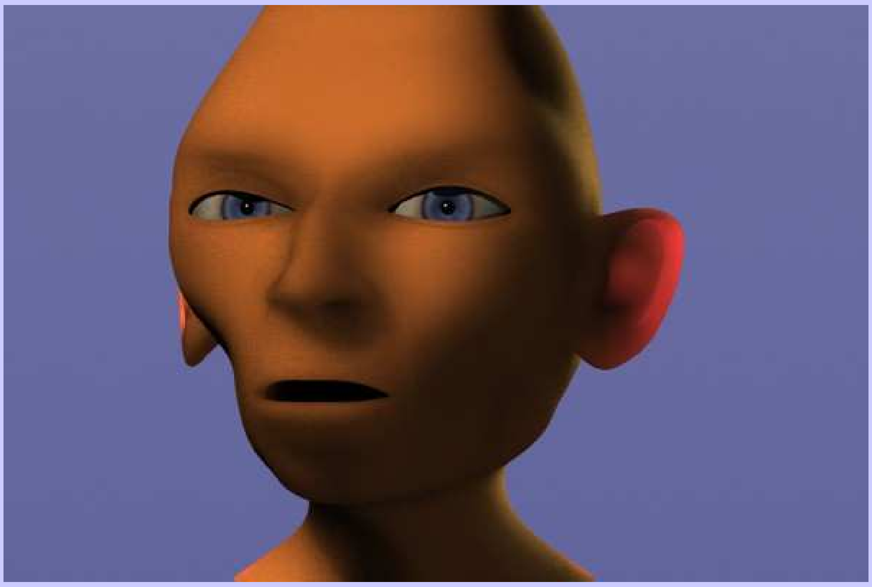
Now we change all the **Subdermal scatter radius (mid_sss_radius)** and **Back scatter radius (back_sss_radius)** scatter radii (and **Back scatter depth (back_sss_depth)**) to 15:



Subdermal radius of 15

This makes the shadow area less blurry, and makes the light look more like ”normal” diffuse lighting.

However, we want a pronounced scattering effect, so let’s set them to 35mm instead:



35mm subdermal and back scatter radius / depth

A rule of thumb is that you should be able to imagine the subdermal layer as a large blob of red Jello. If it looks somewhat like that, you are on the right track. (Envisioning it as Jello actually becomes easier if you turn the specular layer on, but we’ll get to that later).

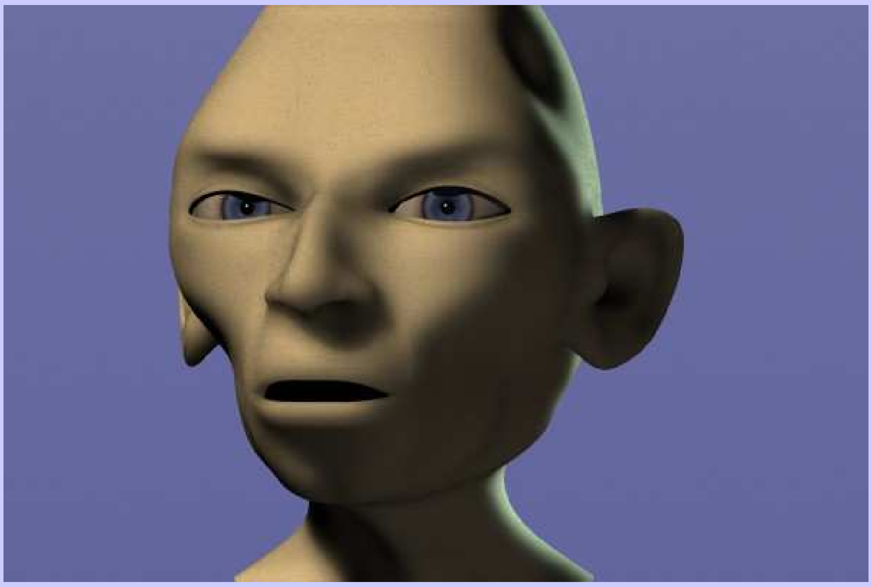
Let’s settle for this value, and move on to the “epidermal” layer.

1.3.2 “Epidermis” - the top layer

Skin is not a single homogenous substance, but has several unique layers. The top layer of skin is called the “Epidermis” and is set by the **Epidermal scatter weight (front_sss_weight)** variable. By default it has a yellowish color. To be able to see it alone, change the following values:

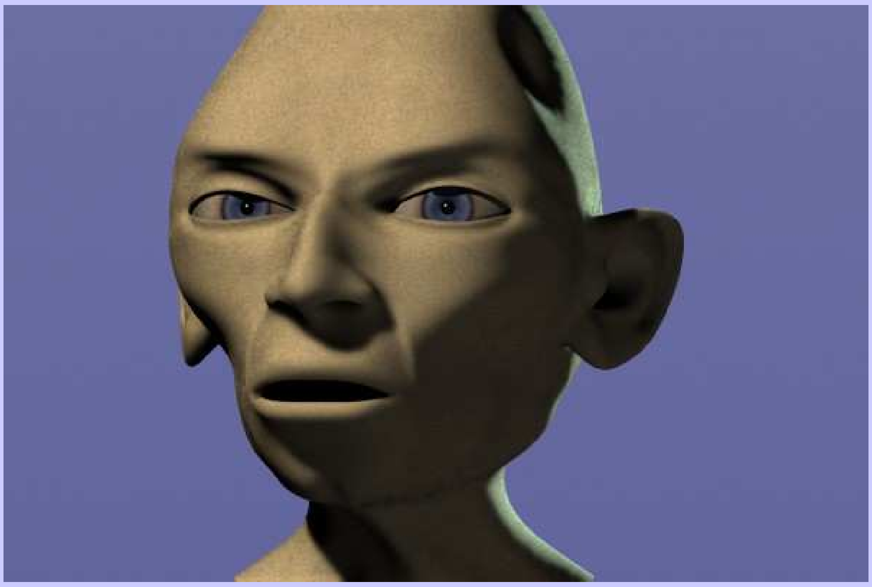
- Set **Epidermal scatter weight (front_sss_weight)** to **1.0**
- Set **Epidermal scatter radius (front_sss_radius)** to **16.0**
- Set **Subdermal scatter weight (mid_sss_weight)** to 0.0
- Set **Back scatter weight (back_sss_weight)** to 0.0

... and let's see what we get:



An "epidermal" scatter radius of 16

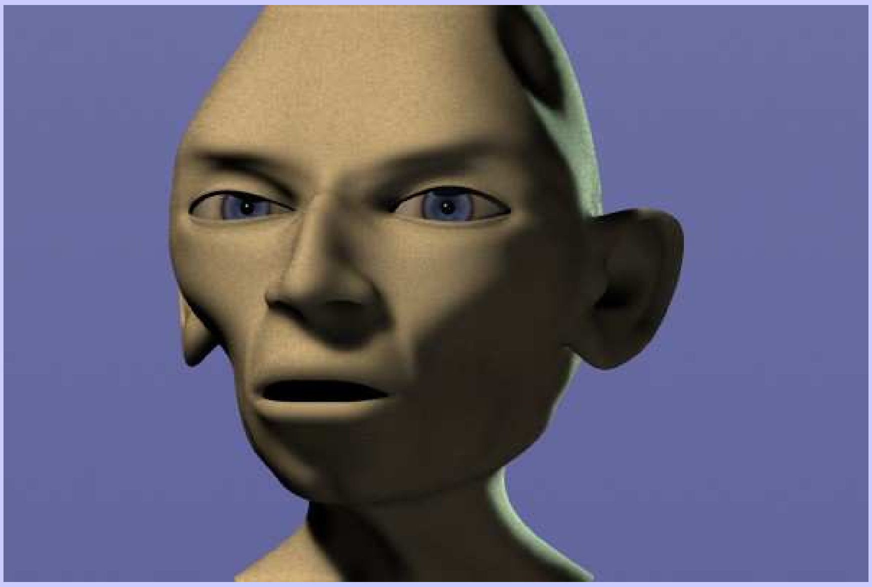
Let's try a smaller radius; set **Epidermal scatter radius (front_sss_radius)** to 5:



An epidermal scatter radius of 5

5mm is a bit too small for the epidermal radius. We see some grain introduced (which can be combated by upping the resolution of the lightmap and using more samples), but more importanty we are not really seeing much scattering happening. Look at the shadow of the nose, it is nearly sharp, and this small scatter radii would not be very different to standard diffuse lighting.

