CORONAVIRUS – Part Nine: 5G, TERAHERTZ, TONY PANTALLERESCO, NANO

Share letter from Ms. Wyona:

Last week Ms. Melanie and her family came here and Melanie was baptized because of Tony sowing seeds and sharing about our ministry to her. See God at work there? If you will step out for Him, He can use you. Praise God for Tony's boldness to share about Jesus.

No one has all the answers. But you sure are not getting the truth from main stream media. They are not going to lay the answers in our lap so we are having to dig and do the best we can to make sense of all of this.

NYC allows 5G equipment on streetlamps…Allowing wireless equipment on its streetlamps isn't something new for New York City. It's been allowing this for 15 years. The effort has resulted in nearly 6,000 pole installations – with 5,000 more in the pipeline – by franchisees throughout the five bouroughs. Date of article Feb. 2020

The towers, transmitters or bases are going up everywhere. They are saturating our world in frequencies, in radiation. This is a major part of the beast system that satan will use to control mankind during the tribulation. He is already using it to some degrees but it is going to get more intensive. He is going to take freewill

from those that bow to him. He is already shutting down minds. That's why so many people cannot even use critical thinking.

TONY'S REPLIES TO MY QUESTIONS

TONY'S RESPONSE

5 g will not fry you the whole thing of 5g is they needed to have antennas really close due to 1. limited range 2. limited PENETRATION---5 g will pump you if you are in a direct line of fire. ---NOW Thz is a different story ---low bands heals, upper bands destroy you to the core. ****THEY KNOW HOW TO USE HEALING FREQUENCIES BUT CHOOSE NOT TO****

What is a virus ? A DATABASE OF INSTRUCTIONS nanobio would be incorporated with this in order for this to transfer from a host. Normally viruses die from high heat or extreme cold. That's why I gave the formula I did with the bleach and heat. You hit it from both in and out---so when nanobio is added to the virus now it can be a kill switch.

When the freq hits it and activated it then allows the thz to conduct through the body releasing from the water hydrogen (why they started selling hydrogen in the health food industry propagating it as healthy). When this is released the Thz is on a higher band, now zings through the body as a super conduit ripping and shredding the mitochondria (why we see the Asians drop like they did).

Please play this video –guy just falls over in China(about .5 min)
https://www.youtube.com/watch?v=Otjn0YMJNdE

(Please loop at :05 to :15 twice but play it at the end of the video)

The name of the media there was very telling "sun." They want to show you what is going on for real. And remember the name of this virus, corona, is all about sun worship. I brought that out in part one. The luciferians worship the sun god baal. That's what all of this plandemic is about. Bringing in the new world order.

Tony Continues: The nano in the body with whatever has been inserted ORRRRRRRRR grown ORRRRR Activated now collapses the immune system since we have no defense against a synthetic biology. And if it is directly assaulted it creates a morphology (alters itself so that whatever you hit it with now has no effect) and it continues to proliferate through the system collapsing it slowly.

Will see this repeatedly offend people who appear to be healthy and have a relapse. Covid -19 does not exist. Another totally bogus (blank) --another cover up for their new biotech assault.

So now you have the freq and now you have the trojan horse where does it go from here?

Since this will repeatedly reinfect you will then (not you) kiss there (blank) for a vaccine. You (again not you) will beg to have some relief anything to stop this infectious spread and this repeated assault---so now a vaccine will be inserted with a implant or chip that will regulate the freq to turn down the program and put it into sleep mode.

Now if you get out of line and get tired of being their toy, then they hit you with the on switch and activate with thz. Now you have a collapsing system and a take out –poof! You now have been turned off. Cause of death ---heart ---diabetes-respiratory- brain failure etc. The real cause will be cellular death, mitochondrial disintegration-neuron collapse---basically a total short out.

TONY GAVE A LOT OF ADVICE ON HOW TO WIPE OUT THE PROGRAM AND HOW TO FLUSH THE NANO OUT. THAT INFORMATION IS IN THE LINKS AT THE BOTTOM OF MY SERMON NOTES AND IS IN THE INFO. BOX ON YOUTUBE.

Hope this assist. Go to augmentinforce.com check the data there on nanotoxicology. Somewhere in there you will find mimetic, pay close attention to this.

Tony

TONY'S NEXT REPLY

Genetically modifying a pathogen is similar to genetically modifying food. Once you target or program the sequence required for it to affect a change, all it needs then is to connect to the right proteins and it activates. ---So let's say your of British decent --all I would need to do is access that genome, release it in a vaccine or food, when it has accessed the host, activate it - and boom, you turned it on and now the person is disengaged.

5g 60 Ghz would suffocate a person, if this is even true. ****IF THIS IS EVEN TRUE**** But what I seen when the Asians fell, was not due to suffocation but rather disengaging. When you look at the initial discussion on 5g it can't even penetrate a tree. Why they had to cut them down. This is way way higher up and would say it is 6 not 5g. And why did they need a virus? Cherie, they used a

common cold to create the pandemic. It may not even be viral but synthetic. Why I have been saying for over 9 weeks total (blank). Being exposed to nanopoisoning, I can recognize the symptoms and effects. What we are seeing is a turning on or activation. They want 60% of the population exposed and infected the other 30% will not bow to their "god" their baal or molek. And some of us will not bow to there (blank) vaccine either.

Tony

ANOTHER REPLY FROM TONY

Disengaged means disconnected from their central nervous system. Disconnected from brain cells, from spine---turned off like a TV.

Please play from 4:07 to 4:25 and from 5:42 to 5:57 and from 9:22 to 9:33 and from 11:53 to 12:40 Shows many people in China just falling over and many are shaking like they are being electrocuted.(about 1.5 min's)

https://www.youtube.com/watch?v=NbmCXiVUMHc

TONY CONTINUES: They were vaccinated in Asia 3 months before they tested their prototype. Why the Italians did not die of corona, what happened there was that the village hit was 80+ years old and they euthanized them through over medication. They were murdered.

80% of the corona has been misdiagnosed and there is No test for it. Did you see the vid in Wuhan where the officials walked in and the people shouted it was all fake?? And everyone has been saying this.

What I think is going on is the double blind test to see how their targeting testing is going on, as well their looting the stock market stealing 3.3 trillion dollars out. And now they began assaulting the pensions. Romania just lost theirs today. After this will be cash and after this will be mandatory vaccinations.

Once they officially make it mandatory a lot of them are going to drop dead from the internal tech and the thz targeting. Bing bang boom, down and dead.

Why I am still standing is because I had a (blank) attitude toward there AI and this tech and Jesus kept me on my feet til I got caught up and still catching up on this. It (blank's) me off I have not found better solutions even though these do work they are not efficient enough. None of us should have been violated like this with demonically insane entities. And that also gives me an attitude toward this. I have reasons to be in this battle.

And I intend we win this, if not here, in the afterlife when we return with Christ the king and beat the living _)(*&^%$#$%^& out of these things and toss them into the lake of fire. ---I will smile in that day, you have no idea.

Tony

TONY'S LAST REPLY

They needed a 6g Thz to permeate and activate. Dual hit thz fried the mitochondria, the program shut off or shut down the people, instant death.

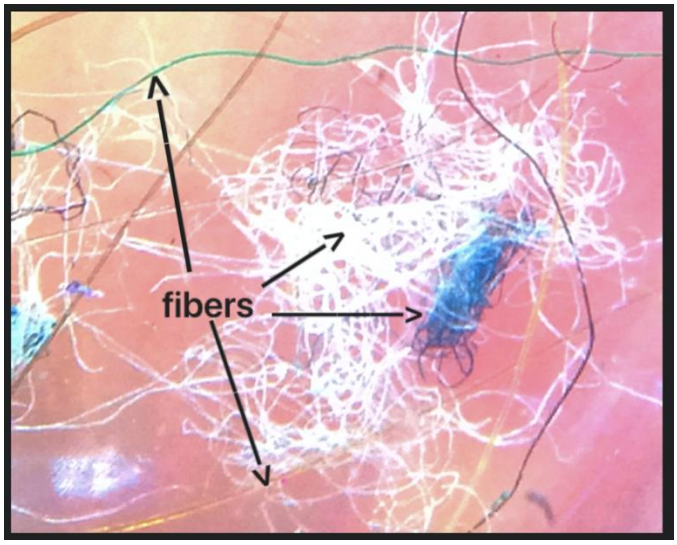
As far as the spread, if they have the vaccine then it would enter their genome so any exchange could transfer. But if they had vaccinated the whole community, then they would all be infected, so spreading it would not be an issue since everyone would already have it. And if it was only designed to access Asian

genetics, then there would be little danger to anyone else it could impact. If there was a gene in that person who had Asian mix somewhere in their hereditary but even then it would depend how far back.

The nano is definitely required in order for the implants to access the person, this completes the circuit. So once injected, it assimilates with the network that has already been constructed. You now have someone tagged so if you want to take anyone out in the future ---poof gone. So you're dying due to the de-evolving of the body into a circuit.

Tony

It may be hard to understand what Tony is talking about unless you are already dealing with nano saturation.



Remember we now have people with things that look like computer wires coming out of their bodies. That is from the chemtrails, the metals, assimilating in their bodies. Surely you can see and know that is not naturally occurring. God did not put wires inside of our bodies. This is an assault against mankind.

The video we are about to see was shared to me by Tony and he said, "here is your corona, how it became activated." You may want to get younger children out of the room for about the next 13 min's.

*Please play from 0 to 1:14 and from 1:21 to 2:00 and from 2:05 to 6:56 and from 7:06 to 7:09 and from 7:51 to 7:56 and from 8:11 to 8:13 and from 8:24 to 8:32

and from 8:40 to 14:14 A sci-fi short movie clip called “Nano” showing what the world is headed to with the nanotechnology and our bodies. They called it Bio Affordable Use Act (Baua) **Which is alluding to Bauer which was Rothschild’s real last name. And the agent’s last name was Roth. They were paying tribute to a high luciferic family that has played a significant role in getting this all in place.** She stated version 2.0 of the sensational and now mandatory smart phone peripheral (output, input, hardware) the nano is rapidly gaining market share as Aspire (company in the movie) rolls out public beta testing to some lucky users. 100’s of new body enhancing apps are available exclusively on the nano 2.0 platform. On screen was a message “Remote paralysis” elicits criticism of nano 2.0. She says, remote paralysis is changing the way America does law enforcement. Then she debates a guy who was the former director of the Texas ACLU who was dismissed from the organization for denouncing the organizations position on gun control and nano 2.0. She talks about gun related deaths being down 80% since the 2nd amendment was repealed. Then she says fatal shootings are practically non-existent. He says he believes the technology being used to apprehend criminals is unsafe..unnatural… She says, what compared to guns? He continues…unconstitutional. She says, it is a painless paralysis of the motor function. / Next an online prostitute is coming to the agent’s apartment for a “date” and you see the digital details of the date on screen. The agent is watching the tv debate where they talk about the biotechnology crimes division. She says that one could argue BCD was created in direct response to “Sorcerer” (some hackers that want to stop the mandatory roll out. Then the scene switches to the hall where one of the hackers named Zolee intercepts the prostitute and then takes her place as the agent’s date. / The tv debate: the lady says remote paralysis has the exact same effect as the BCD’s nano gun. She mentions reading a document on nano 2.0 to which the guy says he has not read it. She says, well I have and there is absolutely zero risk to the recipients physical or mental health. The guy says, and their freedom…?? The scene switches to Zolee in the hallway with the prostitute. She threatens her and says, show me your phone. When the prostitute shows her, her phone, she inserts a program called “Naptime” that runs through the phone and because it is biometrically attached to the prostitute, once it runs she completely shuts down. Then the scene cuts back to the tv debate where the man says, I’m talking about the marriage of business and government. I’m talking about the fact that Aspire, the feds and whomever has the ability to effect my body’s motor functions without my permission! She says, don’t you think you’re being a little paranoid. Scene cuts to Zolee who contacts

her partner in crime to let him know that the agent who she is about to have a date with prefers blondes. Her partner dials up an app on his phone called "crazy horse" and punches up blonde hair and blue eyes for Zolee and then we see her hair and eyes change. Zolee enters the apartment and he frisks her for weapons. He digs through her purse and finds a knife. She says she'd carry a gun if you could still get them. The tv debates continues and the man says, till every American has an IP address that can be tracked, monitored and switched off at the push of a button. The lady starts to say, a necessary precaution… The scene goes back to the date. The agent offers Zolee a drink. She tells him if he prefers his women to be drunk there is an app for that, 100's of them actually. She then notices the thumb drive looking thing plugged into his arm. He tells her it gives him direct access to Aspire's central database. He says, do you have any idea what direct integration can do for nano response times? He says, I could rewrite my entire genome in a fraction of the time it would take you to change that pretty hair color. So she says, we don't need that thing to have fun. She pulls out her phone and says, I've got all the apps you need right here. And app called "Body Sync" comes up. She sends the request from her phone to his phone for them to "sync" up. He accepts her request but the device plugged in to his arm blinks and sounds saying: "illicit app detected." She starts teasing him saying his "toy" doesn't want him to have any fun. He says she has a "cracked version" of the app and that it can get her into a lot of trouble with guys like him. She talks him into unplugging the device from his arm so that they can supposedly "sync" on her program which is supposed to be illegal because it is not approved by Aspire. She says, that wouldn't stop a man like you would it? Then he unplugs the device from his arm. Her partner in crime is out in the car hacking Aspire's network at the same time. On screen shows his IP address and that the program is extracting his biometric data. Then it shows it is gathering his data and then goes to her info. and says that it is awaiting connection to "bio-key." Once they are now synched through the program she touches the agent, his name is Max and you see blue streakes as if it was a cold touch. She sets her phone down. / Now we see inside the body, the nano connecting to the blood cells and changing them. / We skip the part where they are about to have sex. Next she grabs her phone and runs the program to put him into nap time mode. He goes to sleep. / She then gets her phone and takes the thing that used to be in his arm and plugs it in to her phone and links to her partner in crime to download the information. He says, you should have used protection Roth. (Because his body and all of his information is now being hacked.) They begin to access the nano 2.0 beta trial.

The download isn't complete and agent Max begins to wake up. Once the "naptime" app is finished running, Roth's phone comes back on and he wakes up. They just barely got the download before he wakes up. He wakes up and says what happened? I deleted this scene – too racy and violent – but she runs and he catches her and finds out she is an agent for "Sorcerer." He tells her she has been preselected to receive the nano 2.0 beta, courtesy of Aspire and Uncle Sam (government). He says, he can't help her with the free apps, for those you had to preregister online. - / Agent Roth then gives Zolee a shot, injecting nano 2.0 beta into her body. You see the new nano attacking the nano that was already inside of her body and shutting it down. Then Agent Roth says, what can we do with Zolee? Real time location tracking, biometric data monitoring and non-lethal immobilization. It remotely induces paralysis forcing the suspect to submit without incident. I did not show where she pulls out a knife, stabs him and manages to get away. / Zolee is running away and he tells her, "welcome to the future." She runs out to her partner in crime and gets in the car and they speed off. Agent Roth pulls the knife out of his leg and runs a program on his phone to heal the wound through the nano inside of his body. As Zolee and her partner are driving off you see a billboard sign that says "nano for pets." Zolee's hair begins to change back-n-forth and her partner realizes that she has been injected with the nano 2.0. Agent Roth calls the station and tells them where to go and pick Zolee up at and states that she will be rp'd which means remotely paralyzed. Her hair flipping back-n-forth is an outward sign of the nano fight within her body. Zolee gets out of the car and her partner asks her not to do it. She says, I've been docked. Then agent Roth has her information pulled up on his cell phone and hits "remote paralysis" and she all of a sudden shuts down. You see the nano inside attach to the blood cells instructing the shut down. At the end you see a bill board advertising that everyone must get their mandatory nano upgrade. The last scene is Agent Roth looking at his phone and seeing that the download of nano 2.0 to Zolee has been completed. Then it asks if he wants to abort the connection Yes or No?.*(about 13 min's)
https://www.youtube.com/watch?v=TAHGZSeGVww

Thank you Tony for sharing that video with us. It truly shows us what they have been up to.

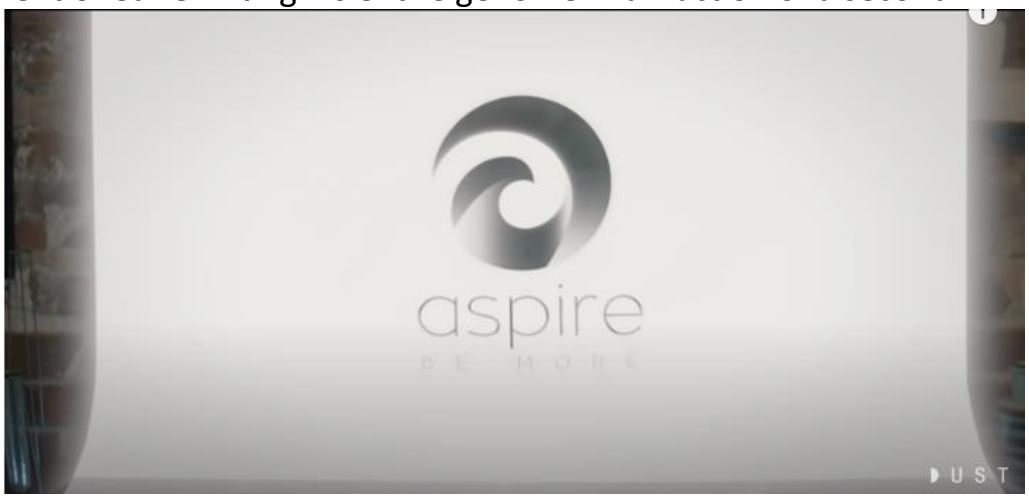
Notice how agent Roth said, "**WELCOME TO THE FUTURE**." Very telling.

FROM DESCRIPTION BOX:

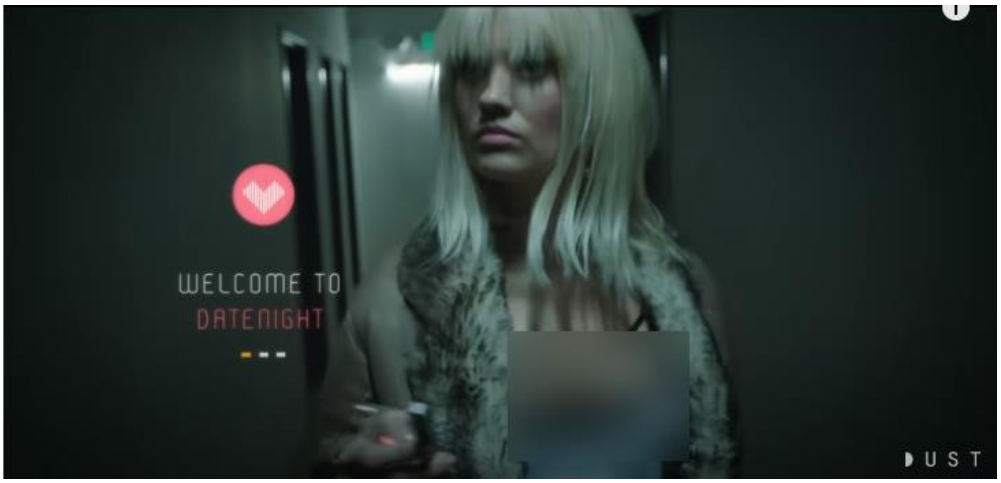
More About Nano (a sci-fi short film): In the near future, advances in biotechnology have bridged the gap between man and machine. Developed by ASPIRE, a seemingly benevolent corporation inspired by the likes of Apple and Google, “Nanos” are microscopic, probe-like machines that have the ability to interact with human DNA and alter expressions of the genome within seconds of entering the bloodstream. For the purpose of health or “bio-maintenance,” they have the ability to alter the body’s autonomic systems and metabolic rates, regulate fat and/or muscle production, and even slow the aging process. They also allow for fun, non-essential “bio-mods,” such as the ability to change one’s hair color, raise one’s adrenaline, or even enhance one’s pleasure during sex. ZOLEE, a member of an underground network of hackers who are conspiring to thwart the impending roll-out of the government mandated “Nano 2.0,” intends to steal classified data pertaining to Aspire’s new government contract. But in order to do so, she must access the Aspire Nano Network using the login credentials of MAX ROTH, a corrupt agent with the Biotechnology Crime Division (BCD). His connection to the Aspire Network is biometrically encrypted, accessible only via a key that’s docked to his arm--a hardlined connection to his own Nanos. Posing as a prostitute, Zolee hopes to seduce Roth (a known deviant with pension for Nano app-enhanced sex), distracting and ultimately subduing him so that she may hack into his account and steal the sensitive data. This proves to be easier said than done during an intense game of cat and mouse, leading to an exciting showdown that pits Zolee against the sadistic BCD Agent.

