Mr. Newtons Answer to the foregoing Letter [of Christiaan Huygens]

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Mr.* Newtons *Answer to the foregoing Letter further explaining his Theory of Light and Colors, and particularly that of Whiteness; together with his continued hopes of perfecting Telescopes by Reflections rather than Refractions.

Concerning the business of Colors; in my saying that when Monsieur *N.* hath shewn how *White* may be produced out of two uncompounded colors, I will tell him, why he can conclude nothing from *that*; my meaning was, that such a White, (were there any such,) would have different properties from the White, which I had respect to, when I described my Theory, that is, from the White of the Sun's immediate light, of the ordinary objects of our senses, and of all white *Phænomena* that have hitherto faln under my observation. And those different properties would evince it to be of a different constitution: Insomuch that such a production of white would be so far from contradicting, that it would rather illustrate and confirm my Theory; because by the difference of that from other whites it would appear, that other Whites are not compounded of only two colours like that. And therefore if Monsieur *N.* would prove any thing, it is requisite that he do not only produce out of two primitive Co <6088> lors a white which to the naked eye shall appear like other whites, but also shall agree with them in all other properties.

But to let you understand wherein such a white would differ from other whites and why from thence it would follow that other whites are otherwise compounded, I shall lay down this position.

That a compounded color can be resolved into no more simple colors then those of which it is compounded

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This seems to be self evident, and I have also tryed it several ways, and particularly by this which follows. Let α represent an oblong piece of white-paper about $\frac{1}{2}$ or $\frac{1}{4}$ of an inch broad, and illuminated in a dark room with a mixture of two colours cast upon it from two Prisms, suppose a deep blew and scarlet, which must severally be as uncompounded as they can conveniently be made. Then at a convenient distance, suppose of six or eight yards, view it through a clear triangular glass or crystal Prism held parallel to the paper, and you shall see the two colors parted from one another in the fashion of two images of the paper, as they are represented at β and γ, where suppose β the scarlet and γ the blew, without green or any other color between them.

Now from the aforesaid Position I deduce these two conclusions. 1. That if there were found out a way to compound white of two simple colors only, that white would be again resolvable into no more than two. 2. That if other whites (as that of the Suns light, *&c.* be resolvable into more than two simple colours (as I find

by Experiment that they are) then they must be compounded of more than two.

To make this plainer, suppose that A represents a white body illuminated by a direct beam of the Sun transmitted through a small hole into a dark room, and α such another body illuminated by a mixture of two simple colors, which if possible <6089> may make it also appear of a white color exactly like A. Then at a convenient distance view these two whites through a Prism, and A will be changed into a series of all colors, Red, Yellow, Green, Blew, Purple, with their intermediate degrees succeeding in order from B to C. But α, according to the aforesaid Experiment, will only yield those two colors of which 'twas compounded, and those not conterminate like the colors at B C, but separate from one another as at β and γ, by means of the different refrangibility of the rays to which they belong. And thus by comparing these two whites, they would appear to be of a different constitution, and A to consist of more colors then α. So that what Monsieur *N.* contends for, would rather advance my Theory by the access of a new kind of white than conclude against it. But I see no hopes of compounding such a white.
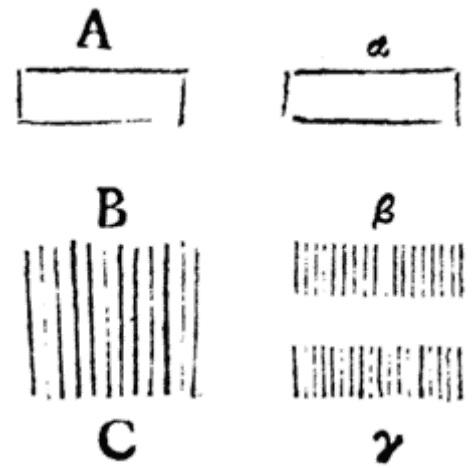
As for Monsieur *N.* his expression, that I maintain my doctrine with some concern, I confess it was a little ungrateful to me to meet with objections which had been answered before, without having the least reason given me why those answers were insufficient. The answers which I speak of are in the Transactions from *pag.* 5093 to *pag.* 5102. And particularly in *pag.* 5095; to shew that there are other simple colors besides blew and yellow, I instance in a simple or homogeneal Green, such as cannot be made by mixing blew and yellow or any other colours. And there also I shew why, supposing that all colors might be produced out of two, yet it would not follow that those two are the only Original colors. The reasons I desire you would compare with what hath been now said of White. And so the necessity of all colors to produce white might have appear'd by the Experiment *pag.* 5097, where I say, that if any color at the L*ens* be intercepted, the whiteness (which is compounded of them all) will be changed into (the result of) the other colors.