We want some slight visible color "bleed" into the shadow, so let's bump this up some ...



Tweaked scatter radius of 8

...and we land at 8, the default value, which is a good compromise.

As a rule of thumb, we can say that the top epidermal layer *by itself* should look akin to having a thin layer of wax on the object.

1.3.3 The layers in context and with textures

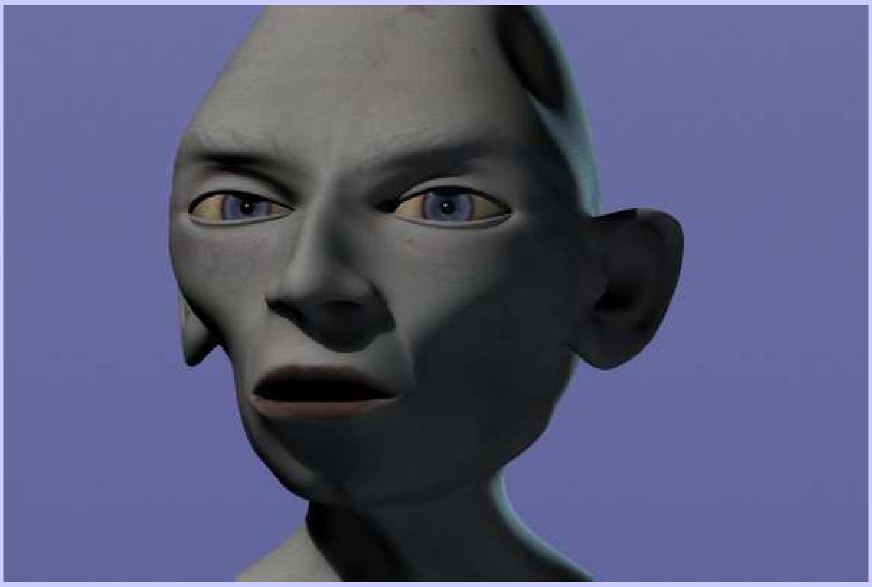
Now, where in all this do we add textures? There are so many places to choose! The answer is "it depends". But for a face, mapping your normal "face texture" to the **Unscattered diffuse color (diffuse_color) and** to **Epidermal scatter color (front_sss_color)** , but leaving **Subdermal scatter color (mid_sss_color)** untextured seems to be the best method.

An *alternative* is to simply put the color texture into **Overall diffuse color (overall_color)** but this can be problematic. If your texture has a dark or black area, *nothing* will ever scatter into that area, because any color multiplied with black is still black.

Texturing with the skin shader can be done in every layer and even the radii and weights can be textured, but we leave that as an exercise for the reader.

Apply the texture map file **Globulous-texture.jpg** to **Unscattered diffuse color (diffuse_color)** and **Epidermal scatter color (front_sss_color)** .

If we now set **Unscattered diffuse weight (diffuse_weight)** and **Epidermal scatter weight (front_sss_weight)** to **0.5**, (a 50/50 mix), we get this:

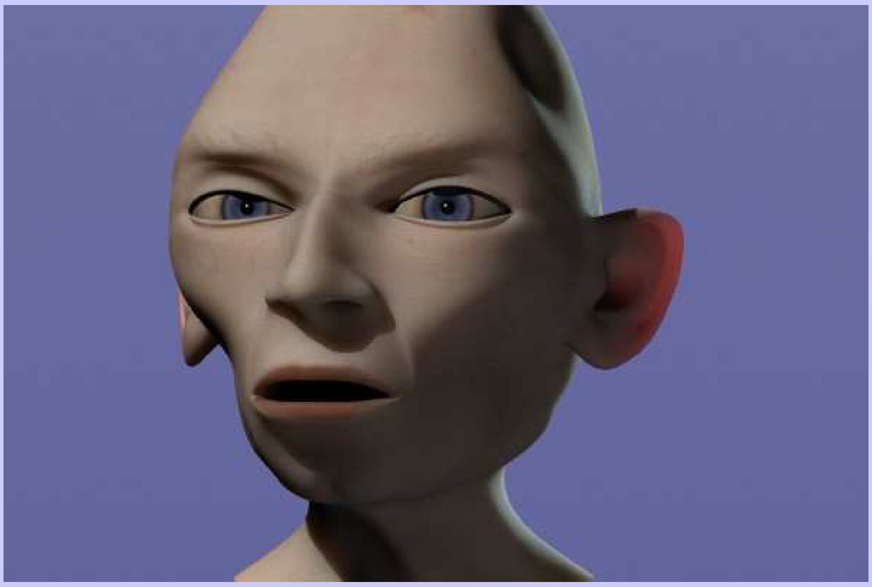


Globulous with textures in two layers

“But he is gray” you say. Yes, he is. Skin isn’t really “skin colored” - skin is (mostly) white. The “Skin color” stems largely from the reddish scattering of the underlying layers. So the advice is *not* to paint your skin textures in a “pretty lucious pink” color, but in a “near grayscale” look.

The rule of thumb, however morbid, is that the a rendering such as this which is *without* any subdermal scattering should look like a corpse (or at least someone really really sick).

When you then turn on the subdermal and back scattering layers by setting both **Subdermal scatter weight (mid_sss_weight)** and **Back scatter weight (back_sss_weight)** to 0.5 (for the reddish subsurface light, and the “shine through the ear” effect, respectively) you will see the blood return to the face, and you get:



Subdermal scattering turned on

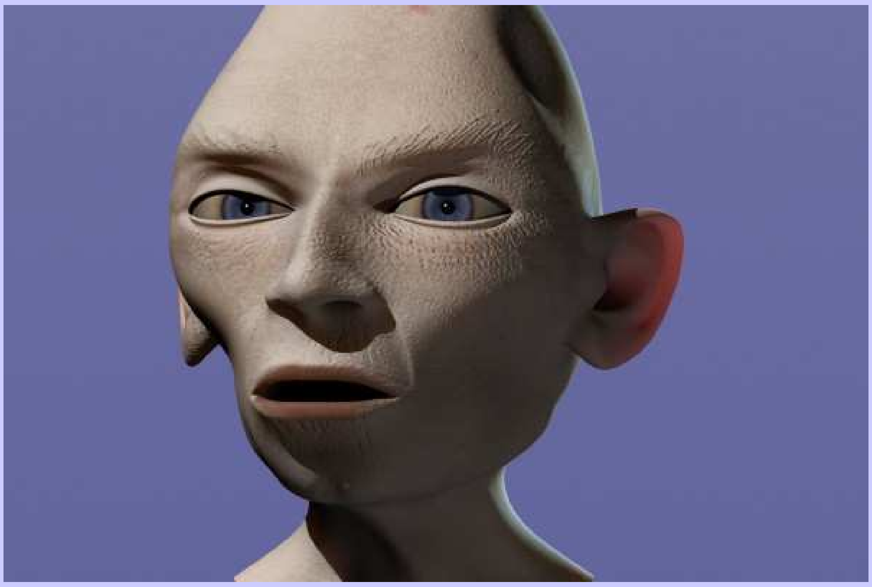
Now we are getting somewhere! But there are still things missing. Let’s apply the bump map.

Apply the **globulous-bump.jpg** file as a bump map.

> *Application specific note:*
> Consult application-specific documentation for details

We now have bumps. The trick now is to *tune* the bumps so the skin translucency is at a “good” level. What is “good” depends largely on your bumpmap and how your color textures are set. But in general, you tweak the balance between the **Unscattered diffuse weight (diffuse_weight)** and **Epidermal scatter weight (front_sss_weight)** until you see “enough” bump, but not too much.