First off the channel name “Dust” is very telling. As in smart dust that is getting inside of all of us. They called it Bio Affordable Use Act (Baua) **Which is alluding to Bauer which was Rothschild’s real last name. And the agent’s last name was Roth. They were paying tribute to a high luciferic family that has played a significant role in getting this all in place.** The tv reporter says, remote paralysis is changing the way America does law enforcement. Then she debates a guy who was the former director of the Texas ACLU who was dismissed from the organization for denouncing the organizations position on gun control and nano 2.0. She talks about gun related deaths being down 80% since the 2nd amendment was repealed. Then she says fatal shootings are practically non-existent. He says he believes the technology being used to apprehend criminals is

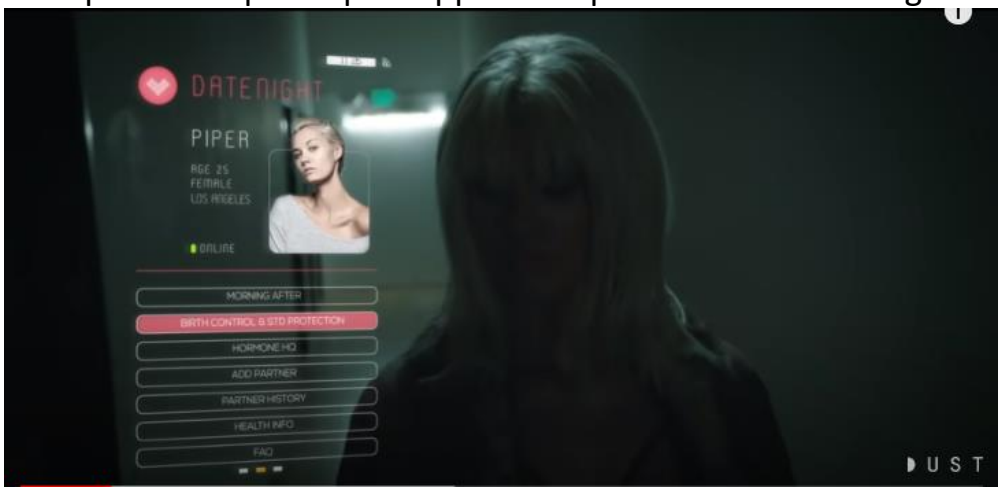
unsafe..unnatural… She says, what compared to guns? He continues…unconstitutional. She says, it is a painless paralysis of the motor function. The reporter says remote paralysis has the exact same effect as the BCD's nano gun. She mentions reading a document on nano 2.0 to which the guy says he has not read it. She says, well I have and there is absolutely zero risk to the recipient's physical or mental health. The guy says, and their freedom…?? the man says, I'm talking about the marriage of business and government. I'm talking about the fact that Aspire, the feds and whomever has the ability to effect my body's motor functions without my permission! She says, don't you think you're being a little paranoid. The tv debates continues and the man says, till every American has an IP address that can be tracked, monitored and switched off at the push of a button. The lady starts to say, a necessary precaution… The agent mentioned rewriting his entire genome in a fraction of a second.



Notice the logo for the tech company Aspire was a 6. In this screen shot it says, aspire, be more. They are introducing you to the idea of moving humanity into a situation where anyone can be shut down, at anytime.

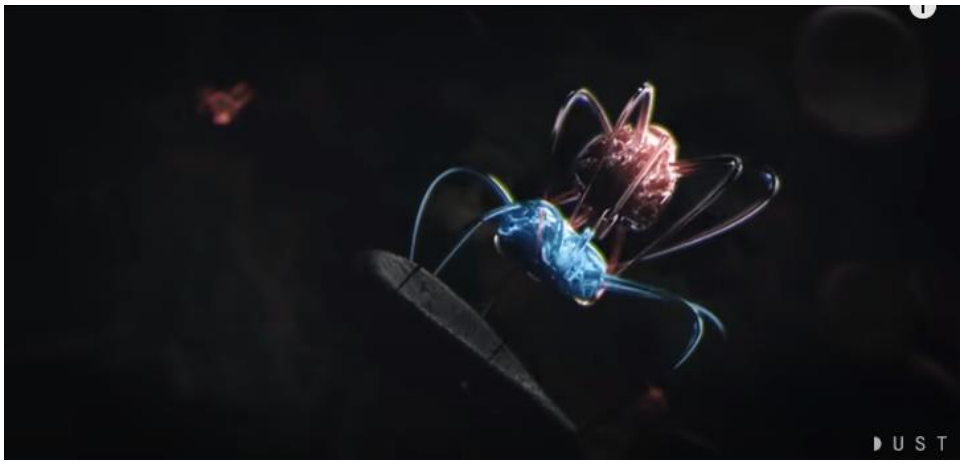


The prostitute pulls up an app on her phone called “datenight.”



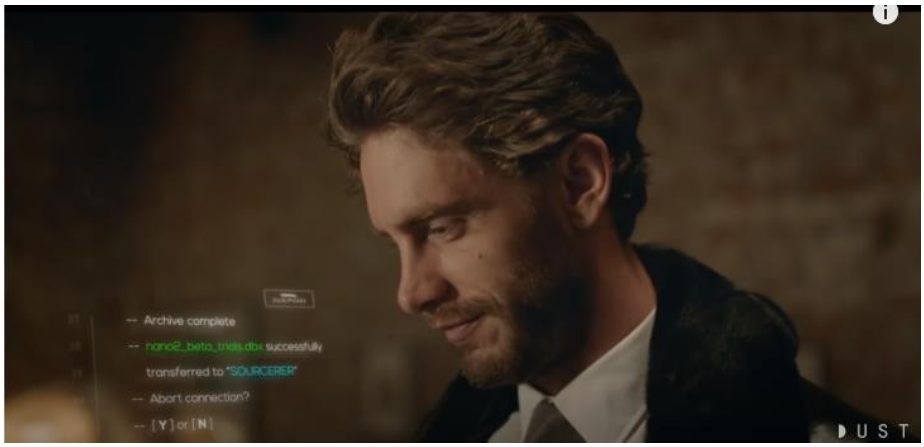
Then she selects birth control and protection and a time limit. All through an app that will run a program through the phone and frequencies working with the nano inside of her body. This is the transhumanism that satan’s elect are working so hard to push us all to.

Notice they were just running apps or programs through the cell phones and it was affecting their bodily functions. An app could make you intoxicated is what the girl said. An app could make you go to sleep instantly. An app could intensify your feelings to touch, increase your adrenaline etc. An app changed her hair color and eye color instantly. These apps were biometrically working in the person through their smart phones. Speaking back-n-forth, sending and receiving. Remember our bodies are antennas. And the main topic of the film was an app that could run remote paralysis on anyone. Or shut them down. It could track and trace everyone.



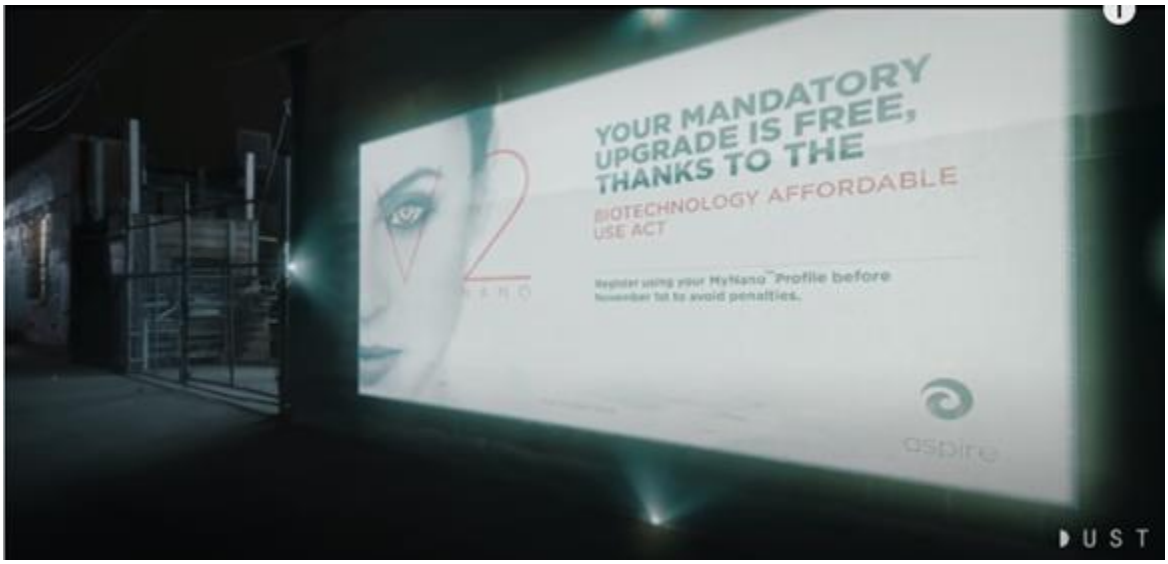
After agent Roth injected Zolee with the upgrade version of nano you saw a picture of what happened inside her body. That is the upgraded nano attacking and deactivating the old nano or program. He said it was courtesy of Aspire (think Bill Gates and the vaccine companies) and Uncle Sam – our governments – working together. Big business and government, they just left the military out of the mix but they are in it as well. They ran a "suicide" program against Tony and he recognized it and stood up and fought against it. There was a super bowl commercial showing a guy trying to decide what beer to buy. He could not make up his mind and it zoomed in and showed a room full of people (like inside his brain) making decisions for him. That is the targeting system and the nanotechnology foundation they have been putting in everyone. They are showing you what they are already doing and it is rolling out to us ever faster now.

Agent Roth ran an app on his phone that healed his knife wound. The luciferians know about the healing frequencies but prefer to use damaging frequencies as a weapon against us.



Last scene of the film: -Archive complete / -nano2.beta.trials dbx successfully / -transferred to “Sourcerer” / -abort connection? / -{Y} or {N}

Pretty sure the government and the freemasonic police are not going to abort the connection. Also I thought it was interesting how they portrayed her as one of the good guys trying to stop the continuing updates to the nano. She was part of a group called “sourcerer.” As Christians we know that all forms of witchcraft, sorcery, divination etc. are all an abomination to God.



The ending scene: V2 Nano – reminds me of V2K which is voice to skull. V stands for 5 in Roman numerals which is also the number that represents Jupiter the false sun god. The five is for the five masonic laws. The 2 on the Pythagorean numerology chart is the color orange and so it stands for the freemasons because when you add the letters of orange up you get 33. The sign says: V2Nano, Your mandatory upgrade is free, thanks to the biotechnology affordable use act. Register using your my Nano Profile before November 1st to avoid penalties.

Remember the V from the tv show "V," is also for vril or reptilians which would be fallen angels and demons. Notice the slit eye on the left. It's us versus them. And boy is it ever! Looks like they used the same picture from the tv series "V" here in their short film.

CLOSING

SOME ADDITIONAL HEALTH ADVICE FROM TONY

Tell everyone in your neck of the woods heat your homes either with space heaters or infra red lights. As well, use 8 drops of bleach in distilled or reverse osmosis water. 1 gallon and allow to sit for an hour then use. And go buy lard, it has BHT in it, potent protector. Use it in cooking or consume straight, will protect, or make the copper chloride and zinc chloride as well and use. The key here is to heat your area and stay in the heated area. Use infra red if you have it and enclose a room and heat it. Will create a fever like effect and kill whatever is in the environment if it is pathological. If it is synthetic, then you are going to have to create a pulse (emp) to disengage the program.
Tony

Romans 8:31-39 - What shall we then say to these things? If God *be* for us, who *can be* against us? He that spared not his own Son, but delivered Him up for us all, how shall He not with Him also freely give us all things? Who shall lay any thing to the charge of God's elect? *It is* God that justifieth. Who *is* he that

condemneth? *It is* Christ that died, yea rather, that is risen again, Who is even at the right hand of God, Who also maketh intercession for us. Who shall separate us from the love of Christ? *shall* tribulation, or distress, or persecution, or famine, or nakedness, or peril, or sword? As it is written, For Thy sake we are killed all the day long; we are accounted as sheep for the slaughter. Nay (No), in all these things we are more than conquerors through Him that (Who) loved us. For I am persuaded, that neither death, nor life, nor angels (fallen angels), nor principalities (demons), nor powers (not even the powers of hell), nor things present, nor things to come, Nor height (no power in the sky above), nor depth (nor in the earth below), nor any other creature, shall be able to separate us from the love of God, which is in Christ Jesus our Lord.

This coronavirus plandemic will not separate us from Christ no matter what they roll out against us. If you are truly His. Nothing happening now and nothing happening in the future can separate us from the love of God. Stand up and fight the good fight of faith. Take comfort knowing nothing can tear you away from Christ. Don't let these luciferians scare you, be a strong soldier in the Lord's army.

Ms. Rhonda shared Psalm 30:1-2 with me and I am going to use it in the prayer today.

PRAYER

Psalm 30:1-2 – I will praise You, O Lord; for You have lifted me up, and hast not made my enemies to rejoice over me. O Lord my God, I cried unto You, and You have healed me.

Salvation for Maritza's friends, and her cousin who walked away from God / Michelle's sister and family to be saved. / Kath's niece – Karen / Ann's children: Adrienna, Noah and Allie / Jesus / Ms. Tommie's children and ex husband

Deliverance for Maritza's friends – several of them are homosexual / Deliverance for Karen from alcoholism & for Matthew

Healing: Yolindie, Patricia, Mary D. – cancer, Matt, Michael, Tommie, Katrina, Emmanuel, Pastor Dalbeer, Sourav, Granddad Mark, Melanie, Jesus

1 hr 43 mins

LINKS:

CAUGHT ON CAMERA: Infected people fall down on streets due to virus?
https://www.youtube.com/watch?v=Otjn0YMJNdE

ɥʇnɹ ɟ əɥʇ sn,ıiʌʌ å u o ɹ o ɔ Part 2
https://www.youtube.com/watch?v=NbmCXiVUMHc

Sci-Fi Short Film "Nano" | DUST
https://www.youtube.com/watch?v=TAHGZSeGVww

LINKS FOR EVERY PART:

Dr. Tent shares about Vaccines
http://www.threeheartschurch.org/index.php/sermons/sermon/243-stop-the-vaccinations-they-are-injecting-us-with-cancer-and-viruses

Vaccination MUST SEE! - The Hidden Truth - Australian Documentary (FULL)
https://www.youtube.com/watch?v=P9CGfYPXDKg&t=4228s

Weather and Chemical Warfare
http://www.threeheartschurch.org/index.php/sermons/sermon/256-weather-and-chemical-warfare-part-one

Promotes using vitamin C against coronavirus and as a preventative
http://doctoryourself.com/

Coronavirus AID SUPPORT Possible cure High doses of Vitamin C Covid 19
https://www.youtube.com/watch?v=g6HCrzGY2kM&feature=youtu.be

Tony's website

http://augmentinforce.50webs.com/

Tony's Youtube Channel

https://www.youtube.com/user/HerbsPlusBeadWorks

Tony's technical stuff

https://www.bitchute.com/channel/independz/

Tony's podcasts *Tony said to start with 3/7/2020 podcast and go to 3/17/2020*

http://independz.podbean.com/

https://independz.podbean.com/e/tonys-show-03072020/

https://independz.podbean.com/e/tonys-show-03092020/

https://independz.podbean.com/e/tonys-show-03132020/

https://independz.podbean.com/e/tonys-show-03162020/

https://independz.podbean.com/?s=Tonys+show+03172020

https://blog.iyannis.com/tony-pantalleresco-2020-03-18-immune-system-booster-and-more-on-viruses-and-namo/

Aroy Mak's youtube channel houses all of Tony's podcasts

https://www.youtube.com/channel/UCoGv8Zjgf4VXWIOOfb-uoAw

How you beat it ---emp or a PEMF (pulsed electro magnetic frequency) wipe out the program discharge the body regularly from any build up of freq by either a grounding strap or stepping on foil both feet. Using chelating agents to further

remove the discharged nano so they do not add to the poisoning of the body either through chelation or absorbents or take the saline baths.

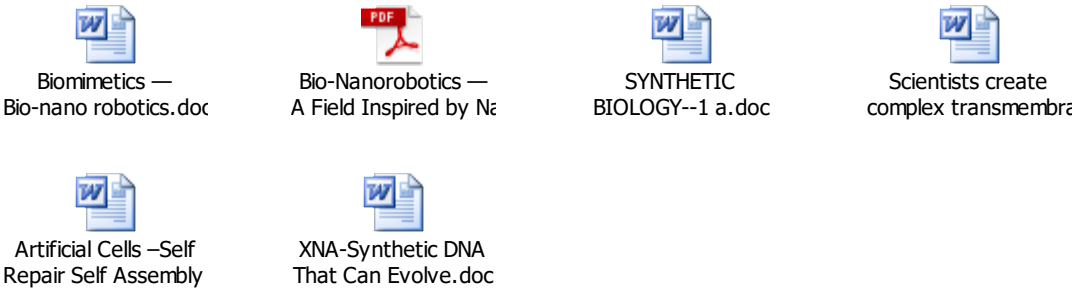
Use the bucket---triangle--increase immune enhancers like chlorides of all kinds copper and zinc chloride would be at the top of the list ---uses of Lugols iodine not nascent, since nascent is a nano iodine short term gain long term fry on the thyroid. Use of selenium especially for men --women use as well vitamin A retinol palmitate, if you cannot afford that, then use carnation canned milk and stock, it is high in vitamin A.

GSE ---grapefruit seed extract ---C --Sulphur based antioxidants---garlic has 3 forms of cysteine should be at the top of the list. Make the garlic msm formula, stock up ---Black tea and onion for quercitrin---minerals top of list should be sodium, phosphorus, chlorides, borax, manganese, copper, zinc, potassium chloride, magnesium chloride and calcium chloride these will flush cells and reduce the build up.

Saturated fats number one butter, creams (without carregenan or without poly sorbate 60 or 80) best form, straight from a cows teat non treated.

Yogurt - full fat, kefir, cottage cheese, and riccota to rebuild what is damaged.

RESEARCH TONY SHARED TO ME WHEN I BEGAN BUGGING HIM FOR A SIMPLIFIED WAY TO SHARE:



Bio-Nanorobotics — A Field Inspired by Nature

A nanorobot is essentially a controllable machine at the nanometer or molecular scale that is composed of nano-scale components and algorithmically responds to input forces and information. **It explains the mimetics at two levels when nano scale is considered**. **One is the "machine nano mimetics"** principle meaning the creation of nano-machine components inspired by the equivalent machine components at the macro-scale and the other is the "**bio nano mimetics" principle where biological entities such as proteins and DNA are used to create the nano-machine components**.

Comment [i1]: One is the " machine nanomimetics " principle meaning the creation of nanomachine components inspired by the equivalent machine components at the macro-scale and the other is the " bionanomimetics " principle where biological entities such as proteins and DNA are used to create the nanomachine components

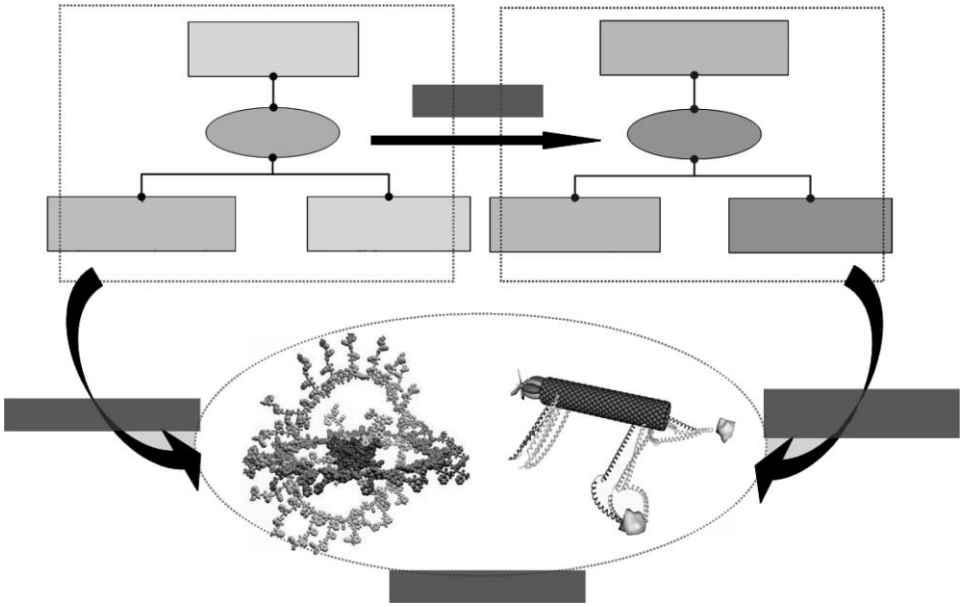
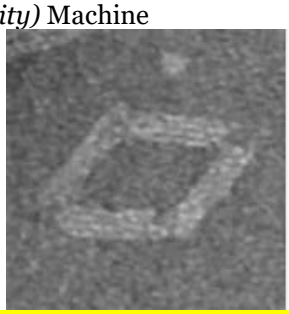
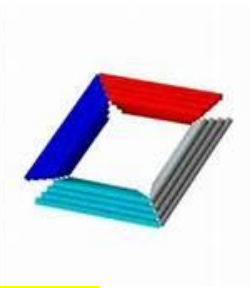


Figure 7.1 (See color insert following page xxx) Biomimetics — bio-nano robotics, inspired by nature and
machine Materials --*(proteins and DNA) De*sign and Mechanisms (revolute joint, actuators)
Characteristics
(self-assembly, selfreplication,self-healing)
Processes
(sensing, actuation, energy production)
Usability range
(applicability in diverse enviroments)

Characteristics
(durability, rigidity) Machine





This is a lattice the pre form for the origami to overlay to build a circuit board for the assembly of the fullerene network to allow quantum dots bots and other carbon nano to move through in it's network

The field of nanorobotics studies the design, manufacturing, programming, and control of the nano- scale robots. This review chapter focuses on the state of the art in the emerging field of nanorobotics and its applications and discusses in brief some of the essential properties and dynamical laws which make this field more challenging and unique than its macro-scale counterpart. This chapter is only reviewing nano-scale robotic devices and does not include studies related to nano-precision tasks with macro-robotic devices that usually are also included in the field of nanorobotics (e.g., AQ1 ATMs and other forms of proximal probe microscopy).