However, since there seems to have happened some misunderstanding bewteen us, I shall endeavor to explain myself a little further in these things according to the following method.

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Definitions.

1 I call that Light homogeneal, similar or uniform, whose rays are equally refrangible.

2. And that heterogeneal, whose rays are unequally refrangible.

Note. There are but three affections of Light in which I have observed its rays to differ. *viz.* Refrangibility, Reflexibility, and Color; and those rays which agree in refrangibility agree also in the other two, and therefore may well be defined homogeneal, especially since men usually call those things homogeneal, which are so in all qualities that come under their knowledg, though in other qualities that their knowledg extends not to there may possibly be some heterogeneity.

3. Those colors I call simple, or homogeneal, which are exhibited by homogeneal light.

4. And those compound or heterogeneal, which are exhibited by heterogeneal light.

5. Different colors I call not only the more eminent species, red, yellow, green, blew, purple, but all other the minutest gradations; much after the same manner that not only the more eminent degrees in Musick, but all the least gradations are esteemed different sounds.

Propositions.

1. The Sun's light consists of rays differing by indefinite degrees of Refrangibility.

2. Rays which differ in refrangibility, when parted from one another do proportionally differ in the colors which they exhibit. These two Propositions are matter of fact.

3. There are as many simple or homogeneal colors as degrees of refrangibilty. For, to every degree of refrangibility belongs a different color, by *Prop.* 2. And that color is simple by *Def.* 1. and 3.

4. Whiteness in all respects like that of the Sun's immediatelight and of all the usual objects of our senses cannot be compounded of two simple colors alone. For such a composition must be made by rays that have only two degrees of refrangibility, by *Def.* 1. and 3; and therefore it cannot be like that of the Suns light, by *Prop.* 1; Nor, for the same reason, like that of ordinary white objects.

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5. Whiteness in all respects like that of the Sun's immediate light cannot be compounded of simple colors without an indefinite variety of them. For to such a composition there are requisite rays indued with all the indefinite degrees of refrangibility, by *Prop.* 1. And those infer as many simple colors, by *Def.* 1. and 3. and *Prop.* 2. and 3.

To make these a little plainer, I have added also the Propositions that follow.

6. The rays of light do not act on one another in passing through the same Medium. This appears by several passages in the *Transactions pag.* 5097, 5098, 5100, and 5101. and is capable of further proof.

7. The rays of light suffer not any change of their qualities from refraction.

8. Nor afterwards from the adjacent quiet *Medium*. These two Propositions are manifest *de facto* in homogeneal light, whose color and refrangibility is not at all changeable either by refraction or by the contermination of a quiet *Medium*. And as for heterogeneal light, it is but an aggregate of several sorts of homogeneal light, no one sort of which suffers any more alteration than if it were alone, because the rays act not on one another, by *Prop.* 6. And therefore the aggregate can suffer none. These two *Propositions* also might be further proved apart by Experiments, too long to be here described.

9. There can no homogeneal colors be educed out of light by refraction which were not commixt in it before: Because, by *Prop.* 7, and 8, Refraction changeth not the qualities of the rays, but only separates those which have divers qualities, by meanes of their different Refrangibility.

10. The Sun's light is an aggregate of an indefinite variety of homogeneal colors; by *Prop.* 1, 3, and 9. And hence it is, that I call homogeneal colors also primitive or original. And thus much concerning Colors.

Monsieur *N.* has thought fit to insinuate, that the aberration of rays (by their different refrangibility) is not so considerable a disadvantage in glasses as I seemed to be willing to make men believe, when I propounded concave mirrors as the only hopes of perfecting Telescopes. But if he please to take his pen and compute the errors of a Glass and Speculum that <6092> collect rays at equal distances, he will find how much he is mistaken, and that I have not been extravagant, as he imagins, in preferring Reflexions. And as for what he says of the difficulty of the praxis, I know it is very difficult, and by those ways which he attempted it I believe it unpracticable. But there is a way insinuated in the *Transactions pag.* 3080. by which it is not improbable but that as much may be done in large Telescopes, as I have thereby done in short ones, but yet not without more than ordinary diligence and curiosity.