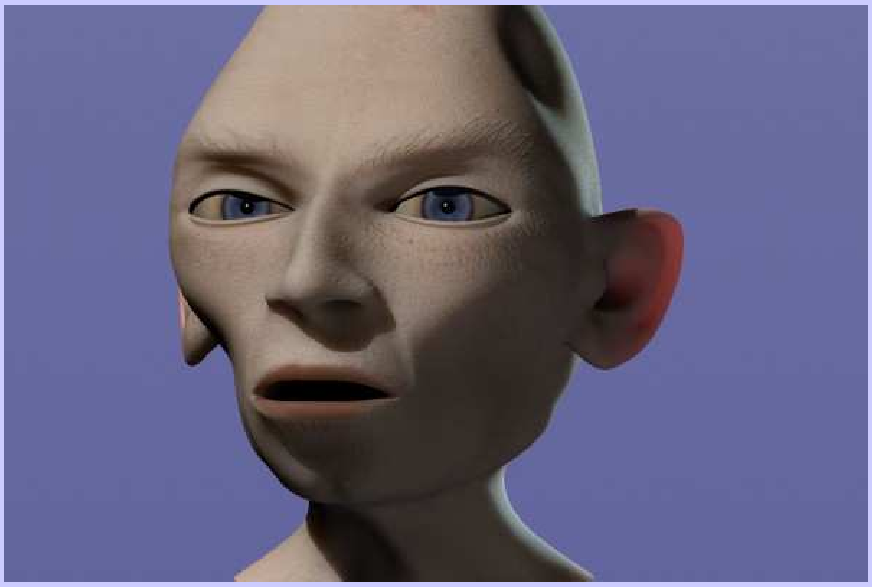
Let’s look at what happens when we use the unscattered diffuse *only*. Set **Unscattered diffuse weight (diffuse_weight)** to 1.0 and **Epidermal scatter weight (front_sss_weight)** to 0.0:



Bumpy skin with only the unscattered diffuse

Looks very harsh and unrealistic!

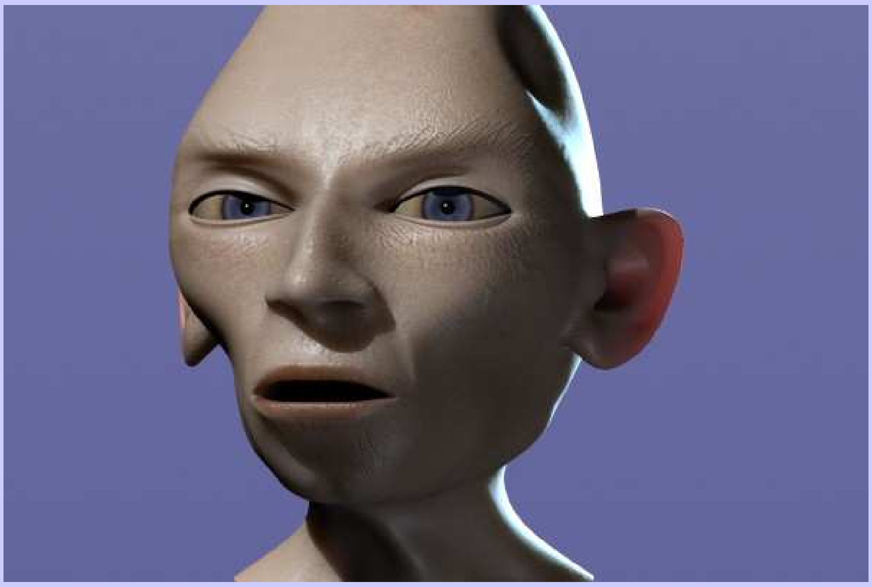
So let's tweak the levels to what "looks good". In our case, we settle for the default 50/50 mix, that is, set both **Unscattered diffuse weight (diffuse_weight)** and **Epidermal scatter weight (front_sss_weight)** to 0.5



Bumpy skin with the levels tuned to be "just right"

1.3.4 Sweet specularity

But something’s missing ... and this is the part where we remember “Oh yeah, we turned **Overall specular weight (overall_weight)** to zero earlier” and promptly turn it back to 1.0 and see:

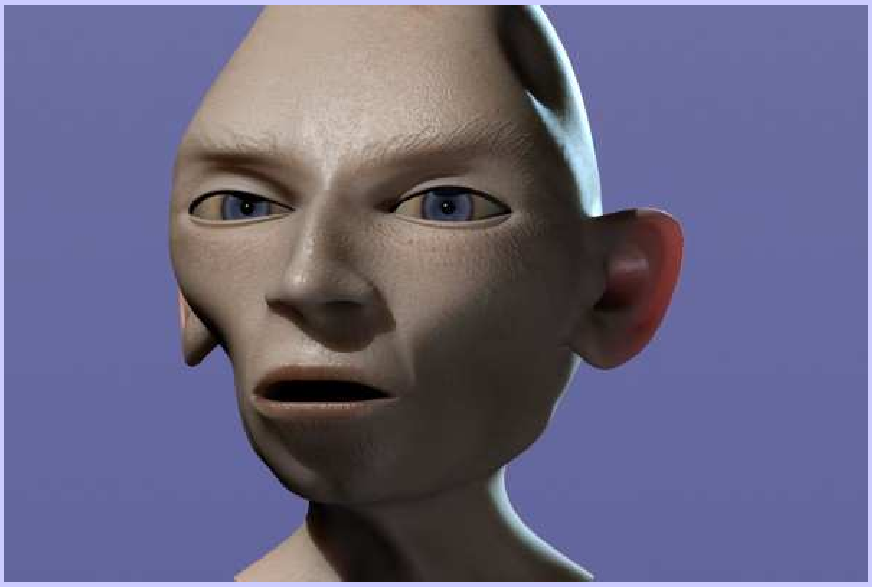


The default skin specularity

Thats nice but... a bit untuned. (Some may wonder about the slightly blueish default specular colors, but they are simply complementary colors to the reddish tones of the skin itself.)

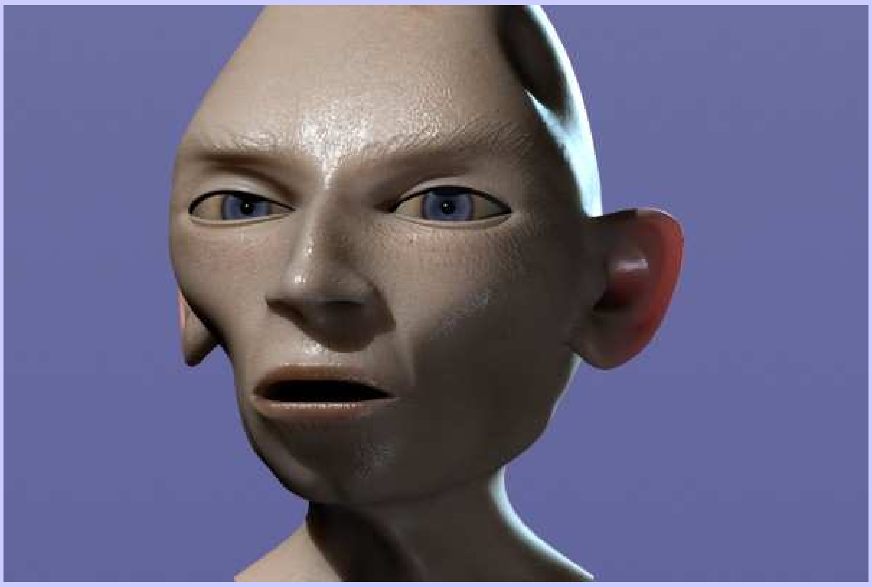
Specularity always looks best when “broken up” a bit with mapping, and we have a specularity map for this model, so we load it.

Application specific note:
The supplied specular map is rather dark; we need to multiply its values by 3 to get a nice result. How to do this is application-dependent; consult your application-specific notes.