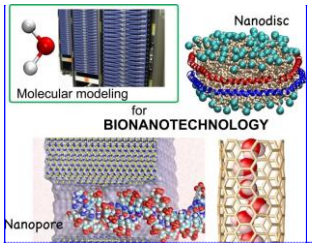
Nanorobots would constitute any active structure (nano-scale) capable of actuation, sensing, signaling, information processing, intelligence, and swarm behavior at nano-scale. These functionalities could be illustrated individually or in combinations by a nanorobot (swarm intelligence and cooperative behavior). So, there could be a whole genre of actuation and sensing or information processing nanorobots having ability to interact and influence matter at the nano-scale. Some of the characteristic abilities that are desirable for a nanorobot to function may include:

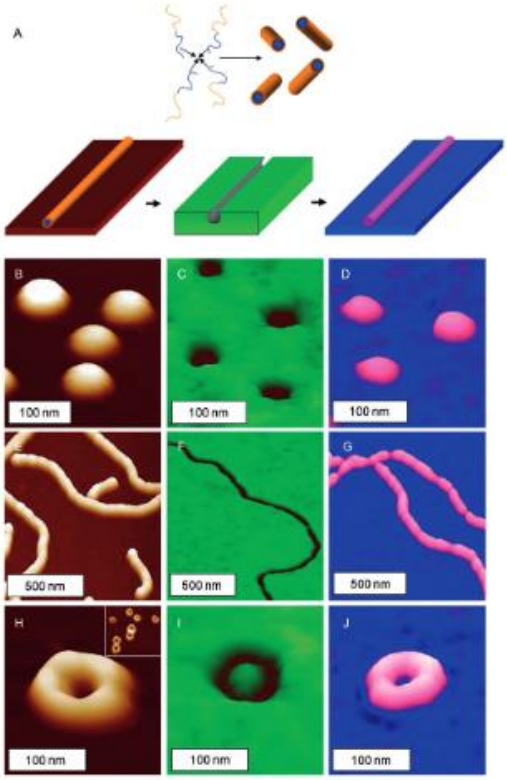
(i)
Swarm intelligence — decentralization and distributive intelligence;
(ii)
Self-assembly and replication — assemblage at nano-scale and "nano-maintenance";
(iii)
Nano-information processing and programmability — for programming and controlling nanorobots (autonomous nanorobots);
(iv)
Nano- to macro-world interface architecture — an architecture enabling instant access to the nanorobots and its control and maintenance;

Comment [i2]: Complex nanodevices can be devised and designed through biomimetics. Bio-nanorobotics, namely biomolecular robots, represents a specific class of nanorobots where proteins and DNA could act as motors, mechanical joints, transmission elements, or sensors. If all of these different components were assembled together they can form bio-nanorobots with multi-degree-of-freedom, able to apply forces and manipulate objects in the nanoscale world

Comment [i3]: There are many differences between macro- and nano-scale robots. However, they occur mainly in the basic laws that govern their dynamics. Macro-scaled robots are essentially in the Newtonian mechanics domain whereas the laws governing nanorobots are in the molecular quantum mechanics domain. Furthermore, uncertainty plays a crucial role in nanorobotic systems. The fundamental barrier for dealing with uncertainty at the nano-scale is imposed by the quantum and the statistical mechanics and thermal excitations

Comment [i4]: The nanorobots are invisible to the naked eye, which makes them hard to manipulate and work with





ure 1. PS-*b*-PI micelle replication. Depending on the block-copolymer composition, self-assembly of *b*-PI in heptane results in micelles with well-defined shapes. A) Schematic image depicting self-embly of micelles and their deposition onto substrates (brown/white), molding (green/black) and lication (blue/magenta); B) spherical micelle master, prepared by self-assembly of a 39 kDa-*b*-kDa PS-*b*-PI copolymer and solution deposition onto mica; vertical scale = 100 nm. C) PFPE mold of a herical micelle master; vertical scale = 20 nm. D) Triacrylate replica of spherical micelles; vertical le = 130 nm. E) Cylindrical micelle master, prepared by self-assembly of a 40 kDa-*b*-10 kDa PS-*b*-PI olymer and solution deposition onto mica; vertical scale = 300 nm. F) PFPE mold of a cylindrical elle master; vertical scale = 200 nm. G) Triacrylate replica of cylindrical micelles; vertical le = 300 nm. H) Toroidal micelle master, prepared by self-assembly and deposition of a 21 kDa-*b*-Da PS-*b*-PI copolymer and solution deposition onto mica; vertical scale = 45 nm. Inset: larger atomic ce microscopy (AFM) image showing a collection of toroidal micelle nano-objects; vertical sca- 150 nm. I) PFPE mold of a toroidal micelle; vertical scale = 25 nm. J) Triacrylate replica of a toroidal

Comment [i5]: Mechanization of Cognition," the state of the art in creating animal cognition in machines

Comment [i6]: DNA has proved to be a versatile material for the rational design and assembly of nanometer scale objects. Here we report the crystal structure of a continuous three-dimensional DNA lattice formed by the self-assembly of a DNA 13-mer. The structure consists of stacked layers of parallel helices with adjacent layers linked through parallel-stranded base pairing. The hexagonal lattice geometry contains solvent channels that appear large enough to allow 3′-linked guest molecules into the crystal. We have successfully used these parallel base pairs to design and produce crystals with greatly enlarged solvent channels. This lattice may have applications as a molecular scaffold for structure determination of guest molecules, as a molecular sieve, or in the assembly of molecular electronics. Predictable non-Watson-Crick base pairs, like those described here, may present a new tool in structural DNA nanotechnology.

Comment [i7]: Molecular self-assembly strategies involve the formation of nanometer scale objects and materials in the absence of significant external control. One increasingly popular self-assembly approach makes use of the unique properties of deoxyribonucleic acid (DNA) including its diminutive size and high capacity for information storage. For many applications, DNA stands alone as the top choice for the programmable construction of supramolecular materials due to its specific and well-understood base-pairing interactions. In this review, we will discuss recent advances in the fabrication of materials via DNA based self-assembly.

Figure 1. PS-b-PI micelle replication. Depending on the block-copolymer composition, self-assembly of PS-b-PI in heptane results in micelles with well-defined shapes. A) Schematic image depicting selfassembly of micelles and their deposition onto substrates (brown/white), molding (green/black) and replication (blue/magenta); B) spherical micelle master, prepared by self-assembly of a 39 kDa-b-94 kDa PS-b-PI copolymer and solution deposition onto mica; vertical scale=100 nm. C) PFPE mold of a spherical micelle master; vertical scale=20 nm. D) Triacrylate replica of spherical micelles; vertical ACHTUNGTRENUNGscale=130 nm. E) Cylindrical micelle master, prepared by self-assembly of a 40 kDa-b-10 kDa PS-b-PI coACHTUNGTRENUNGpolymer and solution deposition onto mica; vertical scale=300 nm. F) PFPE mold of a cylindrical micelle master; vertical scale=200 nm. G) Triacrylate replica of cylindrical micelles; vertical scale=300 nm. H) Toroidal micelle master, prepared by self-assembly and deposition of a 21 kDa-b-4 kDa PS-b-PI coACHTUNGTRENUNG polymer and solution deposition onto mica; vertical scale=45 nm. Inset: larger atomic force microscopy (AFM) image showing a collection of toroidal micelle nano-objects; vertical scale= 150 nm. I) PFPE mold of a toroidal micelle; vertical scale=25 nm. J) Triacrylate replica of a toroidal micelle master; vertical scale=60 nm.

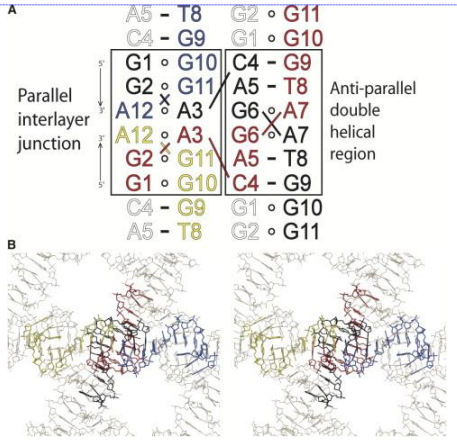
Naturally occurring supramolecular objects, such as proteins,micelles, and viruses, exhibit sophisticated morphological shapes or surface motifs that conventional synthetic and fabrication techniques cannot replicate. These structures owe their interesting shapes and shape-related properties spheres, cylinders, vesicles, and toroids[9, 10] **We have created master templates of these motifs by dispersing micellar solutions of PS-b-PI copolymers in heptane onto mica substrates. A variety of master structures including 50-nm spheres, largely to noncovalent chemical interactions that can produce unique, "evolutionarily designed" shapes with nanometer precision.** These "self-assembly"-driven approaches can be tremendously successful in controlling nanoscale shape in organic and inorganic materials, but the chemical structure of each component must be carefully designed and precisely synthesized to ensure that the desired morphology is obtained.

How it can be Done

photo-curable perfluoropolyether (PFPE) **elastomers to replicate naturally occurring objects** ("master templates").[2–4] The naturally occurring motif is replicated in the PFPE elastomer by pouring the curable PFPE resin over the master template **and photopolymerizing the resin into a flexible "mold" that transfers the details of the master morphology into a crosslinked fluoropolymer** (cf. Figure 1 A). Due to the extremely low surface energy (8–10 dyncm_1 depending on chemical structure) of the PFPE precursor resin**, it will spontaneously spread on materials with a critical surface tension greater than 8–10 dyncm_1, which includes almost all substrates found in nature, including organic materials**.[

Comment [i8]: Bio-Nanorobotics of nature's mechanism, while the DNA-based molecular machines use the basic properties of DNA to design various synthetic mechanisms (which might not be present in the nature). Nature deploys proteins to perform various cellular tasks—from moving cargo to catalyzing reactions, while it has kept DNA as an information carrier. It is hence understandable that most of the natural machinery is built from proteins. With the powerful crystallographic techniques available in the modern world, the protein structures are clearer than ever. The ever increasing computing power makes it possible to dynamically model protein folding processes and predict the conformations and structure of lesser known proteins (Rohl et al., 2004). All this helps unravel the mysteries associated with the molecular machinery and paves the way for the production and application of these miniature machines in various fields including medicine, space exploration, electronics, and military.

Comment [i9]: In this work, we report a nanofabrication method that is able to reproduce shapes normally associated with self-assembly using robust nanoscale replication methods, thereby combining the morphological sophistication of the natural world with the scalable processing technologies associated with lithography



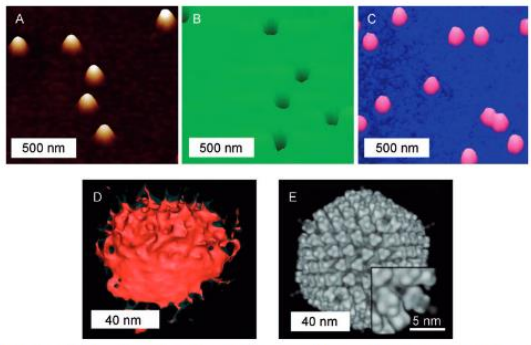


Figure 2. Transmission electron microtomography (TEMT) images depicting molding and replication of adenovirus particles. A) AFM image of an adenovirus master, prepared by depositing adenovirus particles onto a silicon surface; vertical scale = 100 nm. B) AFM image of a PFPE mold formed from an adenovirus master; vertical scale = 50 nm. C) AFM image of a triacrylate/bisphenol A dimethacryate adenovirus replica; vertical scale = 100 nm. D) TEMT reconstruction of a triacrylate/bisphenol A dimethacrylate adenovirus replica. E) Cryo-electron microscopy reconstruction of adenovirus (reprinted with permission from Ref. [23].)

Comment [i10]: DNA has several features that make it an excellent building block for the construction of nanometer-scale structures. First, interstrand cohesion mediated by Watson-Crick base pairing provides predictability to duplex DNA interactions and to helix geometry [9]. Base pairing provides rational programmability for DNA duplex formation in a complex structure. The DNA double helix is stiff over short distances [10], allowing for predictable lengths and orientations during assembly. DNA of designed sequence is easily synthesized through phosphoramidite chemistry [11], both as the conventional structure and as modified derivatives.

Comment [i11]: how mimetics are formed as well

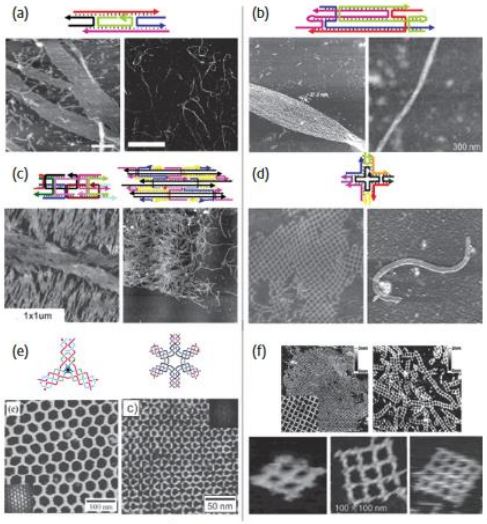


Fig. 1 Schematic diagrams of commonly used building blocks in DNA nanofabrication. (a) DNA double crossover complex and AFM images of resulting 2D arrays and tubes. (Adapted with permission from[12, 23]. © 1993, 2004 ACS.) *(b) DNA triple crossover complex and resulting 2D arrays and tubes.* (Adapted with permission from[13, 22]. © 2000 ACS, 2004 National Academy of Sciences.) *(c) 3-helix-bundle and 6-helix bundle DNA tile complex and AFM images of resulting 2D lattices and nanotubes.* (Adapted with permission from[16, 17]. © 2005, 2007 ACS.) *(d) 4×4 cross-tile and resulting nanogrid and nanoribbon structures.* (Adapted with permission from[26]. © 2003 AAAS.) *(e) Schemes of three-point-star and six-point-star motifs and AFM images of 2D crystalline DNA arrays.* (Adapted with permission from[29, 30]. © 2005, 2006 ACS.) *(f) DNA nanoarrays with increased complexity and defined sizes based on the cross-tile system: nanogrid and nanotrack assembled from 2-tile system (top), molecular pegboard, 4x4 and symmetric 5x5 arrays (bottom from left to right).* (Adapted with permission from[28, 32-34]. © 2005 ACS, 2006 Wiley-VCH.)

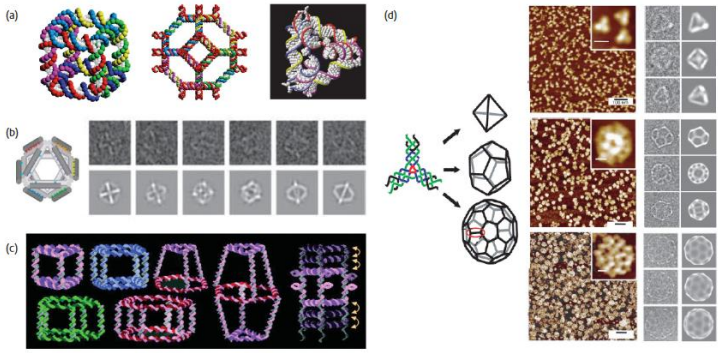


Fig. 2 Three-dimensional structures assembled via DNA self-assembly. (a) DNA molecules with the connectivity of a cube, an octahedron and a tetrahedron. (Adapted with permission from[37, 38, 40]. © 1991 Nature Publishing Group, 1994 American Chemical Society, 2004 Royal Society of Chemistry.) *(b) Design of DNA octahedron from 1,669-nucleotide DNA and cryo-electron micrograph images of individual octahedron particles corresponding projections of their 3D map.* (Adapted with permission from[39]. © 2004 Nature Publishing Group.) *(c) 3D triangular prism, cube, pentameric and hexameric prisms, heteroprism and biprism generated from single-stranded and cyclic DNA triangles, squares, pentagons and hexagons with organic vertices.* (Adapted with permission from[42]. © 2007 American Chemical Society.) *(d) DNA tetrahedra, dodecahedra and buckyballs assembled from three-point-star motifs.* (Adapted with permission from[44]. ©2008 Nature Publishing Group.)

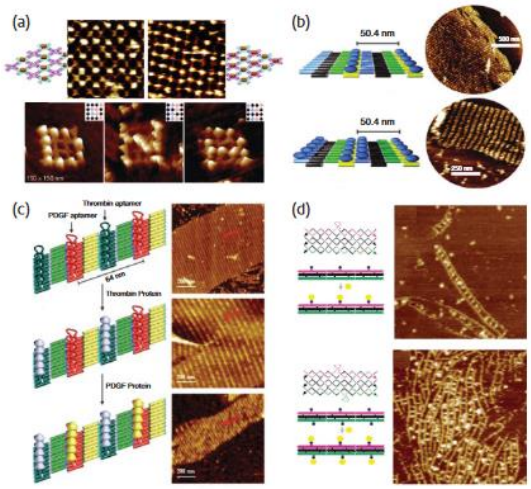


*Fig. 4 DNA nanolattice directed self-assembly of protein molecules. (a) Programmable assembly of streptavidin arrays on nanogrids and addressable 4x4 cross-tile nanogrids. (*Adapted with permission from[27, 34]. © 2006 Wiley-VCH, 2005 American Chemical Society.*) (b) Polyamide-biotin conjugates directed site-specific display of streptavidin along DX lattice scaffolds. (*Adapted with permission from[62]. © 2008 American Chemical Society.*) (c) Periodic 2D multiprotein nanoarrays directed by aptamer tags on DX nanolattices. (*Adapted with permission from[68]. © 2007 American Chemical Society.*) (d) TX tile lattice templated display of single chain antibodies. (*Adapted with permission from[71]. © 2006 Royal Society of Chemistry.*)

Comment [i12]: Lattice construction with proteins to be utilized by the origami to be accessed as a tech board for assembly and networking nanoinfrastructure

7

Bio-Nanorobotics — A Field Inspired by Nature

A. Ummat, A. Dubey, and C. Mavroidis

CONTENTS

7.1 INTRODUCTION

The underlying principle of biomimetics deals with the understanding, conceptualization, and mimicking nature's way of handling various problems and situations. Nature has inspired mankind for ages and has been a key source from which we can learn and adapt. Natural processes are extremely efficient in terms of energy and material usage and provide us with many inspiring and thought provoking designs and principles. This chapter discusses biomimetics at the nano-scale, where we talk about nanorobotics and its design principles, which are inspired by nature's way of doing things at that scale.

Figure 7.1 describes the biomimetics principle and details the various aspects of mimetics. It explains the mimetics at two levels when nano-scale is considered. One is the "*machine nanomimetics*" principle meaning the creation of nanomachine components inspired by the equivalent machine components at the macro-scale and the other is the "*bionanomimetics*" principle where biological entities such as proteins and DNA are used to create the nanomachine components. The field of nanorobotics hence encapsulates these two mimetic principles and inherits their various characteristics, design logic, and advantages.

Nanotechnology can best be defined as a description of activities at the level of atoms and molecules that have applications in the real world. A nanometer is a billionth of a meter, that is, about 1/80,000 of the diameter of a human hair, or ten times the diameter of a hydrogen atom. The size-related challenge is the ability to measure, manipulate, and assemble matter with features on the scale of 1 to 100 nm. In order to achieve cost-effectiveness in nanotechnology, it will be necessary to automate molecular manufacturing. The engineering of molecular products needs to be carried out by robotic devices, which have been termed *nanorobots* (Freitas, 1999, 2003). A nanorobot is essentially a controllable machine at the nanometer or molecular scale that is composed of nano-scale components and algorithmically responds to input forces and information.

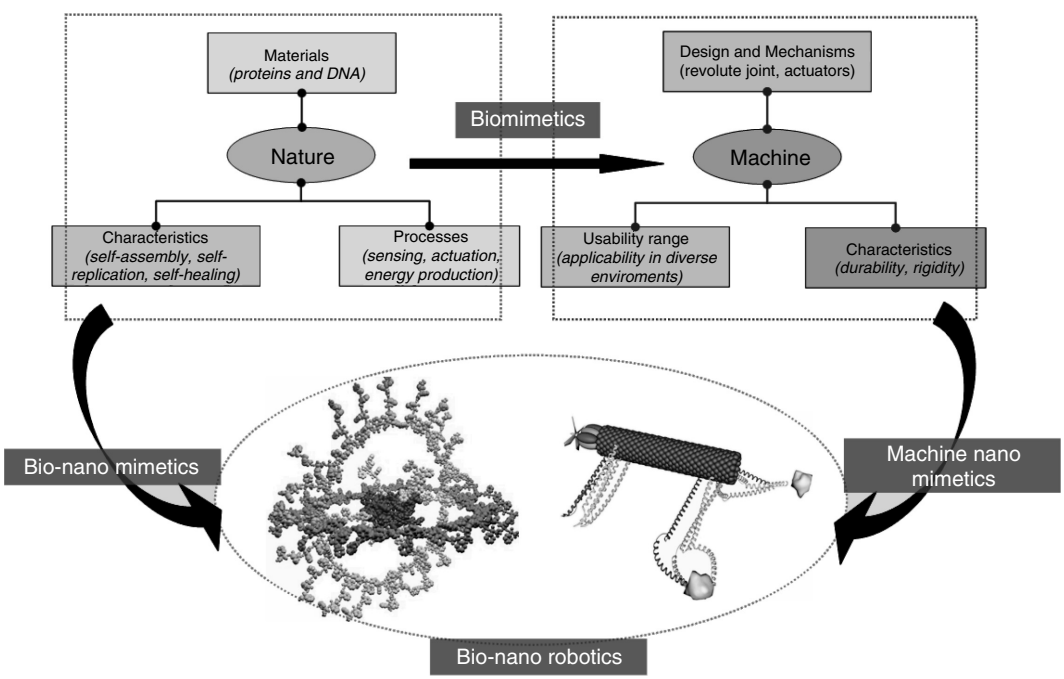


Figure 7.1 (See color insert following page xxx) Biomimetics — bio-nano robotics, inspired by nature and machine.

The field of nanorobotics studies the design, manufacturing, programming, and control of the nano-scale robots.

This review chapter focuses on the state of the art in the emerging field of nanorobotics and its applications and discusses in brief some of the essential properties and dynamical laws which make this field more challenging and unique than its macro-scale counterpart. This chapter is only reviewing nano-scale robotic devices and does not include studies related to nano-precision tasks with macro-robotic devices that usually are also included in the field of nanorobotics (e.g., ATMs AQ1 and other forms of proximal probe microscopy).