Globulous with specularity map

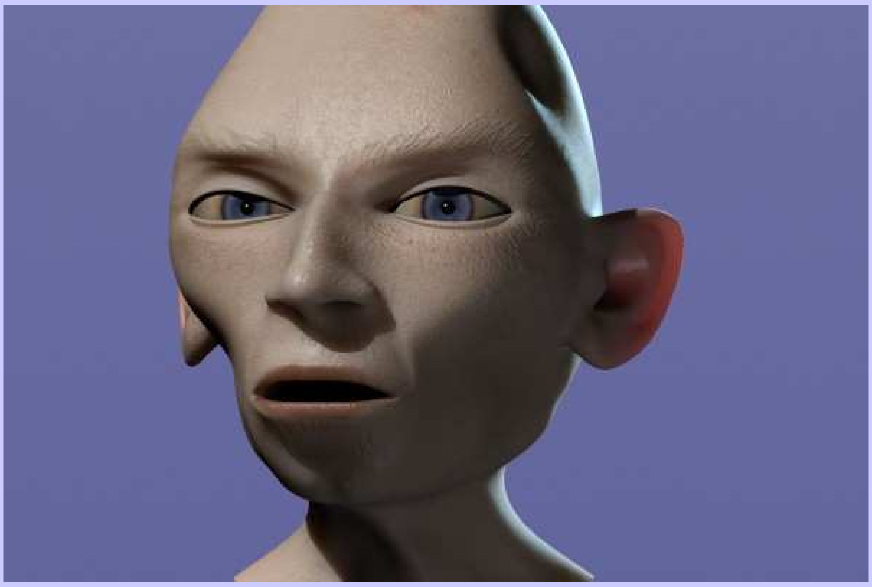
This looks better, now let's try to play with the various specular layers. By default, two layers are set up. One (#1, the "primary") for a broad and soft specular highlight which is accentuated quite a bit along the edges, and a second (#2. the "secondary") much narrower specularity for detail sheen.

Let's set **Specular Weight #2 (secondary_weight)** to 1.0 and try:


Sweaty Globulous

This greatly accentuates the sheen layer and makes Globulous sweaty! Nice, but we are after a dryer look.

Tune down the level, and play with the various specularity settings. A good tip is the old “less is more”. Here is what we arrived at:

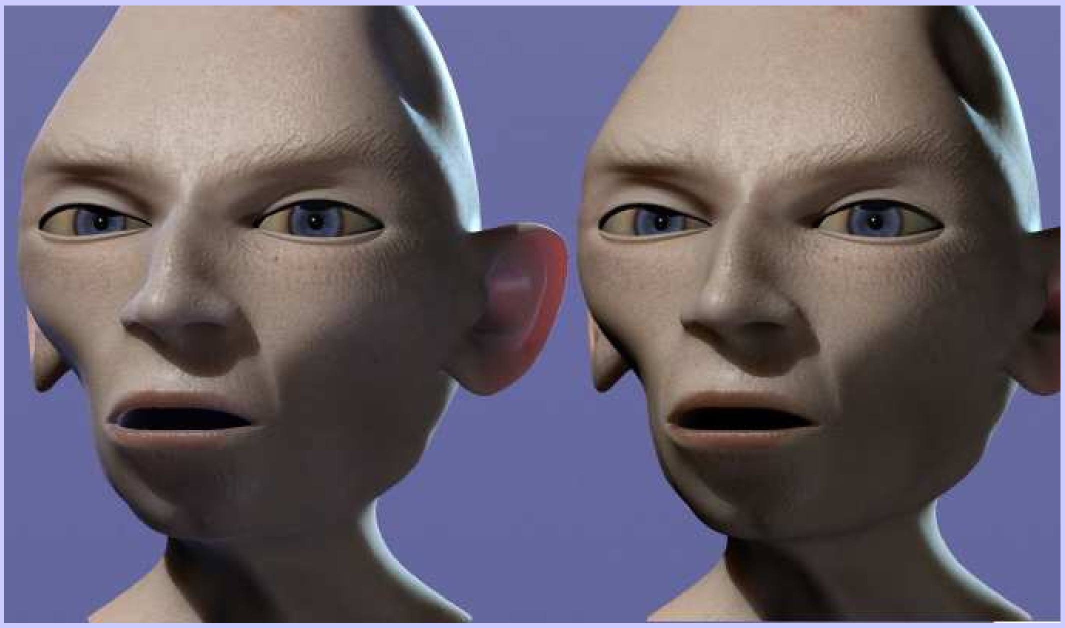


Globulous with tuned specularity

But Globulous is not living in a void; he is, apparently, in a blue room. Well, at least the background is blue! So, let’s give his skin some well-needed reflectivity. The skin shader supports full raytraced *glossy reflections*. The drawback with these is that they are computationally expensive (since multiple reflection rays are cast). So we will employ a trick.

Set **Reflection Weight (reflection_weight)** to 0.1 and **Reflection Edge Weight (reflection_edge_weight)** to 1.0. (Skin reflects a lot more when viewed “from the side” than when viewed “head on” — known as a *fresnel effect* to the guys with the particle accelerators. We just call it “edge enhancement”.)

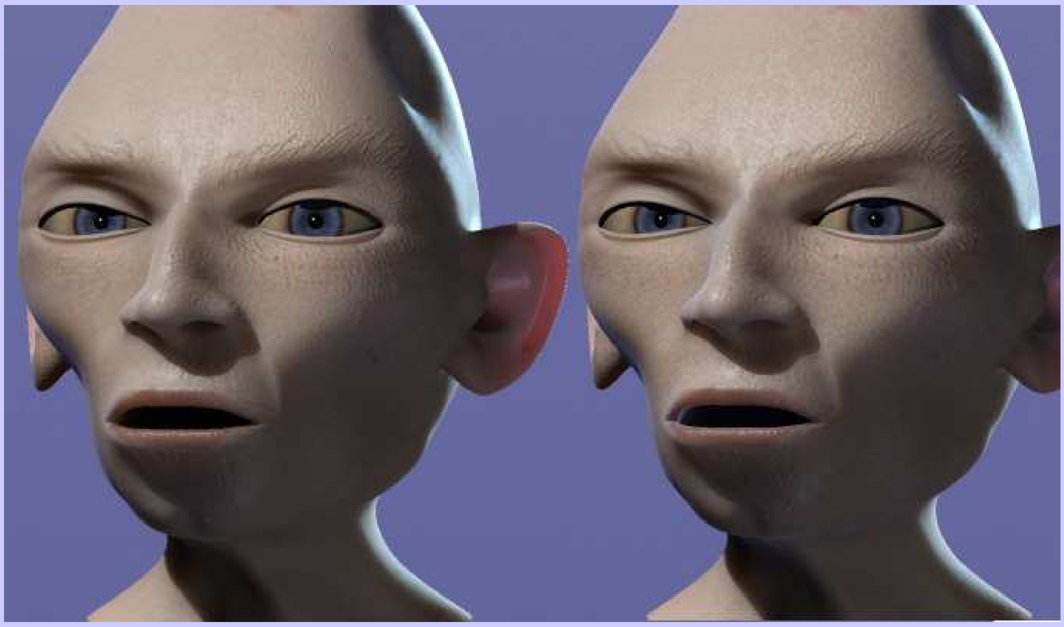
Now turn on **Only reflect environment (reflect_environment_only)** . This will save us some precious render time (because the raytraced glossy reflections are skipped and replaced with pure environment reflections) and we get:



Left: With environment reflections (from the blue background) Right: Without

It is subtle - so subtle we show a side-by-side with the previous image - but it is there. See the edge of the nose or the cheek, plus an overall light tint towards the environment color.

We enabled **Only reflect environment (reflect_environment_only)** and opted out of true raytracing. What were the tradeoffs? Let's study the difference; turn it off:



Left: With true glossy reflections. Right: Only reflecting environment.

The difference is even *more* subtle and again shown side-by-side with the previous result. On the right image there are some false reflections on the lips which are reflecting some background blue, which in reality, they would not. On the left, the edge of the nose reflects skin color, instead of blue background.

Turning **Only reflect environment (reflect_environment_only)** off causes real, multi-sampled ray traced glossy reflections to be generated. These can be computationally expensive, especially in a scene with a lot of complex geometry.

The right image rendered in 30 seconds[3] and the left image in 1 minute 35 seconds. In production use, one must determine, on a case-by-case basis, whether or not true raytraced reflections are necessary. For the remainder of this tutorial we choose the impatient route and set **Only reflect environment (reflect_environment_only)** on again.

1.3.5 It's in the eyes

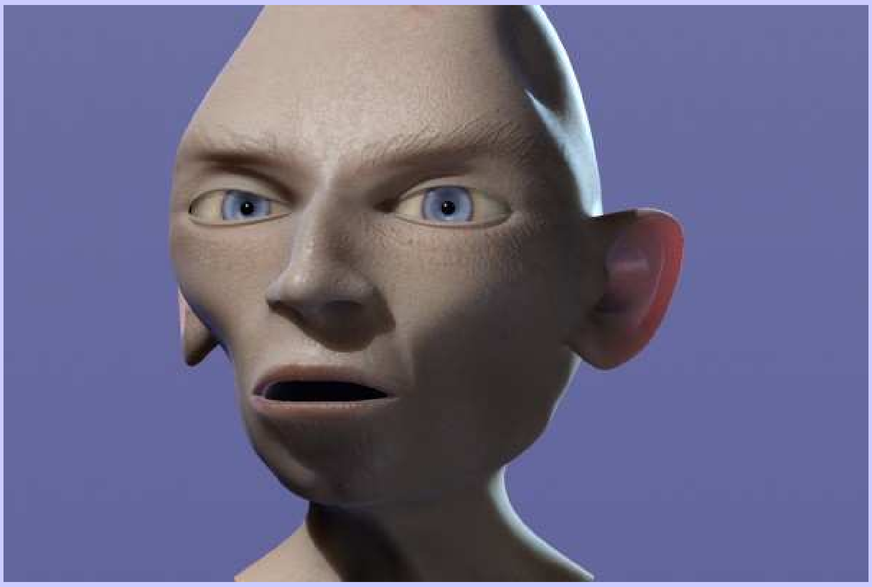
By now, it's becoming apparent that something is wrong with the eyes. We have nice skin but spooky eyes from netherworld. Interestingly, eyes do a lot of subsurface scattering on their own. Let's fix that.

[3]Render times measured on a 3.06 GHz P4 CPU with 1 Gb RAM

Replace the eye material with a **misss_fast_skin_phen** material (we use the “skin” variety rather than the **misss_fast_simple_phen** version because it is more full-featured). Then:

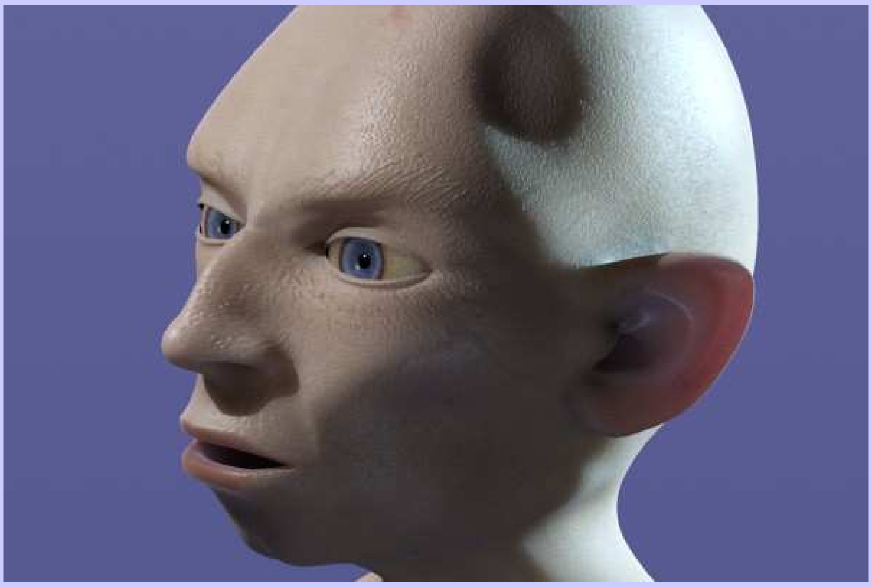
- For **Overall diffuse color (overall_color)** use the **eye_tex.jpg** texture
- Set the **Unscattered diffuse color (diffuse_color)** , **Epidermal scatter color (front_sss_color)** and **Subdermal scatter color (mid_sss_color)** colors to **white**
- Set **Unscattered diffuse weight (diffuse_weight)** to 0.2
- Set **Epidermal scatter weight (front_sss_weight)** to 0.6
- Set **Epidermal scatter radius (front_sss_radius)** to 10
- Set **Subdermal scatter weight (mid_sss_weight)** to 0.8
- Set **Subdermal scatter radius (mid_sss_radius)** to 20
- Set **Reflection Weight (reflection_weight)** to 0.1
- Set **Reflection Edge Weight (reflection_edge_weight)** to 1.0
- Set **Only reflect environment (reflect_environment_only)** to on
- Set **Reflection Shinyness (reflection_shinyness)** to 0.0

Leave the scatter group/light map the same - this means (beyond us saving memory) that light in the eyes can scatter into the skin and vice versa, which may be a feature in this case. Let’s try it:

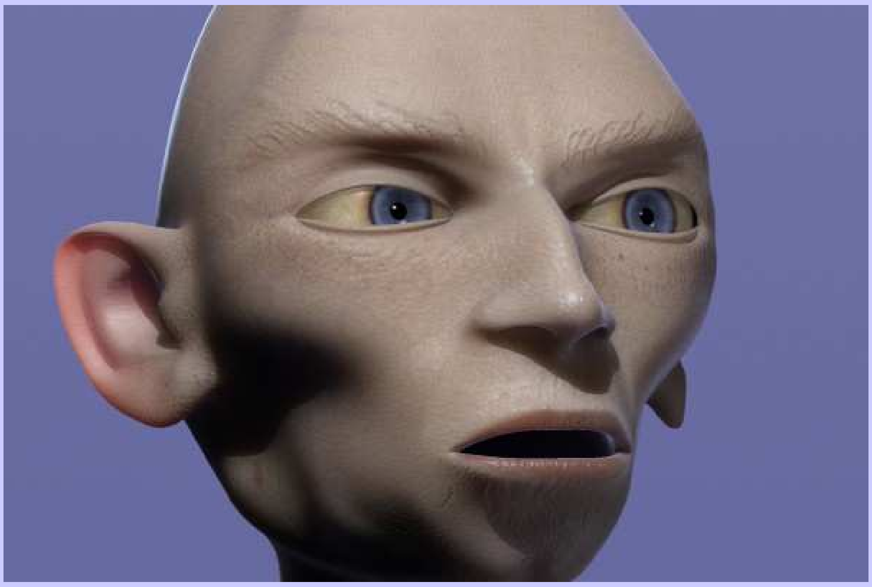

Globulous with subsurface scattering eyes

Okay, now we have something pretty neat. The result, at this point, is provided in the file `globulous-after`, which you can study or play with.

How does it hold up from other viewing angles?

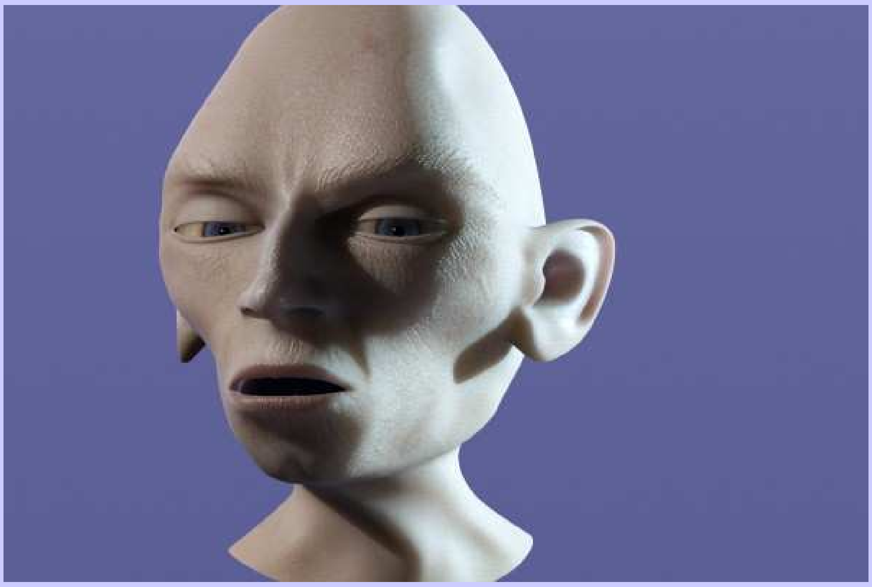


Globulous from another angle



Globulous from yet another angle

Nice, but the real lithmus test is, *how does it act under different lighting conditions?*. Feel free to play around by moving the lights and to observe the results of various types of lighting.