Nanorobots would constitute any active structure (nano-scale) capable of actuation, sensing, signaling, information processing, intelligence, and swarm behavior at nano-scale. These functionalities could be illustrated individually or in combinations by a nanorobot (swarm intelligence and cooperative behavior). So, there could be a whole genre of actuation and sensing or information processing nanorobots having ability to interact and influence matter at the nano-scale. Some of the characteristic abilities that are desirable for a nanorobot to function may include:

(i) *Swarm intelligence* — decentralization and distributive intelligence;
(ii) Self-assembly and replication — assemblage at nano-scale and "nano-maintenance";
(iii) *Nano-information processing and programmability* — for programming and controlling nanorobots (autonomous nanorobots);
(iv) Nano- to macro-world *interface architecture* — an architecture enabling instant access to the nanorobots and its control and maintenance;

There are many differences between macro- and nano-scale robots. However, they occur mainly in the basic laws that govern their dynamics. Macro-scaled robots are essentially in the Newtonian mechanics domain whereas the laws governing nanorobots are in the molecular quantum mechanics domain. Furthermore, uncertainty plays a crucial role in nanorobotic systems. The fundamental barrier for dealing with uncertainty at the nano-scale is imposed by the quantum and the statistical mechanics and thermal excitations. For a certain nanosystem at some particular temperature, there are positional uncertainties that cannot be modified or further reduced (Drexler, 1992).

The nanorobots are invisible to the naked eye, which makes them hard to manipulate and work with. Techniques like scanning electron microscopy (SEM) and atomic force microscopy (AFM) are being employed to establish a visual and haptic interface to enable us to sense the molecular structure of these nano-scaled devices. Virtual reality (VR) techniques are currently being explored in nano-science and biotechnology research as a way to enhance the operator's perception (vision and haptics) by approaching more or less a state of "full immersion" or "telepresence." The development of nanorobots or nanomachine components presents difficult fabrication and control challenges. Such devices will operate in microenvironments whose physical properties differ from those encountered by conventional parts. Since these nano-scale devices have not yet been fabricated, evaluating possible designs and control algorithms requires using theoretical estimates and virtual interfaces or environments. Such interfaces or simulations can operate at various levels of detail to trade-off physical accuracy, computational cost, number of components, and the time over which the simulation follows the nano-object behaviors. They can enable nano-scientists to extend their eyes and hands into the nano-world, and they also enable new types of exploration and whole new classes of experiments in the biological and physical sciences. VR simulations can also be used to develop virtual assemblies of nano and bio-nano components into mobile linkages and to predict their performance.

Nanorobots with completely artificial components have not been realized yet. The active area of research in this field is focused more on molecular machines, which are thoroughly inspired by nature's way of doing things at nano-scale. Mother Nature has her own set of molecular machines that have been working for millions of years, and have been optimized for performance and design over the ages. As our knowledge and understanding of these numerous machines continues to

increase, we now see a possibility of using the natural machines or creating synthetic ones from scratch using nature's components. This chapter focuses more on molecular machines and explores various designs and research prevalent in this field. The main goal in the field of molecular machines is to use various biological elements — whose function at the cellular level creates motion, force, or a signal — as machine components. These components perform their preprogrammed biological function in response to the specific physiochemical stimuli but in an artificial setting. In this way proteins and DNA could act as motors, mechanical joints, transmission elements, or sensors. If all these different components were assembled together in the proper proportion and orientation, they would form nanodevices with multiple degrees of freedom, able to apply forces and manipulate objects in the nano-scale world. The advantage of using nature's machine components is that they are highly efficient and reliable.

Nanorobotics is a field which calls for collaborative efforts between physicists, chemists, biologists, computer scientists, engineers, and other specialists to work towards this common objective. Figure 7.2 details the various fields which come under the field of bio-nano robotics (this is just a representative figure and not exhaustive in nature). Currently this field is still developing, but several substantial steps have been taken by great researchers all over the world who are contributing to this ever challenging and exciting field.

The ability to manipulate matter at the nano-scale is one core application for which nanorobots could be the technological solution. A lot has been written in the literature about the significance and motivation behind constructing a nanorobot. The applications range from medical to environmental sensing to space and military applications. Molecular construction of complex devices could be possible by nanorobots of the future. From precise drug delivery to repairing cells and fighting tumor cells, nanorobots are expected to revolutionize the medical industry in the future. These applications come under the field of nanomedicine (Freitas, 1999, 2003), which is a very active area of research in nanotechnology. These molecular machines hence form the basic enablers of future applications.

In the next section, we shall try to understand the principles, theory, and utility of the known molecular machines and look into the design and control issues for their creation and modification. A majority of natural molecular machines are protein-based which involve using the exact replica

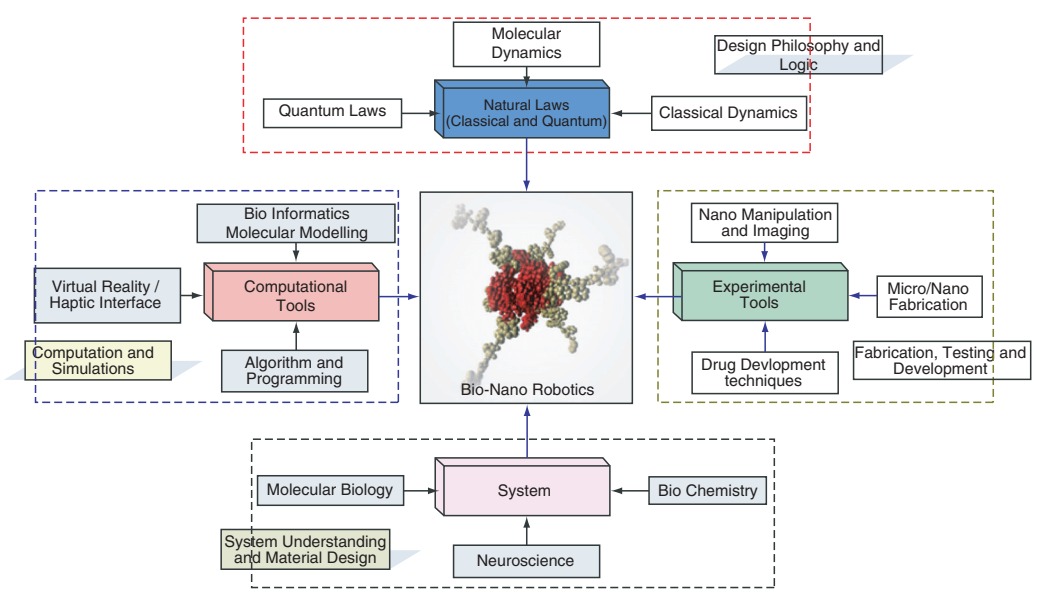


Figure 7.2 Bio-nano robotics — a truly multidisciplinary field.

of nature's mechanism, while the DNA-based molecular machines use the basic properties of DNA to design various synthetic mechanisms (which might not be present in the nature). Nature deploys proteins to perform various cellular tasks — from moving cargo to catalyzing reactions, while it has kept DNA as an information carrier. It is hence understandable that most of the natural machinery is built from proteins. With the powerful crystallographic techniques available in the modern world, the protein structures are clearer than ever. The ever increasing computing power makes it possible to dynamically model protein folding processes and predict the conformations and structure of lesser known proteins (Rohl et al., 2004). All this helps unravel the mysteries associated with the molecular machinery and paves the way for the production and application of these miniature machines in various fields including medicine, space exploration, electronics, and military.

7.2 BIOMOLECULAR MACHINES: BACKGROUND AND SIGNIFICANCE

7.2.1 Significance

The recent explosion of research in nanotechnology, combined with important discoveries in molecular biology have created a new interest in biomolecular machines and robots. The main goal in the field of biomolecular machines is to use various biological elements — whose function at the cellular level creates motion, force, or a signal, or stores information — as machine components. These components perform their preprogrammed biological function in response to the specific physiochemical stimuli but in an artificial setting. In this way proteins and DNA could act as motors, mechanical joints, transmission elements, or sensors. If all these different components were assembled together in the proper proportion and orientation, they would form nanodevices with multiple degrees of freedom, able to apply forces, and manipulate objects in the nanoscale world. The advantage of using nature's machine components is that they are highly efficient (Kinosita et al., 2000) and reliable. Just as conventional macro-machines are used to generate forces AQ2
and motions to accomplish specific tasks, bionanomachines can be used to manipulate nano-objects to assemble and fabricate other machines or products and to perform maintenance, repair, and inspection operations.

Such bio-nano robotic devices will hopefully be part of the arsenal of future medical devices and instruments that will: (1) perform operations, inspections, and treatments of diseases inside the body, and (2) achieve ultra-high accuracy and localization in drug delivery, thus minimizing side effects. Figure 7.3 shows an idealized rendition of a biomolecular nanorobot repairing an infected cell in a blood vessel. The bio-nanorobot will be able to attach to the infected cell alone and deliver a therapeutic drug that can treat or destroy only the infected cell, sparing the surrounding healthy cells.

Development of robotic components composed of simple biological molecules is the first step in the development of future biomedical nanodevices. Since the planned complex systems and devices will be driven by these components, we must first develop a detailed understanding of their operation. From the simple elements such as structural links to more advanced concepts as motors, each part must be carefully studied and manipulated to understand its functions and limits.

Figure 7.4 lists the most important components of a typical robotic system or machine assembly and the equivalence between macro and potential bio-nano components. Beyond the initial component characterization is the assembly of the components into robotic systems. Figure 7.5 shows one such concept of a nano-organism, with its "feet" made of helical peptides and its body using carbon nanotubes while the power unit is a biomolecular motor. For this phase to be successful, a library of biological elements of every category must be available. At that point, conventional robotics can be used as a guide for fabrication of bio-nanorobots that function in the same manner. There will be systems that have mobile characteristics to transport themselves, as well as other objects, to desired locations.

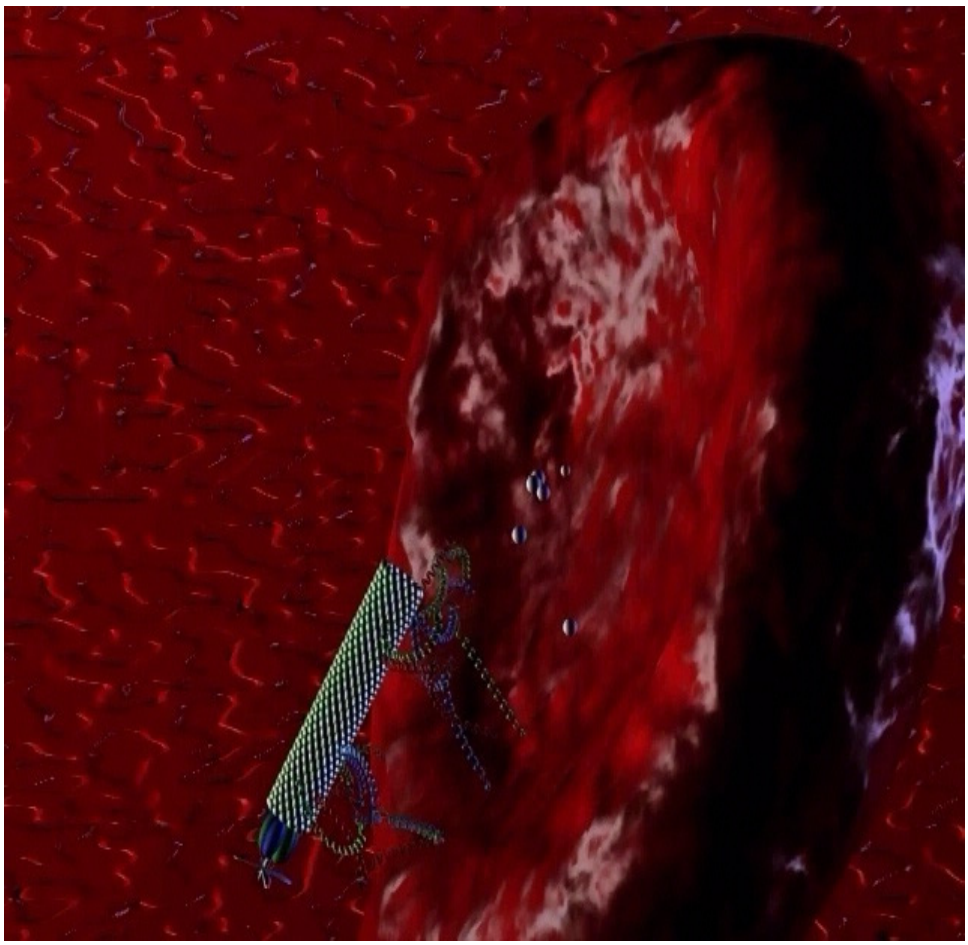


Figure 7.3 A 'nanorobot' flowing inside a blood vessel finds an infected cell. The nanorobot attaches to the cell and projects a drug to repair or destroy the infected cell.

Some bio-nanorobots can be conceived as able to manufacture additional elements and various structures. There may also be robots that not only perform physical labor, but also sense the environment and react accordingly. There is no doubt that biomedical applications will be both a driving force and a beneficiary of these developments.

7.2.2 Brief Review of Biomolecular Machines

While the majority of the prior research in this field has largely focused on biomolecular motors, several other nano components such as sensors and even assemblies of components in the form of mechanisms have been studied. In the macroscopic world, what we understand by a 'motor' is a machine capable of imparting motion associated by the conversion of energy. Biomolecular motors have attracted a lot of attention recently because: (1) they operate at high efficiency, (2) some could be self-replicating and hence cheaper in mass usage, and (3) they are readily available in nature (Boyer, 1998). A number of enzymes function as nano-scale biological motors, such as kinesin (Block, 1998; Schnitzer and Block, 1997), RNA polymerase (Wang et al., 1998), myosin (Kitamura et al., 1999), and adenosine triphosphate (ATP) synthase, function as nano-scale biological motors (Montemagno and Bachand, 1999; Bachand and Montemagno, 2000; Soong et al., 2000; Noji et al., 1997; Yasuda et al., 1998; Walker, 1998).

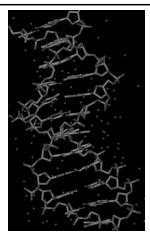
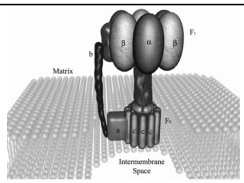
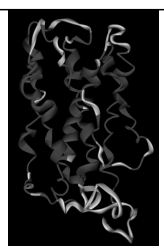
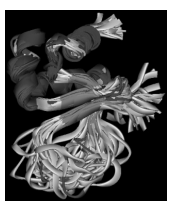
Component	MacroRobots	Bio-Nano Robots
Structural Elements- Links	Metal, Plastic Polymer	 DNA [PDBfile:119D] Nanotubes
Joints	Metal, Plastic Polymer material *Revolute joints* *Prismatic joints* *Spherical joints* *Cylindrical joints*	*DNA* hinge *Molecular* bonds, Synthetic joints
Actuators	Electric motors, Pneumatic motors, Hydraulic motors, Smart material-based actuators	 ATPase protein flagella motors, DNA actuators, Viral protein motors etc.
Transmission Elements	Springs (Metal,Polyvinyl) Bearings Gears	β Sheets Molecular camshaft design Smith ss (2001). United States Patent No. 6,200,782 13 March 2001.
Sensors	Light sensors, force sensors, position sensors, temperature sensors	 Rhodopsin [PDB file-1JFP]  Heat Shock Factor [PDB file–3HSF]

Figure 7.4 Macro- and bio-nano-equivalence of robot components.

7.2.2.1 The ATPase Motor

One of the most abundant rotary motors found in life forms is F0F1 ATP synthase, commonly known as the "ATPase motor." Oxidative phosphorylation was demonstrated over 50 years ago as an important process by which our bodies capture energy from the food we eat. The mechanism of this process was not known until 1997, when Boyer and Walker described the key role that ATP plays in the process (Boyer, 1998; Walker, 1998). Noji et al. published the structural and performance data of the ATPase motor in 1997 (Noji et al., 1997; Yasuda et al., 1998). According to this study, the γ?-subunit, which is about 1 nm in diameter, rotates inside the F1 subunit, which is about 5 nm in diameter, to produce approximately 40 pN-nm of rotary torque. Montemagno and his group were the first to indicate that the rotation of the γ?-subunit of the ATPase motor could be mechanically useful based on fabricated nanomechanical inorganic devices, which could be compatible with the force

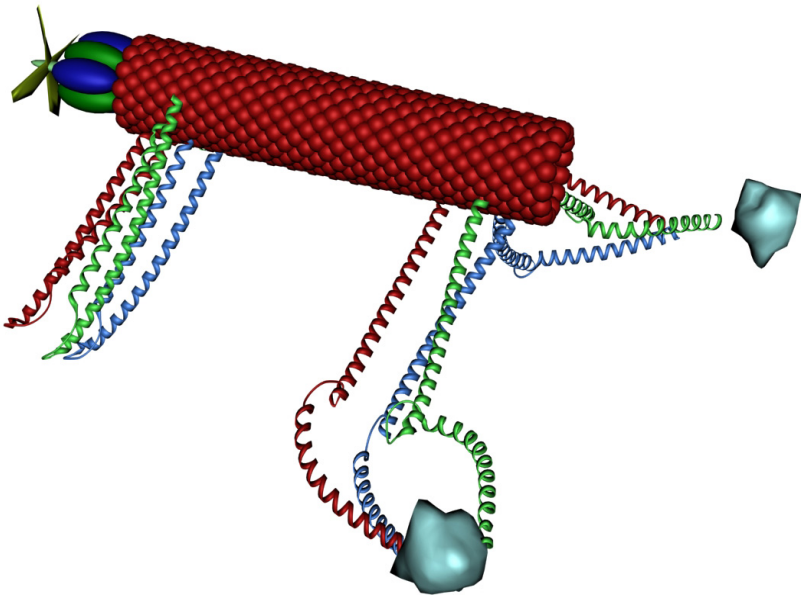


Figure 7.5 The biological elements will be used to fabricate robotic systems. A vision of a nano-organism: carbon nanotubes (CNT) form the main body; peptide limbs can be used for locomotion and object manipulation, a biomolecular motor located at the head can propel the device in various environments.

production and dimensions of the molecular motors (Montemagno and Bachand, 1999; Bachand and Montemagno, 2000; Soong et al., 2000). Frasch's group is currently studying the binding of metals to amino acids of the motor protein. These experiments are providing new insights into the means by which the energy obtained from the hydrolysis of ATP can be converted into the physical action of pumping a proton in a unilateral direction (Frasch, 2000).

7.2.2.2 Kinesin and Myosin

Motor proteins are tiny vehicles that transport molecular cargoes within cells. These minute cellular machines exist in three families: the kinesins, the myosins, and the dyneins (Farrell et al., 2002). Conventional kinesin was found to be a highly processive motor that could take several hundred steps on a microtubule without detaching (Block et al., 1990; Howard et al., 1989), whereas muscle myosin has been shown to execute a single "stroke" and then dissociate (Finer et al., 1994). A detailed analysis and modeling of these motors has been done (Vale and Milligan, 2000). Hackney's group has concentrated upon the usage of ATP energy by motors like kinesin, myosin, dynenin, and related motor families (Hackney, 1996). Unger's group is currently working towards developing a microtubule–kinesin system as a biological linear-motoric actuator. Their work is aimed at producing force multiplication by parallel action of numerous single driving units as well as a more efficient means for system control (Bohm et al., 1997). Other researchers have discovered a new member of the myosin-V family (Myo5c) and have implicated this myosin in the transport of a specific membrane compartment (Mehta et al., 1999). The role of ATP hydrolysis in kinesin motility has also been recently described (Farrell et al., 2002).

7.2.2.3 The Flagella Motors

Escherichia coli and similar organisms are equipped with a set of rotary motors only 45 nm in diameter. Each motor drives a long, thin, helical filament that extends several cell body lengths out

into the external medium. In addition to rotary engines and propellers, *E. coli*'s standard accessories include particle counters, rate meters, and gearboxes and thus has been described as a nanotechnologist's dream (Berg, 2000). Berg developed one of the earliest models for the rotary motor (Berg, 1974). Improved models came in 1992 (Ueno et al., 1992, 1994). Flagella motor analysis coupled to real-time computer assisted analysis of motion has also been performed (Khan et al., 1998). Researchers in Japan have applied crystallographic studies in order to understand the molecular structure of flagella motors as well as that of kinesin (Namba and Vonderveczt, 1997). Finally, Hess' group is attempting to build a nano-scale train system, complete with tracks, loading docks and a control system. Since motor proteins are a thousand times smaller than any man-made motor, they aim to utilize them in a synthetic environment as engines powering the nanotrains (Hess and Vogel, 2001).

7.2.2.4 Other Motors and Mechanisms

In addition to work on naturally existing motors, considerable effort is also being applied to develop synthetic molecular motors. The structure of the ATP synthase, a rod rotating inside a static wheel, suggests the use of rotaxanes as potential artificial models for natural motors (Harada, 2001). Rotaxanes are organic compounds consisting of a dumbbell-shaped component that incorporates one or more recognition sites in its rod section and is terminated by bulky "stoppers", encircled by one or more ring components. The possibility of manufacturing specific forms of rotaxane and creating molecular motors capable of guided rotary motion and the possibility of fueling such a motor by light, electrons, and chemical energy has been proposed (Schalley et al., 2001).

Schemes for using pseudorotaxanes, rotaxanes, and catenanes as molecular switches to perform chemical, electrochemical, and photochemical switching and controllable molecular shuttles have also been proposed recently (Balzani et al., 1998). Molecular shuttles have been reported using α-cyclodextrin — a parent of rotaxanes and catenanes (Harada, 2001). A light-driven monodirectional rotor made of helical alkene, with rotation around a central carbon–carbon covalent bond due to chirality has been reported (Koumura et al., 1999). Another simple way to convert chemical energy into mechanical motion in a controlled fashion is by using a metal ion which can be translocated reversibly between two organic compartments with the change of its ionization state, controllable by redox reaction or pH change (Amendola et al., 2001). Motility of unicellular organisms like vortecellids reminds us of energy storage and release by mechanical springs on a macromolecular scale. Spring-like action has been observed in sperm cells of certain marine invertebrates during fertilization. Springs and supramolecular ratchets by actin polymerization have yet to be built *in vitro,* but they theoretically can be generalized, as recently demonstrated (Mahadevan and Matsudaira, 2000).