Globulous lit differently. No change to any material parameters

Some more examples of how it might look are available in the *inspirational gallery* on page 33.

1.4 Advanced methods

1.4.1 Environment lighting of Globulous

So far, we have lit globulous with traditional light sources. What if we want to light him with an HDRI environment light? There are a few ways to do this. Let's try "Final Gathering".

First, delete or turn off all existing lights in the scene (two point lights and one spot).

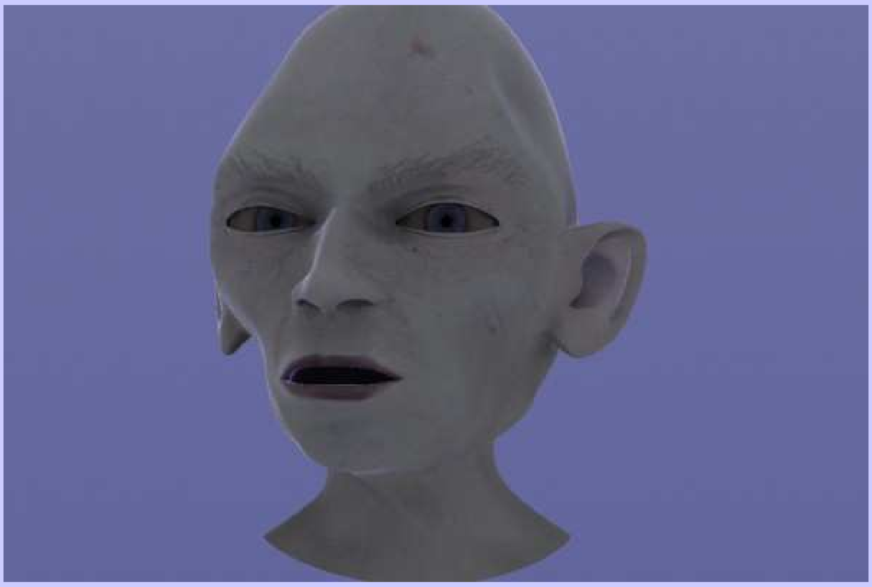
Enable **final gathering** and set the following accuracy parameters.

Application specific note:
The exact process of doing so varies due to different OEM integrations of mental ray. See the application-specific notes.

- Set number of samples to 1000 (that's plenty)

- The maximum radius to 10
- The minimum radius to 5

Let’s start out by making an *intentional mistake*. In both the “Skin” and “Eye” materials, make sure the **Scatter indirect illumination (indirect)** parameter is **off**, and render:

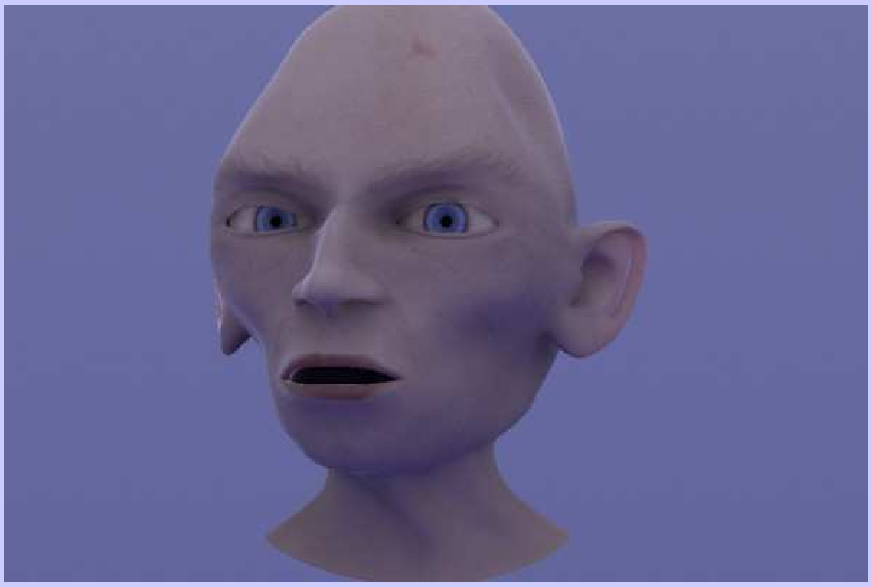


Hey, this looks strange.... can’t be right?

Something is seriously wrong - he is all gray! What happened?

The answer is that by setting **Scatter indirect illumination (indirect)** to off, the skin shader does not scatter indirect illumination. In *most* cases, indirect illumination is weak, and whether or not it is scattered is visually insignificant. Since accumulating indirect light during the lightmapping phase can be computationally expensive, one can save rendering time by setting **Scatter indirect illumination (indirect)** to **off**.

But we are using indirect illumination *only*, and definitely want this to be scattered. So turn on the **Scatter indirect illumination (indirect)** option **on** in both your “Skin” and “Eye” materials.

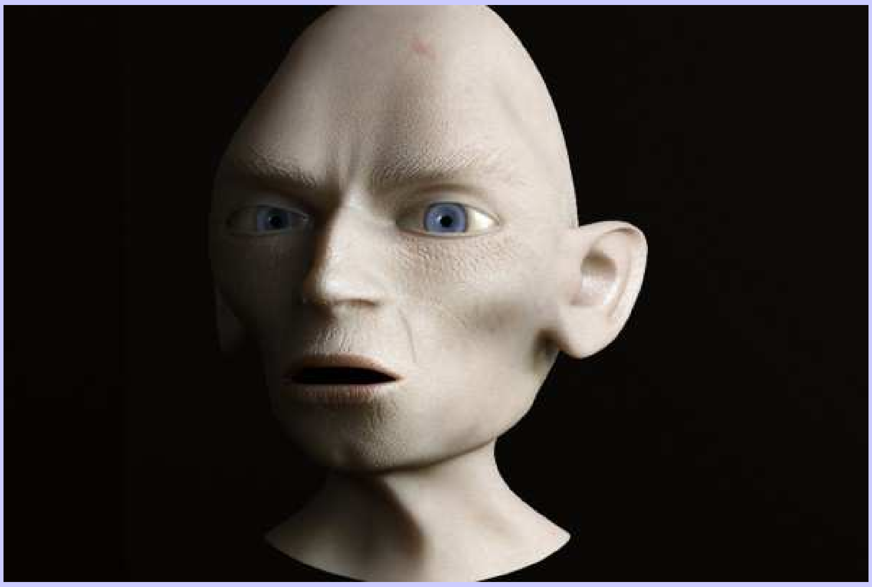


Now THAT is much better!

Ah, now the skin regained its color! But let's see if we can light it with something a bit more interesting than a blue gradient.

Load the **livingroom.hdr** and apply it as a spherical environment map.

> *Application specific note:*
> The method to do this is application-specific; consult your documentation


Globulous lit by HDRI environment

The result, at this point, is available as `globulous-after2`.

This concludes the tutorial for the skin shader, hope it was enjoyable.

1.5 Technical considerations

1.5.1 Application of the shader

The skin shader is an advanced shader utilizing the bleeding edge of the latest and most advanced mental ray shader technology with automatically created lightmaps, self-modifying parameters and multi-component sub-shader based feature set.

To simplify its use, it is implemented as *material Phenomenon* **misss_fast_skin_phen**, which sets up all these features automatically and appears to the user as a single unit.

Due to the fact that a material Phenomenon "takes over" the entire definition of a material (surface shader, shadow shader, photon shader, lightmap shader, displacement shader etc.), different OEM integrations handle material phenomena differently. Various applications do not support them fully or do not support them in certain situations.

In these cases, application-specific phenomena are supplied, often separated into two Phenomena, one to apply as the surface shader, and one to apply as the lightmap shader. In some cases, one has to add a writable lightmap manually.