7.2.2.5 DNA-Based Molecular Nanomachines, Joints, and Actuators

Several researchers are exploring the use of DNA in nano-scale mechanisms. DNA is small, relatively simple, and homogeneous and its structure and function is well understood. The predictable self-assembling nature of the double helix makes it an attractive candidate for engineered nanostructures. This property has been exploited to build several complex geometric structures, including knots, cubes, and various polyhedra (Seeman, 1998). Mathematical analyses of the elastic structure of DNA using energy minimization methods have been performed to examine its molecular stability, wherein short DNA strands were treated as an elastic rod (Tobias et al., 2000). Initial experiments on DNA visualization and manipulation using mechanical, electrical, and chemical means have been underway for a decade (Yuqiu et al., 1992; Hu et al., 2002). A dynamic device providing atomic displacements of 2–6 nm was proposed in Mao et al. (1999), wherein the chemically induced transition between the B and Z DNA morphologies acts as a

moving nano-scale device. A method for localized element-specific motion control was seen in the reversible transition between four stranded topoisomeric DNA motifs (PX and JX2) thereby producing rotary motion (Yan et al., 2002). A very important, though simple DNA machine that resembles a pair of tweezers has been successfully created, whose actuation (opening and closing) is also fueled by adding additional DNA fuel strands (Yurke et al., 2000).

7.2.3 Nanosensors

The technology of nanosensing is also under development. For example, silicon probes with single walled carbon nanotube (CNT) tips are being developed (MIT media laboratory Nanoscale Sensing, http://www.media.mit.edu/nanoscale/). For sensing certain analytes, genetically engineered versions of pore-forming proteins like *Staphylococcus aureus* alpha-hemolysin are also being studied (Kasianowicz and Bayley, 2003). Efforts to detect biological warfare agents like cholera toxins by utilizing their ability to bind to a bilayer membrane in the presence of gangliosides is another example (Plant and Silin, 2003). Light sensors could be made using certain photoreceptive polypeptides containing azobenzene or spyropyran units as they respond to light or dark environmental conditions by undergoing conformational change, for example, transition from random coil to a α-helix (Pieroni et al., 2001). An optical DNA biosensor platform has been reported using etched optical fiber bundles filled with oligonucleotide-functionalized microsphere probes (Ferguson et al., 1996). Finally, work is in progress to develop sensors for brain implantation, which would foretell the development of a stroke and be useful for perioperative online monitoring during coronary by-pass surgery (Manning and McNeil, 2001).

In addition to many of the examples mentioned above which generally correspond to one degree of freedom (DOF) rotary actuators, there are many other machine elements, the functional capabilities of which have not yet been represented by biomolecular elements. In addition, the assembly of different molecules in a multi-degree of freedom machine or the formation of hybrid systems composed of biomolecules and synthetic nonorganic elements has not yet been explored. In this context, our long term goal is to identify novel biomolecules that can be used as different types of machine components and to assemble them into controlled multi-degree of freedom systems using organic and synthetic nonorganic parts.

7.3 DESIGN AND CONTROL PHILOSOPHIES FOR NANOROBOTIC SYSTEMS

The design of nanorobotic systems requires the use of information from a vast variety of sciences ranging from quantum molecular dynamics to kinematic analysis. In this chapter we assume that the components of a nanorobot are made of biological components, such as proteins and DNA strings. So far, no particular guideline or a prescribed manner that details the methodology of designing a bio-nanorobot exists. There are many complexities that are associated with using biocomponents (such as protein folding and presence of aqueous medium), but the advantages of using these are also quite considerable. These biocomponents offer immense variety and functionality at a scale where creating a man-made material with such capabilities would be extremely difficult. These biocomponents have been perfected by nature through millions of years of evolution and hence these are very accurate and efficient. As noted in the review section on Molecular Machines, F_1-ATPase is known to work at efficiencies which are close to 100%. Such efficiencies, variety, and form are not existent in any other form of material found today. Another significant advantage in protein-based bio-nano components is the development and refinement over the last 30 years of tools and techniques enabling researchers to mutate proteins in almost anyway imaginable. These mutations can consist of anything from simple amino acid side-chain swapping, amino acid insertions or deletions, incorporation of nonnatural amino acids, and even

the combination of unrelated peptide domains into whole new structures. An excellent example of this approach is the use of zinc to control F_1-ATPase, which is able to rotate a nanopropeller in the presence of ATP. A computational algorithm (Hellinga and Richards, 1991) was used to determine the mutations necessary to engineer an allosteric zinc-binding site into the F_1-ATPase using site-directed mutagenesis. The mutant F_1-ATPase would rotate an actin filament in the presence of ATP with average torque of 34 pN nm. This rotation could be stopped with the addition of zinc, and restored with the addition of a chelator to remove the zinc from the allosteric binding site (Liu et al., 2002). This type of approach can be used for the improvement of other protein-based nano components.

These biocomponents seem to be a very logical choice for designing nanorobots. In addition, since some of the core applications of nanorobots are in the medical field, using biocomponents for these applications seems to be a good choice as they both offer efficiency and variety of functionality. This idea is clearly inspired by nature's construction of complex organisms such as bacteria and viruses which are capable of movement, sensing, and organized control. Hence our scope would be limited to the usage of these biocomponents in the construction of bio-nano robotics. A roadmap is proposed which details the main steps towards the design and development of bio-nanorobots.

7.3.1 The Roadmap

The roadmap for the development of bio-nano robotic systems for future applications (medical, space, and military) is shown in Figure 7.6. The roadmap progresses through the following main steps:

Step 1: Bio-Nano Components

Development of bio-nano components from biological systems is the first step towards the design and development of an advanced bio-nanorobot, which could be used for future applications (see

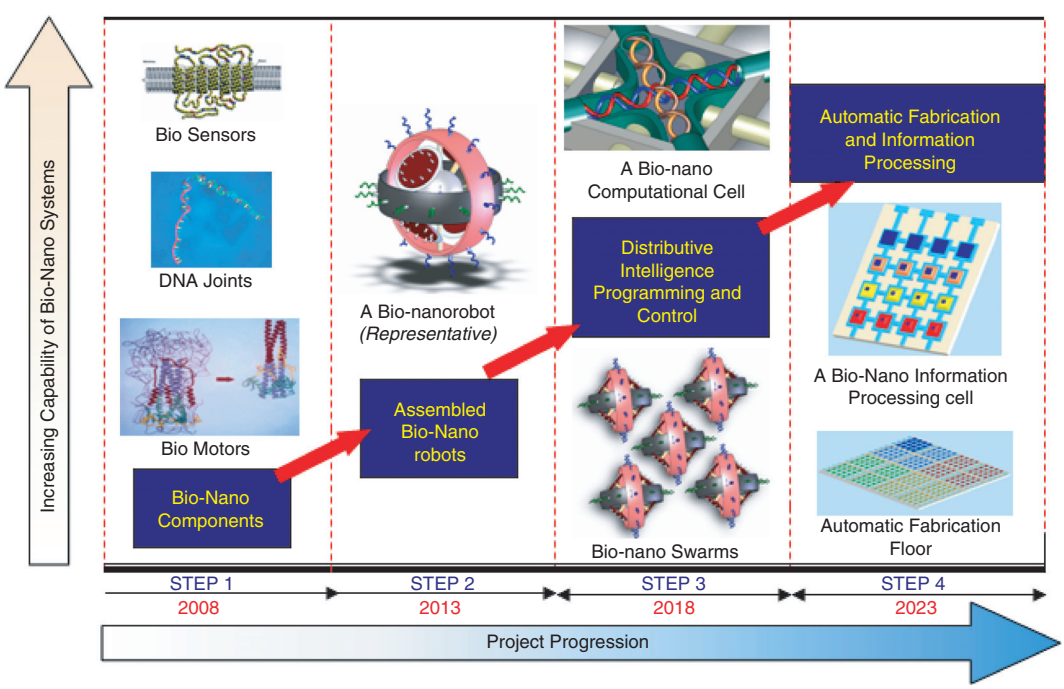


Figure 7.6 (See color insert) The roadmap illustrating the system capability targeted as the project progresses.

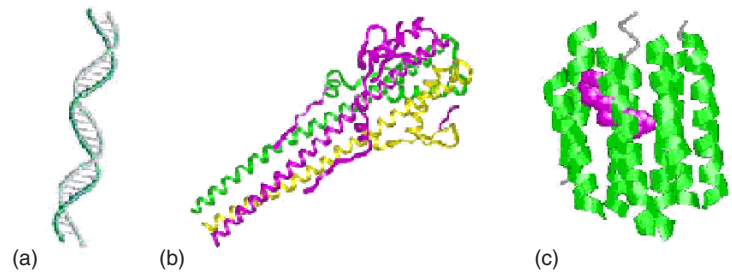


Figure 7.7 (Step 1) Understanding of basic biological components and controlling their functions as robotic components. Examples are: (a) DNA which may be used in a variety of ways such as a structural element and a power source; (b) Hemagglutinin virus may be used as a motor; (c) Bacteriorhodopsin could be used as a sensor or a power source.

Figure 7.7). Since the planned systems and devices will be composed of these components, we must have a sound understanding of how these behave and how they could be controlled. From the simple elements such as structural links to more advanced concepts such as motors, each component must be carefully studied and possibly manipulated to understand the functional limits of each one of them. DNA and carbon nanotubes are being fabricated into various shapes, enabling possibilities of constructing newer and complex devices. These nanostructures are potential candidates for integrating and housing the bio-nano components within them. Proteins such as *rhodopsin* and *bacteriorhodopsin* are a few examples of such bio-nano components. Both of these proteins are naturally found in biological systems as light sensors. They can essentially be used as solar collectors to gather abundant energy from the sun. This energy could either be harvested (in terms of proton motive force) for later use or could be consumed immediately by other components, such as the ATP synthase nano rotary motor. The initial work is intended to be on the biosensors, such as heat shock factor. These sensors will form an integral part of the proposed bionano assemblies, where these will be integrated within a nanostructure and will get activated as programmed, for gathering the required information at the nano-scale. Tools and techniques from *molecular modeling* and *protein engineering* will be used to design these modular components.

Step 2: Assembled Bio-Nanorobots

The next step involves the assembly of functionally stable bio-nano components into complex assemblies. Some examples of such complex assemblies are shown in Figure 7.8. Figure 7.8A shows a bio-nanorobot with its "*feet*" made of helical peptides and its body of CNT, while the power unit is a biomolecular motor. Figure 7.8B shows a conceptual representation of *modular organization* of a bio-nanorobot. The modular organization defines the hierarchy rules and spatial arrangements of various modules of the bio-nanorobots, such as the inner core (the brain or energy source for the robot), the actuation unit, the sensory unit, and the signaling and information processing unit. By the beginning of this phase, a "*library of bio-nano components*" will be developed, which will include various categories, such as actuation, energy source, sensory, signaling, etc. Thereafter, one will be able to design and develop such bionanosystems that will have enhanced mobile characteristics and will be able to transport themselves as well as other objects to desired locations at nano-scale. Furthermore, some bio-nanorobots need to assemble various biocomponents and nanostructures, including *in situ* fabrication sites and storage areas; others will manipulate existing structures and maintain them. There will also be robots that not only perform physical labor, but also sense the environment and react accordingly. There will be systems that will sense an oxygen deprivation and stimulate other components to generate oxygen creating an environment with stable homoeostasis.

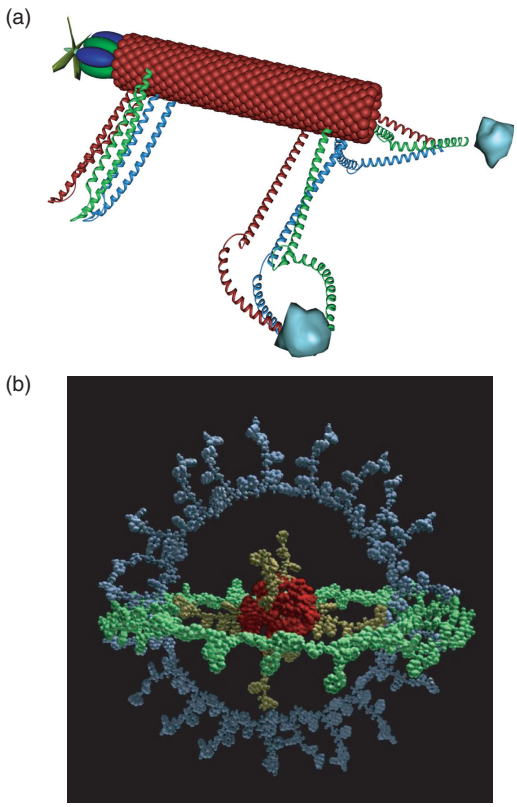


Figure 7.8 (Step 2) (a) The bio-nano components will be used to fabricate complex bio-robotic systems. A vision of a nanorobot: carbon nanotubes (CNT) form the main body; peptide limbs can be used for locomotion and object manipulation and the biomolecular motor located at the head can propel the device in various environments. (b) Modular organization concept for the bio-nanorobots. Spatial arrangements of the various modules of the robots are shown. A single bio-nanorobot will have actuation, sensory, and information processing capabilities.

Step 3: Distributive Intelligence, Programming and Control

With the individual bio-nanorobots capable of basic functions, we would now need to develop concepts that would enable them to collaborate with one another to develop "colonies" of similar nanorobots. This design step could lay the foundation towards the concept of *bionanoswarms* (distributive bio-nanorobots) (see Figure 7.9A). Here work has to be done towards the control and programming of such swarms. This will evolve concepts like distributive intelligence in the context of bio-nanorobots. Designing swarms of bio-nanorobots capable of carrying out complex tasks and capable of computing and collaborating amongst them will be the focus of this step. Therefore, the basic computational architectures needs to be developed and rules need to be evolved for the bio-nanorobots to make intended decisions at the nano-scale.

To establish an interface with the macro-world, the computers and electronic hardware have to be designed as well. Figure 7.10 shows the overall electronic communication architecture. Humans should be able to control and monitor the behavior and action of these swarms. This means that basic computational capabilities of the swarms will need to be developed. A representative computational bionanocell, which will be deployed within a bio-nanorobot, is shown in Figure 7.9B. This basic computational cell will initially be designed for data retrieval and storage at the nano-scale. This capability will enable us to program (within certain degrees of freedom) the swarm behavior in the bio-nanorobots. We will further be able to get their sensory data (from nano-world)

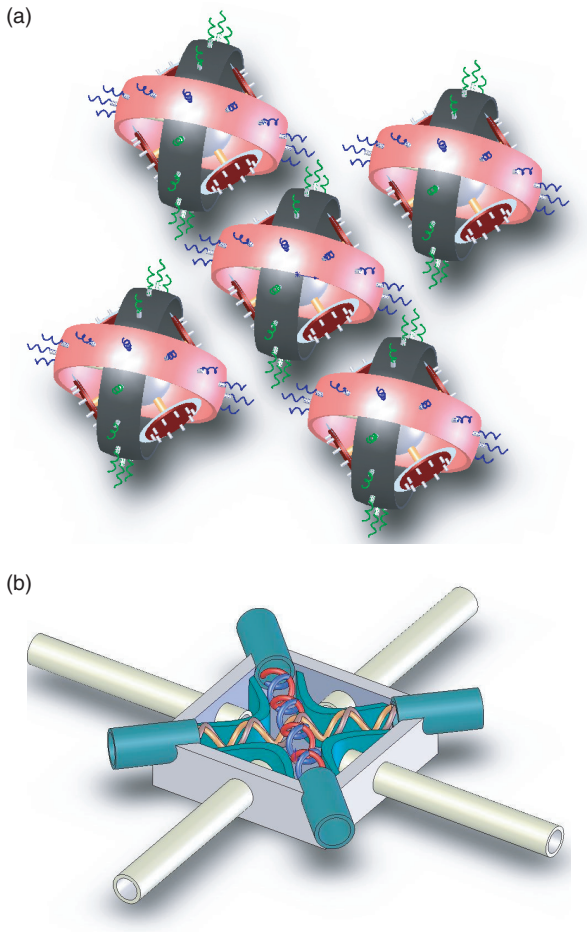


Figure 7.9 (Step 3) (a) Basic bio-nanorobot forming a small swarm of five robots. The spatial arrangement of the individual bio-nanorobot will define the arrangement of the swarm. These swarms could be re-programmed to form bindings with various other types of robots. The number of robots making a swarm will be determined by the mission. Such swarms will attach additional bio-nanorobots at run time and replace any non functional ones. (b) A basic bio-nano computational cell. This will be based on one of the properties of the biomolecules, which is 'reversibility.'

back to the macro-world through these storage devices. This programming capability would control the bio-nano robotics system and hence is very important.

Step 4: Automatic Fabrication and Information Processing Machines

Specialized bio-nano robotic swarms would need to be designed to carry out complex missions, such as sensing, signaling, and data storage. The next step in nanorobotic designing would see the emergence of automatic fabrication methodologies (see Figure 7.11, *which only shows the floor concept of assembling bio-nanorobots*) of such bio-nanorobots *in vivo* and *in vitro*. Capability of information processing will be a key consideration of this step. This would enable bio-swarms to have capability of *adjusting* based on their interacting environment they will be subjected to. These swarms could be programmed for more than one energy source and hence would have an ability to perform in an alternate environment. Energy management, self-repairing, and evolving will be some of the characteristics of these swarms.

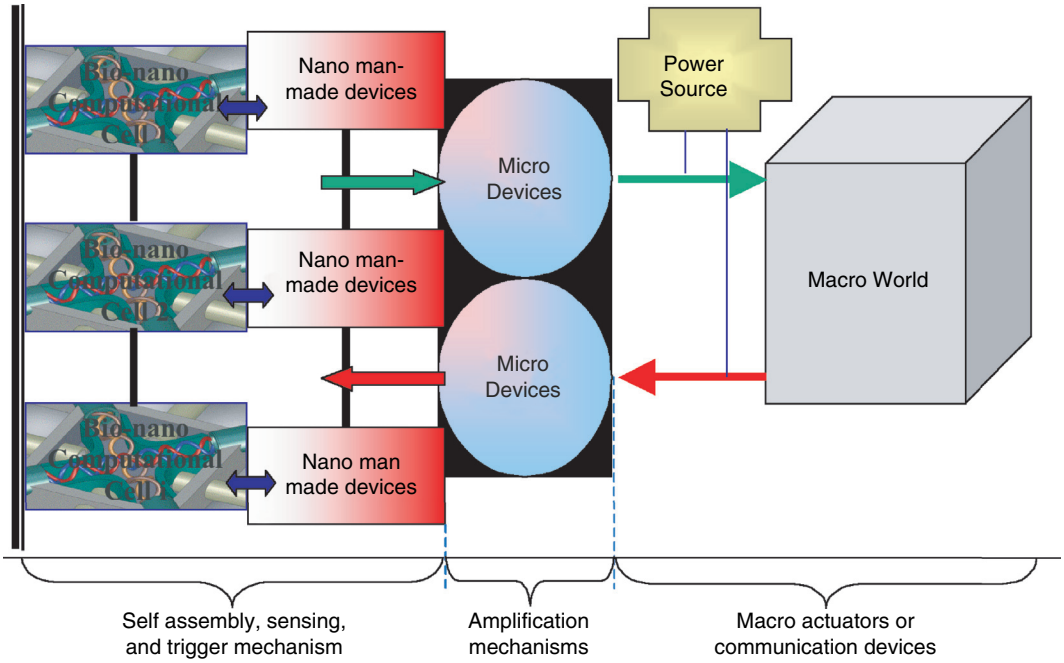


Figure 7.10 (See color insert) Feedback path from nano- to macro-world route.

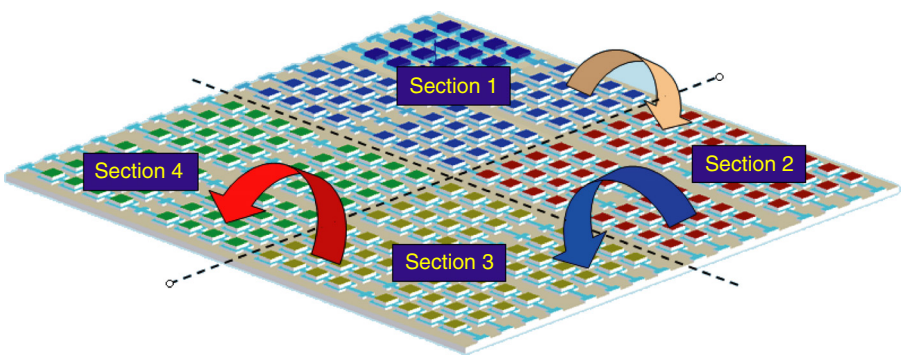


Figure 7.11 (Step 4) An automatic fabrication floor layout. Different colors (Balaji: Is this a color insert as well?) represent different functions in automatic fabrication mechanisms. The arrows indicate the flow of components on the floor layout. **Section 1**→Basic stimuli storage — control expression; **Section 2**→Biomolecular component manufacturing (actuator or sensor); **Section 3**→Linking of bio-nano components; **Section 4**→Fabrication of bio-nanorobots (assemblage of linked bio-nano components).