For this reason, you need to consult your application-specific documentation about the exact process of applying the material to an object.

1.5.2 Parameters, names and useage

Different OEM integrations of mental ray display more user friendly names for the parameters in their user interface. The names shown in this document are the *suggested* names, with the actual shader parameter names as exposed in the .mi declaration file following in parenthesis. What is shown on screen in dialog boxes may be different; consult your application-specific documentation.

These Phenomena use structures to group the input parameters in logical groups, which are automatically grouped by the user interface of different OEM integrations of mental ray. The groups are "d" for "diffuse", "s" for "specular" and "a" for advanced. Since these are *material* Phenomena they are applied directly to an object instance using a **material** statement. In a

.mi file for standalone mental ray, this would look as follows (code fragment):

```
link "subsurface.so"
$include <subsurface.mi>

shader "myskin" "misss_fast_skin_phen" (
    "d" {
        "diffuse_weight"   0.3,
        "front_sss_color"  0.8 0.5 0.3,
        "front_sss_radius" 0.5,
        "front_sss_weight" 0.8
    },
    "s" {
        "primary_spec_color" 0.4 0.4 0.9
    }
)
object "myMesh"
    ...
end object

instance "myObject"
    "myMesh"
    material "myskin"
    ...
end instance
```

1.5.3 Shader declaration

The **subsurface.mi** declaration of **misss_fast_skin_phen** looks like this:

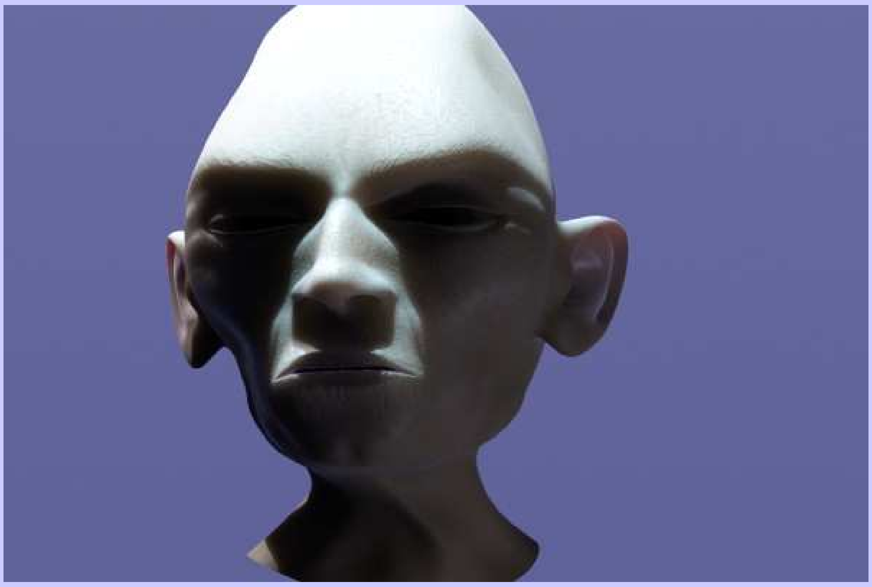
```
material "misss_fast_skin_phen" (
    color texture  "lightmap",
    color texture  "depthmap",
    string         "lightmap_group",
    scalar         "lightmap_size",
    integer        "samples",
    shader         "bump",
    struct "d" {
        color   "ambient",
        color   "overall_color",
        color   "diffuse_color",
        scalar  "diffuse_weight",

        color   "front_sss_color",
        scalar  "front_sss_weight",
        scalar  "front_sss_radius",
        color   "mid_sss_color",
        scalar  "mid_sss_weight",
        scalar  "mid_sss_radius",
        color   "back_sss_color",
        scalar  "back_sss_weight",
        scalar  "back_sss_radius",
        scalar  "back_sss_depth"
    },
    struct "s" {
        scalar  "overall_weight",
        scalar  "edge_factor",
        color   "primary_spec_color",
        scalar  "primary_weight",
        scalar  "primary_edge_weight",
        scalar  "primary_shinyness",

        color   "secondary_spec_color",
        scalar  "secondary_weight",
        scalar  "secondary_edge_weight",
        scalar  "secondary_shinyness",

        scalar  "reflect_weight",
        scalar  "reflect_edge_weight",
        scalar  "reflect_shinyness",
        boolean "reflect_environment_only",
        shader  "environment"
    },
    struct "a" {
        scalar  "lightmap_gamma",
        boolean "indirect",
        scalar  "scale_conversion",
        scalar  "scatter_bias",
        scalar  "falloff",
        boolean "screen_composit"
    },
    integer     "mode",      # light selection mode 0..2
    array light "lights"
)
```

1.6 Inspirational Gallery

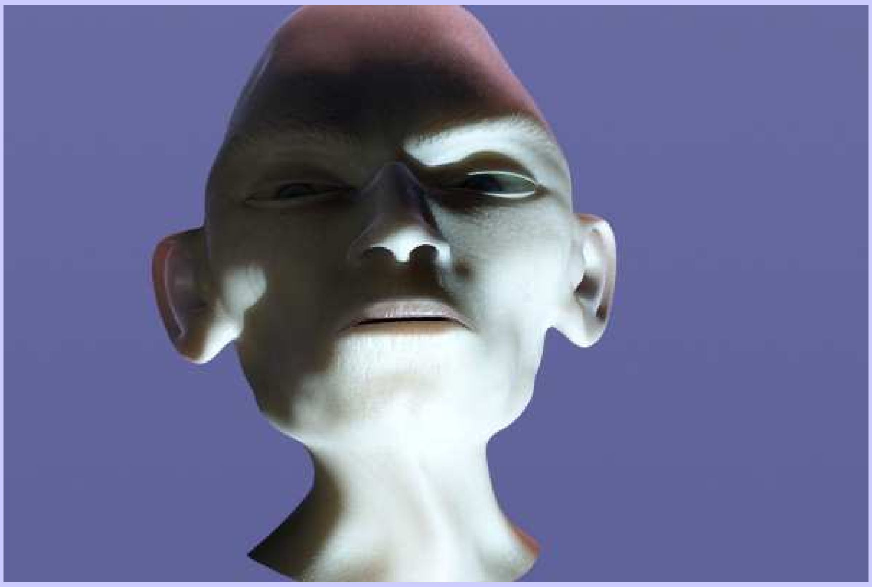
This section shows renders which are not part of the tutorial but are examples of what is possible.

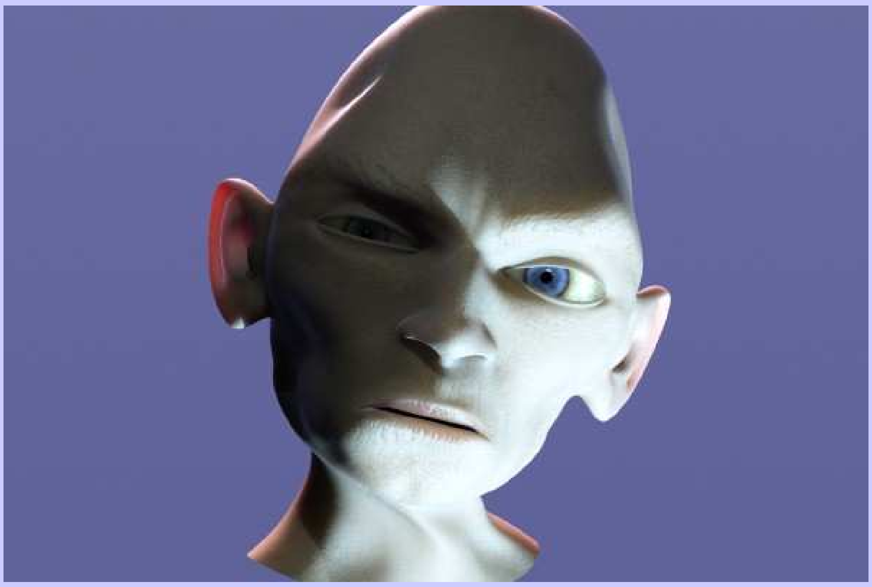
1.6.1 Standard lighting

Here is Globulous lit in “many-splendored” ways.