7.3.2 Design Architecture for the Bio-Nano Robotic Systems

(a) Modular Organization: Modular organization defines the fundamental rule and hierarchy for constructing a bio-nano robotic system. Such construction is performed through *stable integration* (energetically in the most stable state) of the individual '*bio-modules or components*', which constitute the bio-nanorobot. For example, if the entity **ABCD**, defines a bio-nanorobot having some *functional specificity* (as per the Capability Matrix defined in Table 7.1) then A, B, C, and D are said to be the basic bio-modules defining it. The basic construction will be based on the techniques of molecular modeling with emphasis on principles such as *energy minimization* on

Table 7.1 Defining the Capability Matrix for the Bio-Modules

Functionality	BioNanoCode	Capabilities Targeted	General Applications
Energy storage and carrier	E	Ability to store energy from various sources such as solar and chemical for future use and for its own working	Supplies the energy required for the working of all the bio-chemical mechanisms of the proposed bio-nano robotic systems
Mechanical	M	Ability to precisely move and orient other molecules or modules at nano-scale — includes the ability to mechanically bind to various target objects and carry them to desired locations	1. Carry moities and deliver them to the precise locations in correct orientations 2. Move micro-world objects with nano-precision
Input Sensing	S	Sensing capabilities in various domains such as chemical, mechanical, visual, auditory, electrical, and magnetic	Evaluation and discovery of target locations based on either chemical properties, temperature, or other characteristics
Signaling	G	Ability to amplify the sensory data and communicate with bio-systems or with the micro controllers and ability to identify their locations through various trigger mechanisms such as fluorescence	Imaging for medical applications or for imaging changes in nanostructures
Information storage	F	Ability to store information collected by the sensory element — behave similar to a read–write mechanism in computer field	1. Store the sensory data for future signaling or usage 2. Read the stored data to carry out programmed functions 3. Back bone for the sensory bio-module 4. Store nano-world phenomenon currently not observed with ease
Swarm behavior	W	Exhibit binding capabilities with 'similar' bio-nanorobots so as to perform distributive sensing, intelligence, and action (energy storage) functions	All the tasks to be performed by the bio-nanorobots will be planned and programmed keeping in mind the swarm behavior and capabilities
Information processing	I	Capability of following algorithms (Turing equivalent)	Programmable
Replication	R	Replicate themselves depending on the situation and requirement	Replicate by assembling raw components into nanorobots, and programming newly-made robot to form swarms that form automated fabricators consistent with the Foresight Guidelines for safe replicator development (Foresight Institute, 2000)

the hypersurfaces of the bio-modules, *hybrid quantum-mechanical and molecular mechanical* methods, *empirical force field* methods, and *maximum entropy production* in least time.

Modular organization also enables the bio-nanorobots with capabilities, such as organizing into *swarms,* a feature, which is extremely desirable for various applications. Figure 7.12A and Figure 7.12B show the conceptual representation of modular organization. Figure 7.12C shows a more realistic scenario in which all the modules are defined in some particular spatial arrangements based on their functionality and structure. A particular module could consist of other group of modules, just like a fractal structure (defined as *fractal modularity*). The concept of *bionanocode*

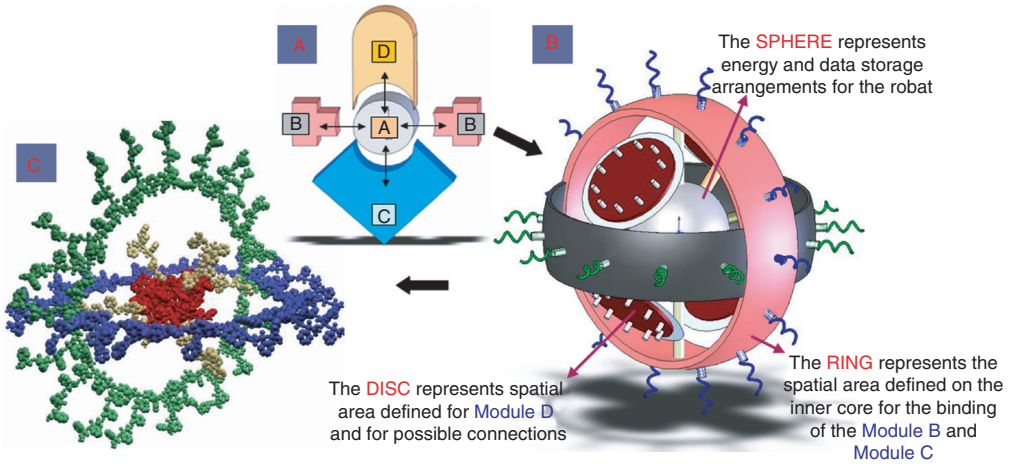


Figure 7.12 (See color insert) (A) A Bio-nano robotic entity 'ABCD', where A, B, C and D are the various bio-modules constituting the bio-nanorobot. In our case these bio-modules will be set of stable configurations of various proteins and DNAs. (B) A bio-nanorobot (representative), as a result of the concept of modular organization. All the modules will be integrated in such a way so as to preserve the basic behavior (of self-assembly and self-organization) of the biocomponents at all the hierarchies. The number of modules employed is not limited to four or any number. It is a function of the various capabilities required for a particular mission. (C) A molecular representation of the figure in part B. It shows the red core and green and blue sensory and actuation bio-modules.

has been devised, which basically describes the unique functionality of a bio-nano component in terms of alphabetic codes. Each bionanocode represents a particular module defining the structure of the bio-nanorobot. For instance, a code like **E-M-S** will describe a bio-nanorobot having capabilities of energy storage, mechanical actuation, and signaling at the nano-scale. Such representations will help in general classifications and representative mathematics of bio-nanorobots and their swarms. Table 7.1 summarizes the proposed capabilities of the bio-modules along with their targeted general applications. The bio-nano code **EIWR** || **M** || **S** || **FG** representing the bio-nano system shown in Figure 7.12B which could be decoded as shown in Figure 7.13.

(b) The Universal Template — BioNano STEM System: The modular construction concept involves designing a universal template for bionanosystems, which could be 'programmed and grown' into any possible bionanocoded system. This concept mimics the embryonic stem cells found in the human beings, that are a kind of primitive human cells which give rise to all other specialized tissues found in a human foetus and ultimately to all the three trillion cells in an adult human body. Our BioNano STEM system will act in a similar way. This universal growth template will be constituted of some basic bionanocodes, which will define the BioNano STEM system. This STEM system will be designed in a manner that could enable it to be programmed at runtime to any other required bio-module. Figure 7.14 shows one such variant of the BioNano STEM system, having the bionanocode: EIWR || M || S || FG and having enhanced sensory abilities.

7.4 SELF-REPLICATION — MIMETICS: A NOVEL PROPERTY OF LIVING SYSTEMS

7.4.1 Significance

Mimetics of self-replication, as exhibited by nature, would influence any nano-level application. We would need an army of nanorobots (or living systems), mass-produced via techniques of self-replication (or life), to carry out many meaningful tasks at the nano-scale. These applications

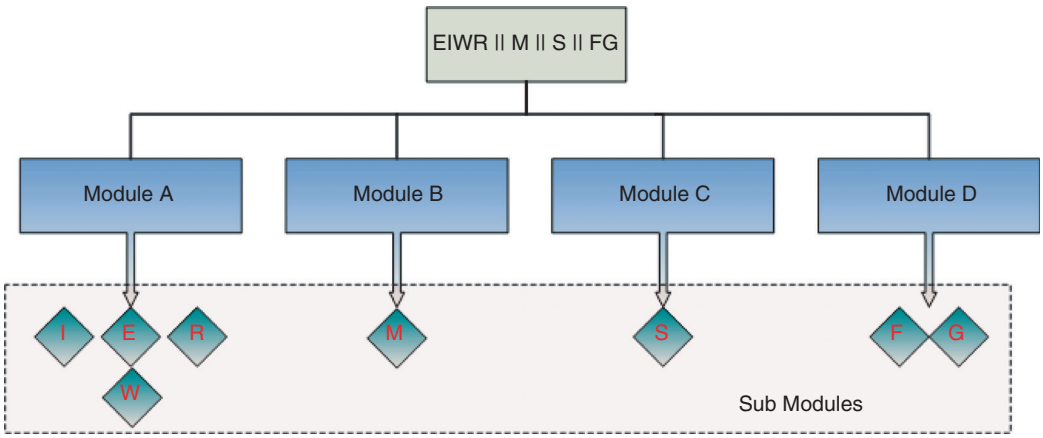


Figure 7.13 Showing the bio-nano code and the fractal modularity principle. The letter symbols have the values specified in Table 7.1. The '||' symbol integrates the various bio-modules and collectively represents a higher order module or a bio-nanorobot.

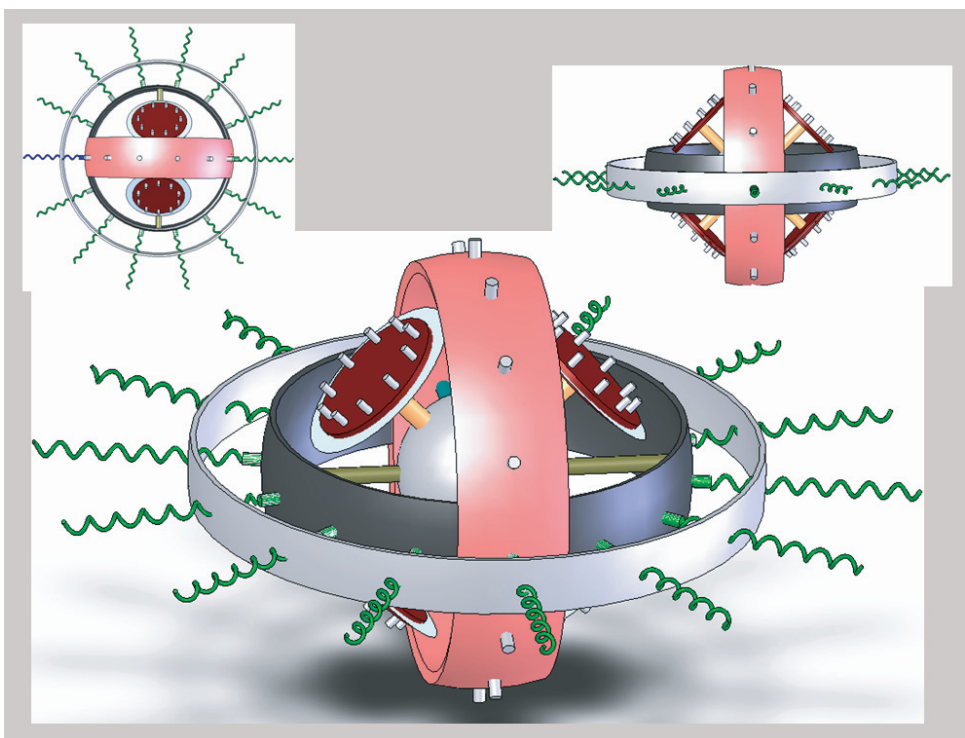


Figure 7.14 Shows a variant of the initial Bio-Nano STEM system (Figure 21B), fabricated with enhanced bio-nano code S, which defines it as a bio-nanorobot having enhanced sensory capabilities. The other features could be either suppressed or enhanced depending upon the requirement at hand. The main advantage of using Bio-Nano STEM system is that we could at runtime decide which particular type of bio-nanorobots we require for a given situation. The suppression ability of the Bio-Nano STEM systems is due to the property of 'Reversibility' of the biocomponents found in living systems.

involving nanorobots demand that these machines are manufactured in millions or billions and in a timeframe reasonable for a particular application. One of nature's noblest properties is that of life. It is how nature progresses through its environment ever adapting and evolving. Although philosophically what life means and what constitutes it is not very clear, what is clear is how nature propagates itself with time and survives, every day and every moment! This is one attribute of nature which is of prime importance to us as researchers of science and engineering, and which, if understood, would bring a unique revolution that in a way would change the course of our lives.

The concept of self-replicating mechanisms (SRM) or mimetics of life is not new (Freitas and Merkle, 2004). We are perfect examples of these kinds of systems. We are wounded and our internal mechanisms heal it with some differences in some cases. Taking the example of the wound and its healing process, we move ahead and try to analyze how we can achieve such behaviors in the mechanisms that we design. At the core of the concept of self-replication lies the basic material (DNA/RNA) which undergoes such activity. Though we hardly know why these materials behave in this fashion, what we do know is how they behave and this provides the stepping stone for us to move ahead.

Before looking at some of the possible designs, a brief discussion on the application of such mechanisms is necessary. Why do at all we need living systems or self-replications? Where would they be best suited?

7.4.2 Applications

(a) Consider that our application depends upon a particular part —mechanical or electrical, or any other physical, biological, or chemical element — which fails or starts developing problems. We need self-rectifying mechanisms within our application to detect the problem and rectify it. It is similar to our example of the wound. We can think of many applications where we would desire such behavior. Given some initial material feedstock, it would be desired that the self-replicating mechanisms would rectify the problems. Having said that, we can classify the self-replicating mechanisms in the order we classify our main mechanisms or machines.

- Mechanical self-replicating mechanisms;
- Electrical self-replicating mechanisms;
- Chemical or biological self-replicating mechanisms.

There could be other classifications as well and numerous other examples following the lines of our wound example, can be thought of. It just depends on our imagination. For example, suppose that we build some SRM which mimics the living system. Its function is to detect the crucial defect in a mechanical element and then mend that defect. If we are able to devise such an application, it could significantly enhance the life and performance of the system. The system in this example would be designed and constructed to work at nano-scale, and therefore it would have an ability to detect the slightest of defects and start working towards rectifying it.

(b) Remote Applications would also benefit from SRM systems. Maintaining remote applications requires constant human interaction. If these systems mimic the coded logic and goals of the living system, then it would be able to performance optimally with minimal human interventions. For example, deep space explorations would require circuits, machines, and equipments to adjust and adapt with time and as per the conditions they would be subjected to.

(c) Applications at the nano-scale. This category of applications would be most influenced by our bio mimetic systems because they could lay the foundations of nanodevices that have the capability of manipulating molecular matter.

In the following section we try to define some of the guidelines and working philosophies for designing and fabricating such replicating systems. The details are the thoughts and ideas of the authors and are not verified or supported by experimental facts.

7.4.3 The Design of Life Mimetic Systems

The design of life-mimetic systems requires new innovative materials to be designed that behave in the same fashion as that designed by nature. These new materials are termed "intrinsic materials" from here on.

7.4.3.1 Intrinsic Material

The unique arrangement of the constituent atoms of intrinsic materials would give rise to:

- unique potential field surface around them;
- unique charge distribution;
- unique internal energy gradients.

It is through these internal energy gradients that two particular intrinsic materials would interact with each other. Hence the behavior of the intrinsic material would be a direct function of its internal energy gradients.

7.4.3.2 Interaction Laws

The final objective of any interacting intrinsic materials would be to achieve the intrinsic balance of the resulting system (termed *self-balancing*). This would translate to achieving minimum energy gradients in all directions for all interacting materials. The final system would then be defined by its new achieved internal energy gradients. These intrinsic energy gradients would also be influenced by the external fields.

7.4.3.3 Self-Balancing

It implies that the materials considered would tend to align with its intrinsic energy gradients and would try to minimize the formed unbalance. The classical instance self-replication via energy-minimized self-assembly was first demonstrated in the late 1950s. The canonical example of this approach is called the Penrose Blocks (Penrose and Penrose, 1957; Penrose, 1958). The unbalance and the property of self-balancing are similar in essence to what is postulated by the law of entropy. This concept of self-balancing is motivated from the law of maximum entropy production according to which a system follows a path which minimizes the potential or maximizes entropy at the maximum rate (Archives of Science, 2001).

7.4.3.4 Growth and the Reproductive Limit

An intrinsic material would have a property of growth (an important variable for replication). This property of growth only occurs when the system is provided with some energy maybe in the form of additional intrinsic material or external gradients. Growth cannot happen in isolation. This implies that in the process of self-balancing, it is possible that the particular configuration of the intrinsic material is stable up to a particular level. This level would be governed by the strength of the potential gradients for that intrinsic material and the extrinsic gradients. Therefore, the growth implies that the intrinsic material can achieve higher state by not disturbing its self-balance or increasing it further. But this growth can only be achieved to a particular extent; beyond it, it tends to disintegrate by following the paths defined by the laws of maximum entropy production. And this particular limit of growth is termed Reproductive Limit.

7.4.3.5 Self-Filtering and Self-Healing

The concept of replication further demands that the materials thus designed should exhibit the property of self-filtering and self-healing. Self-filtering implies that the material involved in the systems exhibiting self-replication will not allow any kind of growth pattern but only a particular one. This particular growth pattern (which inherently depends on the interactions of the components) will determine which material it binds to and to which it doesn't. Hence such systems will only interact with certain intrinsic materials.

In the process of this growth, a realignment of the intrinsic material occurs. As the addition of further intrinsic material takes place, the whole system tries to realign itself towards the most stable state and in the fastest possible time. This realignment goes on with the self-filtering process. If at any incremental stage system doesn't find the kind and type of material it is looking for, it doesn't realign and rejects that particular material and doesn't grow. By rejection, it might imply that either the system doesn't align with the material or marks it as an unstable configuration and seeks for the opportunity to replace it immediately. Hence it acts as a self-healer.

7.4.4 Self-Replication — A Thought Experiment

Let us try to replicate a system, based on the above properties. Consider a system A, consisting of some intrinsic materials (Figure 7.15). The system A is completely defined by the way these intrinsic materials are associated and aligned with in it. According to the above properties of self-replicating mechanisms, it is observed that, the intrinsic materials of the system could be broken down into further fundamental intrinsic materials.

Any stable configuration of the individual intrinsic material is in sync with the property of self-balancing. Now when a particular intrinsic material (say 1) gets in an interactive distance of another intrinsic material (say 2), then these two intrinsic materials try to form another subsystem A1 within the super system A, following the property of self-balancing. These two intrinsic materials combined will have some other function of intrinsic energy gradient and could be the sum of the individual intrinsic energy gradients of the intrinsic materials and the applied external fields.

Now this argument could be extended to the situation when the third intrinsic material (say 3) comes into the picture. This intrinsic material 3 would not only interact with intrinsic material 1 but also with intrinsic material 2. Finally, a system A comes into generation, because of self-balancing acts of these three intrinsic materials. The configuration they achieve becomes highly stable for that

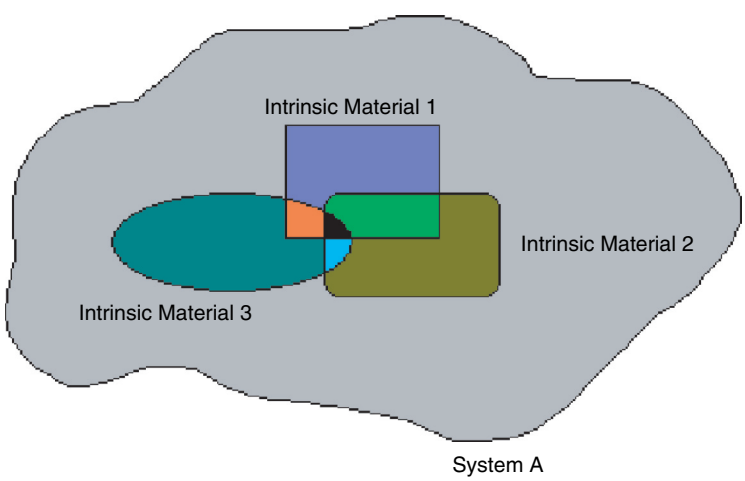


Figure 7.15 System of intrinsic materials — a self-replicative system A.

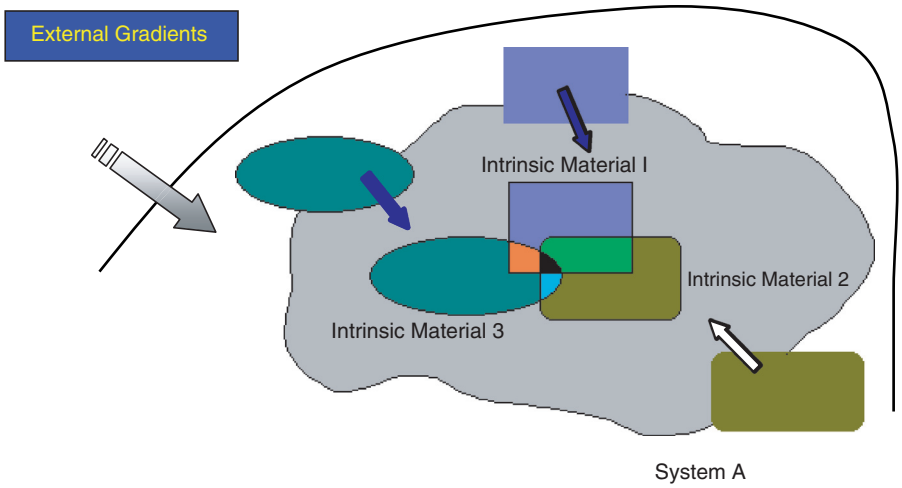


Figure 7.16 Energy being added to the self-replicative system A in the form of newer intrinsic material (1, 2 and 3) and external gradient (this external gradient is applied either to aid the interaction between the intrinsic materials or to impart a particular dynamics to the system for favorable environment for the interaction).

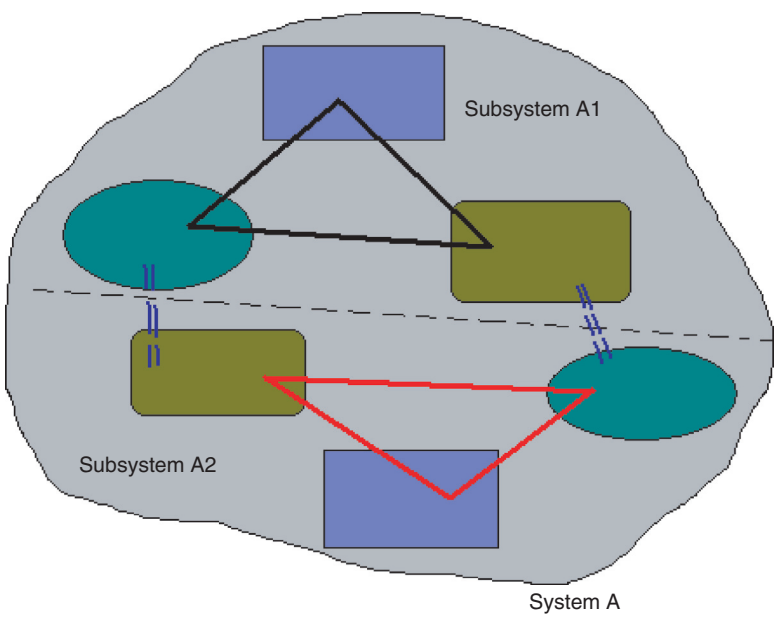


Figure 7.17 Creation of stable subsystems within the original system A (which as a whole is marginally unstable under the external gradients and two independently stable subsystems). This step is the most crucial in the process of attaining a self-replicative super system. This demands a unique selection of such replicative intrinsic materials in the initial place, namely, 1, 2 and 3.

particular situation. Now let's introduce more *energy* to the system A. It would be in the form of introducing intrinsic materials or applying external gradients to the system A or both. Figure 7.16 explains the concept.

Here because of the process of self-filtering, copies of intrinsic material 1, 2 and 3 are introduced. The property of self-balancing comes into dominance and the systems tries to adjust itself into the most stable state. As defined earlier, the initial state is the most stable state; following is what happens to the system A. Two subsystems within the main systems are made as shown in Figure 7.17. The alignment of *subsystems A1* and *A2* is similar to the one of the initial system, that is, *A*. Please note that

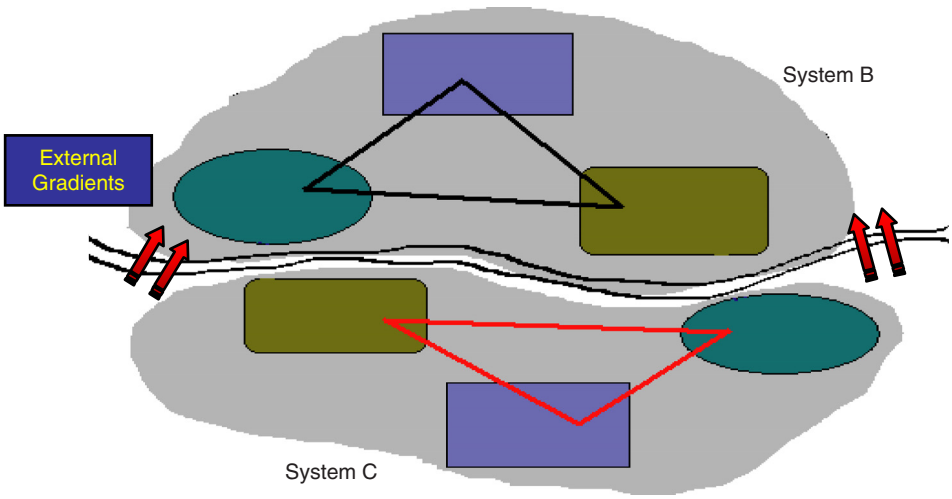


Figure 7.18 Replicating stage of the system A into system B and system C. Systems B and C which could be called the child systems are similar to system A in function and its configurations.

such system is possible, because we can control the external parameters, namely, extrinsic gradients and the intrinsic material introduced. The triangles drawn in the figure above shows the configuration of the intrinsic materials of *subsystems A1* and *A2*. The dotted lines, depict the interaction between the old intrinsic materials and the new ones and the possible configuration that could be achieved. Now because the external gradients are still applicable a unique instability in the system occurs. The system tries to self-balance and in the process leads to its most stable configurations, which was its initial one (the initial configuration, system A). Figure 7.18 explains the concept.

In the end, the original *system A* replicates into *systems B* and *C*. Both these new systems, have the same functionalities as defined by the original system (A), because the have received the same configuration and the same intrinsic materials.

7.4.5 Design Parameters for Self-Replicating Systems

Following are the various design parameters that need to be considered while designing a self-replicating system.

7.4.5.1 Selection of Intrinsic Materials

This is, of course, the most important parameter in designing the desired system. The obvious choices would be biomaterials and chemicals found in the human body, which have exhibited self-replication. Their choice is mainly because of their availability and the fact that they themselves are the materials resulting from a replicative process. This does not limit the selection of other replicative materials. Also a lot of data on nature's biomaterials is available from the experiments performed in the field of biology and genetic engineering. The field of nanotechnology is the biggest area where the concept of self-replication system would be a success and the biomaterials could be managed at that scale.

7.4.5.2 Defining the External Gradient Parameters

It is extremely important to define the external gradient parameters within which the system needs to perform. Our choice of the intrinsic materials would be greatly impacted by their behavior. Also their sensitivities to these external gradients need to be calculated so as to fine-tune the system.

7.4.5.3 Generating Stable Alignment and Internal Gradients

Selection of the appropriate intrinsic materials for our system implies that we need to also select the appropriate internal gradient functions and the alignment generated by these intrinsic materials. We need to calculate the most stable configuration for our system at no external gradient level and then fine tune our alignment as it is applied. Application of these external gradients could generate a situation where no stable configuration is possible within our operating conditions. This calls for adding some further intrinsic materials to the system, which would help us to get to the stable configuration (closure engineering) (Robert et al., 2004). This variation of the intrinsic gradient in this manner is termed as *intrinsic variational gradients* to distinguish it from the inherent intrinsic gradients generated due to the intrinsic materials. AQ6

The parameters mentioned above create the foundation for the development of mathematics for this field. To create any system with self-replicating mechanism we need to first find out its most stable state, then we need to calculate its behavior in the extrinsic gradients and then we need to excite it with energy and supply of intrinsic materials so that it replicates. Though these methodologies are not verified, further research in this area is being carried on by the authors and their collaborators.

7.5 CONCLUSIONS

Biomimetics and its principles would greatly influence the field of nanorobotics and nanotechnology. The way nature is designed and the way natures solves its problems is of great interest to us because they allow us to understand basic principles that would pave the way to practical nanotechnology.

The recent explosion of research in nanotechnology, combined with important discoveries in molecular biology have created a new interest in bio-nano robotic systems. The preliminary goal in this field is to use various biological elements — whose function at the cellular level results in a motion, force or signal — as nanorobotic components that perform the same function in response to the same stimuli — but in an artificial setting. This way proteins and DNA could act as motors, mechanical joints, transmission elements, or sensors. Assembled together, these components would form nanorobots with multiple degrees of freedom, with the ability to apply forces and manipulate objects at the nano-scale, and transfer information from the nano- to the macro-scale world.

The first research area is in determining the structure, behavior and properties of basic bio-nano components such as proteins. Specific problems include the precise mechanisms involved in molecular motors like ATP Synthase, and of protein folding. The next step is combining these components into complex assemblies. Next concepts in control and communication in swarms need to be worked out. Again, we plan to follow nature's path, mimicking the various colonies of insects and animals, and transforming principles learned to our domain. Since it would require specialized colonies of nanorobots to accomplish particular tasks, the concepts of cooperative behavior and distributed intelligence need to be developed, possibly by using knew hierarchical and other techniques. AQ7

Principles like self-replication are the ones of greatest importance for the field of nanorobotics. It is this life mimetics which will enable us to design and fabricate the future nanorobots having immense capabilities and potential. These would require innovative materials (intrinsic materials) and fabrication methodologies, with due regard to well-known manufacturing- and applications-related safety concerns. The safety issue is of paramount importance in this field for researchers and scientists. The proposed bio-nanorobots would be completely controlled molecular devices and are far from being dangerous to society. Though these devices would have many unique capabilities, which are not seen currently, they are harmful as projected in science fiction movies and books. There is an increasing need for educating the community about the exact nature of this research and its essential differences with the projections of the science fiction community.

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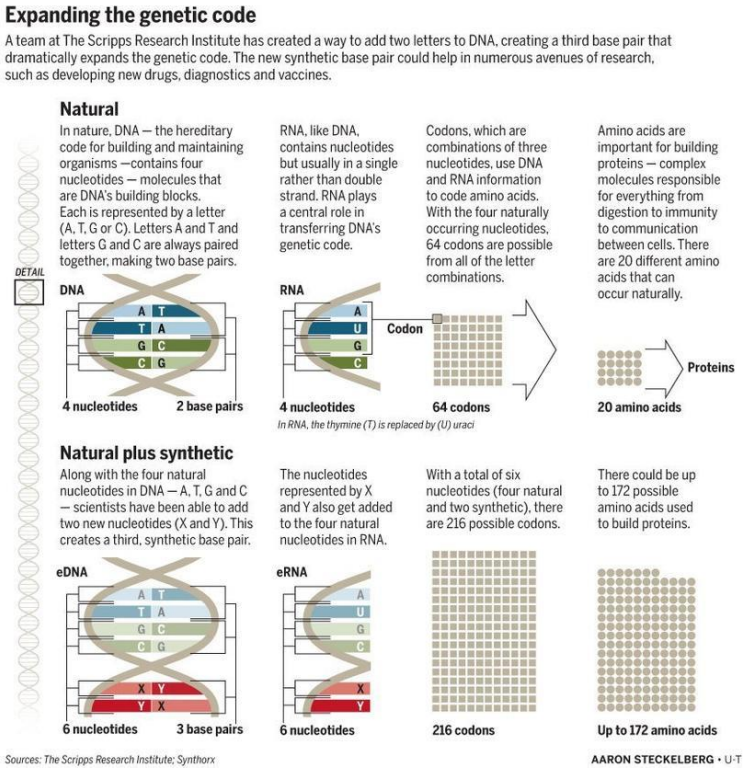
SYNTHETIC BIOLOGY (SYNBIO)



May 7, 2017 by Dr Rajiv Desai

Synthetic Biology (synbio):

Prologue:

The advent of digital technology is considered one of the biggest revolutions of all time for how quickly and deeply it changed the world forever. Even more powerful revolution is coming, which goes under the name of synthetic biology. The potential of this discipline is very well understood in the biological scientific world. It is time I make general public aware of the impact it will have on our lives. Synthetic biology brings together a bewildering number of disciplines: biotechnology, molecular biology, systems biology, biophysics, computer engineering, genetic engineering, and more. **Synthetic biology will allow scientists and engineers to create biological systems that do not occur naturally as well as to re-engineer existing biological systems to perform novel and beneficial tasks**. The term "synthetic biology" was introduced in 1978 by molecular

biologist and geneticist Wacław Szybalski. **Synthetic biology is considered as an amalgamation of principles of engineering and biology**. At its core, it's all about the **selective assembly of genetic information**. This is where the connection with computer science comes into play. Synthetic biologists aren't just copying and pasting existing DNA from one place to another—they're looking to figure out **how specific sequences work and then putting them together into new configurations**. The idea is that you can figure out what given segments of DNA do and then patch them together, **much as you would with lines of computer code, effectively programming cells to behave in new ways.** The scientists involved treat DNA a bit like a computer programme. **The aim is to rewrite life's internal operating system: design a new programme, print it out and run it in a cell which has been cleaned of its own genetic material to perform functions that may or may not be found in nature or create genetic machines from scratch**. **Now we can read and write the genetic code, put it in digital form and translate it back into synthesized life**. Ten years ago, genetic engineering was limited to cutting and pasting DNA from existing organisms. **Today's biologists can write down gene sequences that have never existed anywhere, place an order over the Internet, and receive the desired DNA by return mail**. As the cost of sequencing and DNA synthesis continues to drop, ambitious ideas for synthetic biology are becoming more affordable and achievable. In Boston, scientists and students conduct so called "synbio" projects developing odorless E. coli cells meant to synthesize wonder protein containing essential amino acids. Synthetic biology can create synthetic food, chemicals, biofuels, diagnostics, antibiotics and even building materials. It's easy to imagine nightmarish synbio-powered science fiction scenarios such as terrorists designing custom viruses designed to target specific populations. Alternately, seemingly benign lab-grown organisms might behave in unexpected ways when they interact with ecosystems, threatening the natural balance. The danger is not just bio-terror, but bio-error. And, at a more structural level, some fear that these technologies could suddenly disrupt industries such as farming, potentially driving billions deeper into poverty. But that's all very far away. In many ways, it's the very definition of an emerging field. Its promises are enormous, but progress remains incremental.

Comment [i1]: This is alarming to no end that something like this can be enroute and without any dire reasoning or cosequence-with the implications here--this is by far the most insidious means of weaponization to date

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"A Scientist discovers that which exists; an Engineer creates that which never was."

– Theodore von Karmen

Note: Please read my articles 'Genetically Modified' and 'Gene Therapy' published earlier in this website. **A genetically modified organism (GMO) is an organism (plant/ animal/ microorganism etc.) whose genetic material (DNA) has been altered using genetic engineering techniques by either adding a gene from a different species or over-expressing/ silencing a pre-existing native gene**. Genetic material in an organism can be altered without genetic engineering techniques which include mutation breeding where an organism is exposed to radiation or chemicals to create a non-specific but stable change, selective breeding (plant breeding and animal breeding), hybridizing and somaclonal variation. However, these organisms are not labelled as GMO. Gene

therapy can broadly be considered any treatment that changes gene function to alleviate a disease state. Gene therapy means man-made transfer/alteration/ expression/suppression of DNA/RNA in human/animal cells for the purpose of prophylaxis and/or treatment of a disease state. Replacing a defective gene by normal gene is one of the types of gene therapy. Other types include gene editing, gene silencing, insertion of novel genes, gene reprogramming, DNA vaccine etc. Gene therapy is one of the methods of genetic engineering and in the puritan medical terminology; any individual who has received gene therapy necessarily becomes genetically modified organism (GMO). Synthetic biology is an extreme version of genetic engineering and organism created by synthetic biology is labelled as synthetically modified organism (SMO).

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Abbreviations and synonyms:

XNA = xeno-nucleic acids

SB = synthetic biology = synbio

AL = artificial life

AI = artificial intelligence

bp = base pairs

Mbp = million bp

GMO = genetically modified organisms

GE = genetic engineering

SMO = synthetically modified organisms

JCVI = J. Craig Venter Institute in Rockville, Maryland.

CRISPR = Clustered Regularly Interspaced Palindromic Repeats

PCR = polymerase chain reaction

SBPs = Synthetic biology projects

_____

Terminology:

Comment [i2]:
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Here's a list of some important terms that will help you understand what we're talking about when discussing synbio technology.

Amino acid: The building block of proteins, which are essential to all life forms. There are twenty-two different amino acids, twenty of which are encoded by human genes and two are produced by other biological processes. These amino acids, also called residues, can be strung together in different combinations, each combination resulting in a unique protein.

Protein: A biological polymer made of amino acids strung together in a specific sequence.

Base: One of five chemical structures that can make up part of a nucleoside. The names of the bases are adenine (A), cytosine (C), guanine (G), thymine (T) and uracil (U). Adenine, cytosine, and guanine are used in both DNA and RNA whereas thymine is only used in DNA and uracil is its RNA counterpart.

Base pair: A specific pairing of bases that enable the helical structure of both DNA and RNA. Cytosine always pairs with guanine using three hydrogen bonds, and adenine with thymine (in DNA) or uracil (in RNA) with two hydrogen bonds

Nucleoside: Nucleosides consist of a **ribose** (or deoxyribose) sugar linked to a base. They are strung together to form DNA and RNA, with **a phosphate** group linking each nucleoside to the next.

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Nucleotide: Nucleotides are the building blocks of nucleic acids; they are composed of three subunit molecules: a nitrogenous base, a five-carbon sugar (ribose or deoxyribose), and phosphate group. Nucleotide is nucleoside with phosphate.

Codon: A sequence of three nucleotides that codes for a specific amino acid.

Oligonucleotide (oligo): A short DNA or RNA polymer that is usually less than 100 nucleotides in length. It is often **man-made (synthetic DNA or RNA).**

Recombinant DNA: **DNA that has been formed artificially by combining constituents from different organisms. Recombinant DNA** (rDNA) molecules are DNA molecules formed by laboratory methods of genetic recombination (such as molecular cloning) **to bring together genetic material from multiple sources, creating sequences that would not otherwise be found in the genome**.

Synthetic DNA: **DNA generated using synthetic biology tools rather than extracted from a living organism.** The resulting synthetic DNA can be created in exactly the same sequence as the DNA from a living organism. **Synthetic DNA cannot create new organisms (even microscopic ones) from scratch, but can be used to add beneficial**

Comment [i3]: with nanobio you have the ligands (protein polymers utilized by the hosts protein and attracts other nano to it for assembly forming a fullerene complex to create networks or to transport other building blocks of synthetic dna or other nano materials

Comment [i4]: Or Detrimental -- bio/nano warfare -targetting sequence looking for specific DNA to attach to to cause whatever conditions that is in the programming of the other dna

character traits to a plant (self-fertilizing, drought tolerant) or engineer new drugs or vaccines like artemisinin for malaria.

Part (Biological part): is a sequence of **DNA that encodes for a biological function**, for example promoters or protein coding sequences. At its simplest, a basic part is a single functional unit that cannot be divided further into smaller functional units. Basic parts can be assembled together to make longer, more complex composite parts, which in turn can be assembled together to make devices that will operate in living cells.

BioBricks: **Standard synthetic DNA sequences of known structure and function that can be used as "Lego-like" building blocks**. These can be combined in different ways to generate a specific form and function. **When inserted into living organisms, BioBricks create new, or replicate existing, biological systems**. Over 20,000 parts are currently available in the Registry of Standard Biological Parts.

DNA-based circuits: The rational **design of DNA sequences to create biological circuits with predictable, discrete functions, which can be combined in various cell hosts**.

Chassis: The cell or organism **into which BioBricks are inserted**, **producing a new biological system.**

Minimal genome: It is generally defined as the smallest set of genes that allows for replication of the organism in a particular environment. It is the minimal number of parts (genes) needed for life, to serve as a chassis for engineering minimal cell factories for new functions.

Cloning: Molecular cloning is the process of **inserting foreign DNA into a cell in order to create many copies of it and/or translate it into protein**.

CRISPR/Cas9: A naturally-occurring system that has recently been used as a synthetic biology tool **to edit genes**. **This system allows for the precise inactivation or recoding of any gene through the insertion, deletion or substitution of nucleotide sequences**.

Data storage: A term that refers to any method used **to store and archive digital data**. **Synthetic DNA can be used to store digital data**, which researchers predict would be error-free when recovered after up to 1 million years.

DNA synthesis: A process for producing DNA from individual nucleotides in the laboratory. **These DNA fragments can be used as gene parts or building blocks to assemble whole genes or libraries**. They are also used ubiquitously throughout academia and industry to study biology and develop medical products, such as vaccines and diagnostic tests

Engineering Biology: another term used to refer to **synthetic biology (synbio)**.

Comment [i5]: NANO equivalent lattices--these are basically what is put in to allow origami to assemble to allow other nano(bio) to attach assemble into a platform and integrate into cells tissue and DNA to fully be incorporated

Comment [i6]: when you add NANOBIOLOGY (synthetic bio) this is what happens with the integration and re programming of dna

Comment [i7]: the concept of whole gene or libraries indicates a over writing what maybe there and a new operation or systems are now being changed

Expression: **The process by which genetic information stored in DNA is transformed into a cellular function**. Expression is a-2 step process, **first transcription of DNA into RNA, and second translation into protein.** Example of expression is production of insulin to process sugar.

Gene: The basic unit of heredity; **a specific DNA sequence that codes for a protein or RNA required for the organism to develop and function**.

Genome: **The complete set of genetic information of an organism, stored in genes made of DNA** (most often) or RNA (rare).

Gene editing: **The ability to insert a beneficial sequence, replace a mutated sequence or remove a diseased sequence of DNA** using systems such as CRISP/Cas9.

Gene regulation: The control of gene expression. This can be effected by turning the expression of genes on and off at specific times through modulation of both direct and indirect factors such as promoters and enhancers.

Genetic engineering: **Direct human manipulation of an organism's genetic material, to add new traits not already found in that organism, or to delete an unwanted disease gene**.

iGEM (international Genetically Engineered Machine competition): A foundation dedicated to advancement of synthetic biology through education and competition. In its annual worldwide competition, college and high school level participants use standard parts and their own design to build new biological systems.

Mutation: **Change in a gene that occurs randomly or in response to radiation or chemical mutagens.** Alternatively, **using the synthesis of DNA, specific mutations can be designed on purpose** by researchers for precise and controlled experimentation.

Nanobiology: A branch of **biology that deals with biological interactions at a very small (nano) scale, often involving structures** that are only millionths of an inch in size.

Pathway: In biology, a pathway describes **a series of actions between molecules that can lead to a change in a cell and/or a product such as sugar, protein, fat or organic molecules. A pathway is usually encoded as a string of genes in a long fragment of DNA**.

PCR (Polymerase Chain Reaction): It is a technique used in molecular biology to **amplify a single copy or a few copies of a segment of DNA across several orders of magnitude, generating thousands to millions of copies of a particular DNA sequence through the action of polymerases**.

Comment [i8]: **Basically the operating system that that accesses the program to causse the body to function or other operations in the body to work**

Comment [i9]: **the operating system of the body**

Comment [i10]: **the ability to replace insert or program dna is not always beneficial -when you look at vaccines you can see what happens when this operations is being done and the mutations that occur and the disarray of function occurs as a result of insertion of genetic or nano paterials that now overwrite and initiate a new program wiping out the old one as a esult of the over write -similar to a cassette tape when you record and the re record over what you had**

Comment [i11]: **Self assemblying and Self replication**

Sequence: The specific order in which amino acids, deoxynucleotides, and ribonucleotides are strung together to form a specific protein, DNA or RNA, respectively.

Sequencing: Process by which scientists determine the specific order of base pairs within DNA, RNA, or protein.

Living modified organism: Any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology.

Comment [i12]: This can apply to all life even of mankind or humanity

Living organism: Any biological entity capable of transferring or replicating genetic material, including sterile organisms, viruses and viroids.

Comment [i13]: This can apply to all life even of mankind or humanity

Protocell (artificial cell): Protocells are living cells constructed from scratch capable of reproduction, self-maintenance, metabolism and evolution. Bottom-up synthetic biology approach produces protocells cells and compartments.

Xenobiology: The study and development of life forms based on biochemistry not found in nature. This includes xeno-nucleic acids XNA (synthetic alternatives to the natural nucleic acids DNA and RNA) and amino acids that are not found in the natural genetic code of organisms. Xenobiology could provide a biosafety tool by preventing interactions between synthetic organisms and the natural world (xeno-nucleic acids can prevent genetic exchange with wild organisms, as they cannot hybridise with natural genetic material).

Digital logic gate: An idealized or physical device that implements Boolean logic (such as AND, OR, NOT) on one or more inputs to produce a single output

Orthogonal biosystems: Engineering cells/organisms to include systems or parts not found in nature to impart new capacities or chemistry. Orthogonal systems operate independently of the cell's natural machinery.

Bionanoscience: Utilising and exploiting synthetic molecular (nano) machines based on cellular systems

Comment [i14]: Another term can be as well utilized is a Mimetic ---these synthetic molecules can create what appears to be something else in biology --it Mimics there attributes

Biofuels: Sources of energy derived from biomass such as plants, algae and animal waste products. The use of biofuels could substantially reduce greenhouse gas emissions by recycling carbon dioxide from the air and replacing fossil fuels such as oil. Synthetic biology tools are often used to in the development of biofuels.