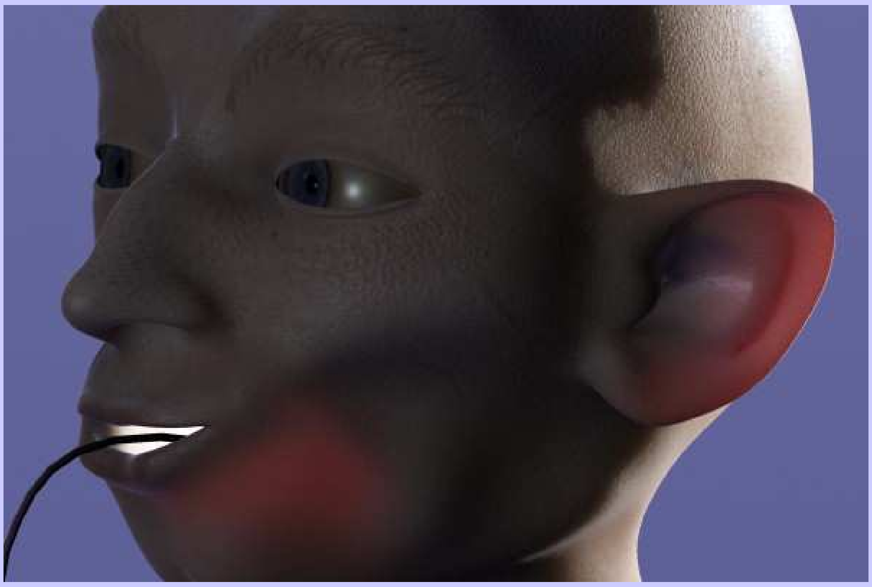


Globulous lit more differently


Globulous lit even more differently

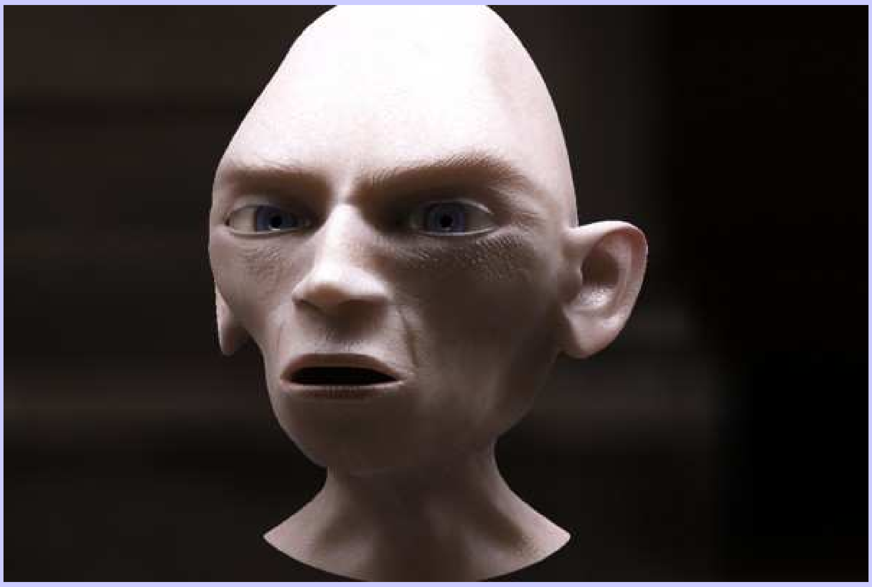

Grrrrr....

Since the "back side (through)" scattering actually allows light to pass through from the other side of the object, we can even light Globulous from within:


Globulous swallows a lightbulb

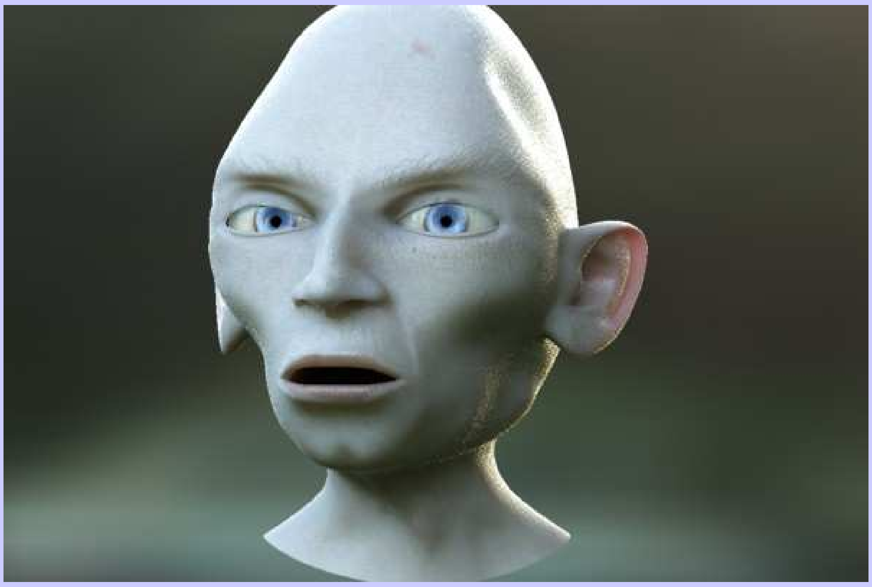
1.6.2 Environment Lighting

Globulous lit by HDRI lightprobe photos:



Using the classic 'Uffizi Gallery, Florence' HDRI from (www.debevec.org/probes) Copyright ©1998, 1999 Paul Debevec

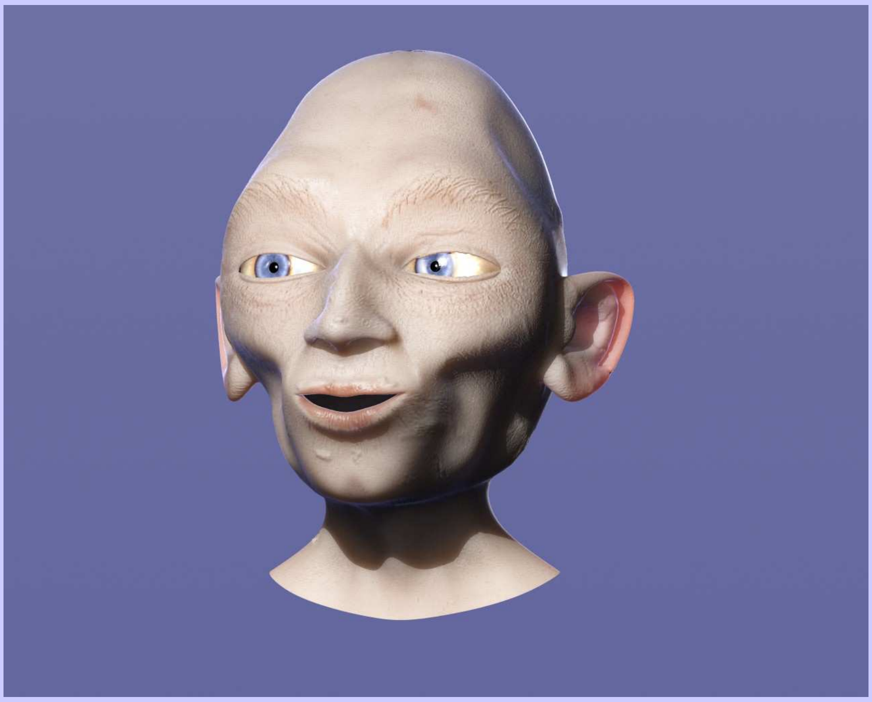
Globulous and friends - fully lit with HDRI image captured in Globulous location.



Using the 'Campus Sunset" HDRI from (www.debevec.org/probes) Copyright ©1998, 1999 Paul Debevec

1.6.3 Displacement

The skin shader that supports displacement — for those really detailed shots. All in all, the sky is the limit. Go forth and create!



Why not try some displacement as well?

1.7 Thank you for listening

Globulous says "thank you for your time"

Globulous was modelled by Jan Hofmeister, captain_solo@gmx.net