DNA and RNA:

Deoxyribonucleic acid (DNA) is a molecule that carries the genetic instructions used in the growth, development, functioning and reproduction of all known living organisms and many viruses. DNA and RNA are nucleic acids; alongside proteins, lipids and complex carbohydrates (polysaccharides), they are one of the four major

types of macromolecules that are essential for all known forms of life. Most DNA molecules consist of two biopolymer strands coiled around each other to form a double helix. The two DNA strands are termed polynucleotides since they are composed of simpler monomer units called nucleotides. Each nucleotide is composed of one of four nitrogen-containing nucleobases—either cytosine (C), guanine (G), adenine (A), or thymine (T)—and a sugar called deoxyribose and a phosphate group. The nucleotides are joined to one another in a chain by covalent bonds between the sugar of one nucleotide and the phosphate of the next, resulting in an alternating sugar-phosphate backbone. The nitrogenous bases of the two separate polynucleotide strands are bound together according to base pairing rules (A with T, and C with G) with hydrogen bonds to make double-stranded DNA. The total amount of related DNA base pairs on Earth is estimated at 5.0 x 10^37 and weighs 50 billion tonnes.

The structure of part of a DNA double helix:

In living organisms, DNA does not usually exist as a single molecule, but instead as a pair of molecules that are held tightly together. These two long strands entwine like vines, in the shape of a double helix. The nucleotide contains both a segment of the backbone of the molecule (which holds the chain together) and a nucleobase (which interacts with the other DNA strand in the helix). A nucleobase linked to a sugar is called a nucleoside and a base linked to a sugar and one or more phosphate groups is called a nucleotide. A polymer comprising multiple linked nucleotides (as in DNA) is called a polynucleotide.

Atoms in DNA:

Figure below shows atoms in the DNA molecule colour-coded by element and the detailed structure of two base pairs are shown in the bottom right.

DNA stores biological information. DNA is a molecule that contains the instructions an organism needs to develop, live and reproduce. These instructions are found inside every cell, and are passed down from parents to their children. The DNA backbone is resistant to cleavage, and both strands of the double-stranded structure store the same biological information. This information is replicated as and when the two strands separate. A large part of DNA (more than 98% for humans) is non-coding, meaning that these sections do not serve as patterns for protein sequences. The two strands of DNA run in opposite directions to each other and are thus antiparallel. Attached to each sugar is one of four types of nucleobases (informally, bases). It is the sequence of these four nucleobases along the backbone that encodes biological information. The order of these bases is what determines DNA's instructions, or genetic code. Similar to the way the order of letters in the alphabet can be used to form a word, the order of nitrogen bases in a DNA sequence forms genes, which in the language of the cell, tells cells how to make proteins. The entire human genome contains about 3 billion bases and about 20,000 genes. RNA strands are created using DNA strands as a template in a process called transcription. Under the genetic code, these RNA strands are translated to specify the sequence of amino acids within

proteins in a process called translation. The regular structure and data redundancy provided by the DNA double helix make DNA well suited to the storage of genetic information, while base-pairing between DNA and incoming nucleotides provides the mechanism through which DNA polymerase replicates DNA, and RNA polymerase transcribes DNA into RNA.

DNA is a long polymer made from repeating units called nucleotides. The structure of DNA is dynamic along its length**, being capable of coiling into tight loops, and other shapes. In all species** it is composed of two helical chains, bound to each other by hydrogen bonds. Both chains are coiled round the same axis, and have the same pitch of **34 ångströms (3.4 nanometres). The pair of chains has a radius of 10 ångströms (1.0 nanometre). According to another study, when measured in a different solution, the DNA chain measured 22 to 26 ångströms wide (2.2 to 2.6 nanometres), and one nucleotide unit measured 3.3 Å (0.33 nm**) long. **Although each individual nucleotide repeating unit is very small, DNA polymers can be very large molecules containing millions to hundreds of millions of nucleotides**. For instance, the DNA in the largest human chromosome, chromosome number 1, consists of approximately 220 million base pairs and would be 85 mm long if straightened.

A gene is a sequence of DNA that contains genetic information and can influence the phenotype of an organism. Within a gene, the sequence of bases along a DNA strand defines a messenger RNA sequence, which then defines one or more protein sequences. **The relationship between the nucleotide sequences of genes and the amino-acid sequences of proteins is determined by the rules of translation, known collectively as the genetic code. The genetic code consists of three-letter 'words' called codons formed from a sequence of three nucleotides (e.g. ACT, CAG, TTT). In transcription, the codons of a gene are copied into messenger RNA by RNA polymerase**

. This RNA copy is then decoded by a ribosome that reads the RNA sequence by base-pairing the messenger RNA to transfer RNA, which carries amino acids. Since there are **4 bases in 3-letter combinations, there are 64 possible codons (64 possible permutations, or combinations of three-letter nucleotide sequences that can be made from the four nucleotides). Of the 64 codons, 61 represent 20 natural amino acids, and three are stop signals. For example, the codon CAG represents the amino acid glutamine, and TAA is a stop codon. The genetic code is described as degenerate, or redundant, because a single amino acid may be coded for by more than one codon**. When codons are read from the nucleotide sequence, **they are read in succession and do not overlap with one another. Within eukaryotic cells, DNA is organized into long structures called chromosomes. During cell division these chromosomes are duplicated in the process of DNA replication, providing each cell its own complete set of chromosomes. Eukaryotic organisms (animals, plants, fungi, and protists) store most of their DNA inside the cell nucleus and some of their DNA in organelles, such as mitochondria or chloroplasts. In contrast, prokaryotes (bacteria and archaea) store their DNA only in the cytoplasm.** Within the eukaryotic chromosomes, chromatin proteins such as histones compact and organize DNA. **These compact**

Comment [i15]: Like a boot drive in a operating system

structures guide the interactions between DNA and other proteins, helping control which parts of the DNA are transcribed.

RNA:

Like DNA, **RNA (ribonucleic acid) is assembled as a chain of nucleotides, but unlike DNA it is more often found in nature as a single-strand folded onto itself, rather than a paired double-strand. In RNA, adenine and uracil** (not thymine) **link together**, while cytosine still links to guanine**. Cellular organisms use messenger RNA (mRNA) to convey genetic information (using the letters G, U, A, and C to denote the nitrogenous bases guanine, uracil, adenine, and cytosine) that directs synthesis of specific proteins. In protein synthesis RNA molecules direct the assembly of proteins on ribosomes. This process uses transfer RNA (tRNA) molecules to deliver amino acids to the ribosome, where ribosomal RNA (rRNA) then links amino acids together to form proteins. Many viruses encode their genetic information using an RNA genome.** Some RNA molecules play an active role within cells by **catalyzing biological reactions, controlling gene expression, or sensing and communicating responses to cellular signals.**

Genome size:

Genome size is the total amount of DNA contained within one copy of a single genome. It is typically measured in terms of mass in **picograms [trillionths of a gram, abbreviated pg]** or less frequently **in Daltons** or as the total number of nucleotide base **pairs typically in megabases (millions of base pairs, abbreviated Mb or Mbp). One picogram equals 978 megabases.**

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bp = base pair (e.g. A with T)

1 kb = 1000 bp (e.g. viral genome)

1Mb = 1000,000 bp (e.g. bacterial genome)

I Gb = 1000,000,000 bp (e.g. mammal genome)

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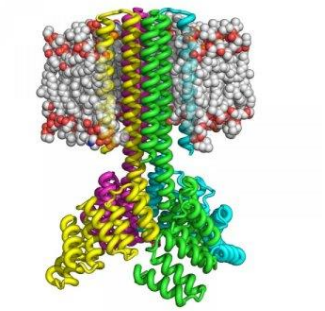
Scientists create complex transmembrane proteins from scratch

Advance paves the way for the design of transmembrane proteins with useful, new functions



This illustration shows how four copies of computer-designed transmembrane protein assembled to form a rocket-shaped tetramer with a wide cytoplasmic base that funnels into eight transmembrane helices and which orients correctly in membrane.
Credit: University of Washington Institute for Protein Design

It is now possible to create complex, custom-designed transmembrane proteins from scratch, scientists report this week. The advance, led by molecular engineers at the University of Washington Institute for Protein Design, will **enable researchers to create transmembrane proteins not found in nature to perform specific tasks**.

In the living world, transmembrane proteins are found embedded in the membrane of all cells and cellular organelles. They are essential for them to function normally. For example, many **naturally occurring transmembrane proteins act as gateways for the movement of specific substances across a biological membrane. Some transmembrane proteins receive or transmit cell signals**. Because of such roles, many drugs are designed to target transmembrane proteins and alter their function. "Our results pave the way for the design of multispan membrane proteins that could mimic proteins found in nature or have entirely novel structure, function and uses," said David Baker, a University of Washington School of Medicine professor biochemistry and director of the UW Institute of Protein Design who led the project. The research is reported in the March 1 issue of the journal *Science*. Peilong Lu, a senior fellow in the Baker lab, is the paper's lead author. But understanding how transmembrane proteins are put together and how they work has proved challenging. Because they act while embedded within the cellular membrane, transmembrane proteins have proven to be more difficult to study than proteins that operate in the watery solution that make up the cells' cytoplasm or in the extracellular fluid. In the new study, Lu and his coworkers used a

Comment [i1]: A protein that spans the entire biological membrane.-- A transmembrane protein is a protein which spans the entire length of the cell membrane. It is embedded between the phospholipids, providing a channel through which molecules and ions can pass into the cell. Transmembrane proteins also facilitate communication between cells by interacting with chemical messengers. Many biological processes, such as the metabolism of glucose and the production of fatty acids, are triggered after a particular transmembrane protein is activated.

computer program, developed in the Baker lab and called Rosetta, that can predict the structure a protein will fold into after it has been synthesized. The architecture of a protein is crucial **because a protein's structure determines its function**. **A protein's shape forms from complex interactions between the amino acids that make up the protein chain and between the amino acids and the surrounding environment. Ultimately, the protein assumes the shape that best balances out all these factors** so that the protein achieves the lowest possible energy state. The Rosetta program used by Lu and his colleagues can predict the structure of a protein by taking into account these interactions and calculating the lowest overall energy state. It is not unusual for the program to create tens of thousands of model structures for an amino acid sequence and then identify the ones with lowest energy state. **The resulting models have been shown to accurately represent the structure the sequence will likely assume in nature.** Determining the structure of transmembrane proteins is difficult because portions of transmembrane proteins **must pass though the membrane's interior, which is made of oily fats called lipids.** In aqueous fluids, amino acid residues that have polar sidechains -- components that can have a charge under certain physiological conditions or that participate in hydrogen bonding -- tend to be located on the surface of the protein where they can interact with water, which has negatively and positively side charges to its molecule. As a result, polar residues on proteins are called hydrophilic, or "water-loving." Non-polar residues, on the other hand, tend to be found packed within the protein core away from the polar aqueous fluid. Such residues are called hydrophobic or "water-fearing**." As a result, the interaction between the water-loving and water-fearing residues of the protein and the surrounding watery fluids helps drive protein folding and stabilizes the protein's final structure**. In membranes, however, protein folding is more complicated **because the lipid interior of the membrane is non-polar, that is, it has no separation of electrical charges**. This means to be stable the protein must place nonpolar, water-fearing residues on its surface, and pack its polar, water-loving residues inside. Then it must find a way to stabilize its structure by creating bonds between the hydrophilic residues within its core. The key to solving the problem, says Lu, was to apply a method developed by Baker lab to design **proteins so that the polar, hydrophilic residues fit in such a way that enough would form polar-polar interactions that can tie the protein together from within**. "Putting together these 'buried hydrogen bond networks' was like putting together a jig-saw puzzle," Baker said. With this approach, Lu and his colleagues **were able to manufacture the designed transmembrane proteins inside bacteria and mammalian cells by using as many as 215 amino acids.** The resulting proteins proved to be highly thermally **stable and able to correctly orient themselves on the membrane**. Like naturally occurring transmembrane proteins, **the proteins are multipass, meaning they traverse the membrane several times, and assemble into stable multi-protein complexes, such as dimers, trimers and tetramers.** "We have shown

Comment [i2]: following there programming

that it is now possible to accurately design complex, multipass transmembrane proteins that can be expressed in cells. This will make it possible for researchers to design transmembrane proteins with entirely novel structures and functions," said Lu. **Story Source-m**aterials provided by **University of Washington Health Sciences/UW Medicine**. **Journal Reference**-Peilong Lu, Duyoung Min, Frank DiMaio, Kathy Y. Wei, Michael D. Vahey, Scott E. Boyken, Zibo Chen, Jorge A. Fallas, George Ueda, William Sheffler, Vikram Khipple Mulligan, Wenqing Xu, James U. Bowie, David Baker. **Accurate computational design of multipass transmembrane proteins**. *Science*, 2018; 359 (6379): 1042 DOI: 10.1126/science.aaq1739

Towards XNA nanotechnology- new materials from synthetic genetic polymers.

Pinheiro VB[1], Holliger P[2].

Author information

Abstract

Nucleic acids display remarkable properties beyond information storage and propagation. **The well-understood base pairing rules have enabled nucleic acids to be assembled into nanostructures of ever increasing complexity**. **Although nanostructures can be constructed using other building blocks, including peptides and lipids, it is the capacity to evolve that sets nucleic acids apart from all other nanoscale building materials**. Nonetheless, the poor chemical and biological stability of DNA and RNA constrain their applications. Recent advances in nucleic acid chemistry and **polymerase engineering enable the synthesis, replication, and evolution of a range of synthetic genetic polymers (XNAs) with improved chemical and biological stability**. We discuss the impact of this technology on the generation of XNA ligands, enzymes, and nanostructures with tailor-made chemistry.

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Synthetic genetic polymers capable of heredity and evolution.

Pinheiro VB[1], Taylor AI, Cozens C, Abramov M, Renders M, Zhang S, Chaput JC, Wengel J, Peak-Chew SY, McLaughlin SH, Herdewijn P, Holliger P.

Author information

Abstract

Genetic information storage and processing rely on just two polymers, DNA and RNA, yet whether their role reflects evolutionary history or fundamental functional constraints is currently unknown**. With the use of polymerase evolution and design, we show that genetic information can be stored in and recovered from six alternative genetic polymers based on simple nucleic acid architectures not found in nature [xeno-nucleic acids (XNAs)].** We also select XNA aptamers, which bind their targets with high affinity and specificity, demonstrating that beyond heredity, specific XNAs have the capacity for Darwinian evolution and folding into defined structures. Thus, heredity and evolution, two hallmarks of life, are not limited to DNA and RNA but are likely to be emergent properties of polymers capable of information storage.

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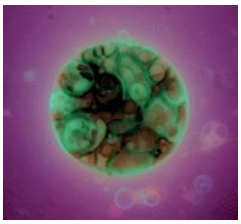
Artificial Cells –Self Repair Self Assembly and Self Production-An EU integrated project in IT- FP6-IST-FET-002035



The European Commission has supported the Integrated Project PACE in its Future Emerging Technologies program from **2004-2008**. This is the final public report of results and experience in PACE.---**PACE has created the foundation for a new generation of embedded IT using programmable chemical systems that approach artificial cells in their properties of self-repair, self-assembly, self-reproduction and evolvability**.

Future projects will build on the technology and experience developed in PACE to **build the first artificial chemical cells and apply them to revolutionize complex construction in and outside IT**. PACE has established a new hybrid IT technology for programming complex chemical systems. PACE has explored the IT potential of future synthetic chemical cells: addressing both the novel embedded IT required to produce and program them and their technical opportunities, both within IT and to other fields**. In contrast with biological approaches to minimize existing cells, applications of these artificial chemical cells will exploit their chemical distinctiveness from biological cells, in particular their ability to function without proteins and below the complexity barrier posed by biological translation machinery.**--A consortium of some 13 partners and 2 cooperating groups from 8 European countries, including Switzerland and Lithuania, and several leading USA organizations are pioneering this new approach under the IST-FET section of the EU 6th Framework Program (FP6).

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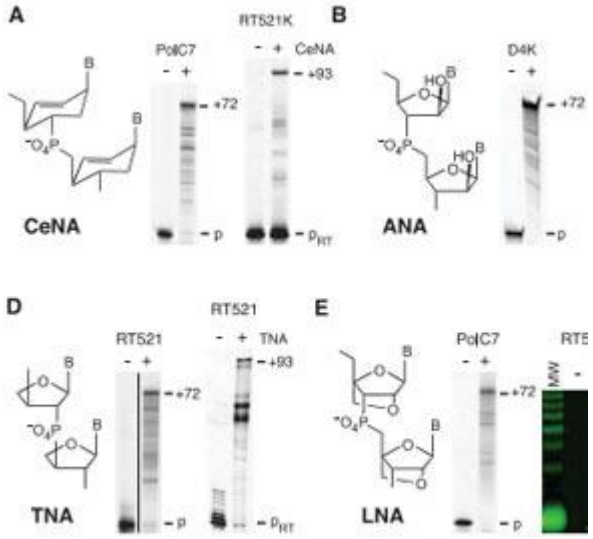
XNA-Synthetic DNA That Can Evolve

By swapping sugars in the DNA helix, scientists have created a new kind of genetic code that can function and evolve like regular DNA.



Every living thing on Earth uses DNA or RNA to carry its genetic instructions for life. These two nucleic acids have different names because they're built from different sugars: DNA uses deoxyribose sugars for a backbone of its double helix, while RNA uses ribose. But what if other sugars could be used too?

Now scientists have shown that at least six other types of sugars can form nucleic acid backbones—and they can be used to store and retrieve genetic information. The researchers built DNA molecules from scratch, but replaced the deoxyribose with six other kinds of sugar, including hexitol, threose, and arabinose. The six types of synthetic genetic chains are called XNAs, or xeno-nucleic acids ("xeno" is Greek for "foreign"). And because XNA shows the possibility of heredity—passing down their genetic information—the researchers say these molecules not only could address fascinating questions about the origin of life, but also could open up the possibility of another kind of life based not on DNA and RNA.

Jack Szostak, a geneticist and Nobel laureate at Harvard University, tells PM in an email that the work "is very interesting with respect to the origin of life—in principle, many different polymers could serve the roles of RNA and DNA in living organisms. Why then does modern biology use only RNA and DNA?"

How to Make Synthetic DNA

This isn't the first time that geneticists have cooked up synthetic nucleic acids in a lab. Some scientists had previously created DNA with new kinds of base pairs beyond the A-T and C-G connections in DNA, and others had already created XNAs that incorporate foreign sugars. John Chaput, a molecular biologist at Arizona State University and an author on the new study in *Science*, says this work asks a new question: "How can you perform Darwinian evolution on something other than DNA or RNA? Lots of DNA and RNA molecules have been evolved in the laboratory, but going the next step and doing it on other molecules has been very challenging. This is one of the first examples of that."

To prove that XNAs could evolve, the researchers first had to create a new kind of enzyme to build the XNAs. Although it's possible to manufacture XNAs by machine, the resulting nucleic acids are short chains that have limited functionality and evolvability. So instead of using the machinated approach, the researchers took thousands of DNA-building enzymes and evolved them into XNA-building enzymes.

That required taking thousands of enzymes and mixing them together with XNA building blocks, as well as DNA strands that served as templates for the scaffolding on which to build XNA molecules. If an enzyme turned out to be good at building XNA strands, it was captured using a filtering process and amplified it for the next round of testing; enzymes that were bad at making XNA were washed away. Over many rounds of filtering, the enzyme population evolved to become more adroit at building XNAs—in fact, they could produce polymers XNA chains that lasted were five times longer than machine-made XNAs.

"They took enzymes that already existed, and evolved mutants of them that are better at making XNAs," says Floyd Romesberg, a chemist at the Scripps Research Institute, who called the technique "impressive."

Next, the researchers tried to evolve the XNAs themselves. To do so, they used a similar filtering technique. In this case, the scientists selected for XNAs that could bind to a specific protein; XNAs that did not bind to the proteins were washed away. Those that did bind were transcribed back into DNA so that they could be replicated. After replication, the team transcribed the copies back into XNA. In this way, the XNAs that had evolved to bind the protein were able to pass on that talent to a new generation of XNAs.

Synthetic DNA, Synthetic Life?

Because the XNAs are able to pass genetic information from one generation to the next and can adapt to the constraints of test tube evolution, Chaput says, XNAs could serve as the building blocks for completely new genetic systems. "Could you create synthetic life with it? That's possible, but it's much further down the road."

Szostak agrees, saying that "in the longer run, a very interesting implication is that it may be possible to design and build new forms of life that are based on one or more of these non-natural genetic polymers." But Romesberg emphasized that creating completely new life forms using XNA would be a long and difficult mission. The foremost challenge: Researchers must find an efficient way to reproduce XNAs directly into more XNAs without having to convert them to DNA and back again.

Some folks are nervous that releasing XNA into the biosphere could allow it to intermingle with DNA and RNA with unpredictable results. But scientists such as Steven Benner and Markus Schmidt retort that XNAs are foreign enough to be invisible to natural organisms (read more about this issue here).

Regardless of whether XNAs can or will be used to create new life forms, the researchers have shown that it is possible to expand evolution into systems based not on DNA or RNA. And the XNAs and their enzymes may also lead to some answers about why life as we know it is based on those to molecules only. Are DNA and RNA the best molecules to store genetic information and catalyze biological reactions, or did they become the building blocks of life by sheer happenstance? Now researchers will have the tools to test the true efficiency against lab-created competitors.

Medicine, too, could benefit from XNAs, Romesberg says. Doctors already prescribe biological products such as enzymes and antibodies to treat certain diseases, but these drugs break down quickly in the stomach and the blood stream. Because XNAs are somewhat foreign, they're not broken down as quickly in the body, as it has not evolved enzymes to digest them.

The experiment also has implications for looking for life on other planets. "Maybe if you look hard enough out in space, you might find a life form based on XNA," Chaput says.