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Government by the Banks, for the Banks: The ESM Coup d'Etat in Europe

By Ellen Brown, Truthout, July 1, 2012

On Friday, June 29, German Chancellor Angela Merkel acquiesced to changes to a permanent Eurozone bailout fund – "before the ink was dry" – as critics complained. Besides easing the conditions under which bailouts would be given, the concessions included an agreement that funds intended for indebted governments could be funneled directly to stressed banks.

According to Gavin Hewitt, Europe editor for BBC News, the concessions mean that: [T]he Eurozone's bailout fund (backed by taxpayers' money) will be taking a stake in failed banks.

Risk has been increased. German taxpayers have increased their liabilities. In future a bank crash will no longer fall on the shoulders of national treasuries but on the European Stability Mechanism (ESM), a fund to which Germany contributes the most.

In the short term, these measures will ease pressure in the markets. However there is currently only 500B euros assigned to the ESM. That may get swallowed up quickly and the markets may demand more. It is still unclear just how deep the holes in the Eurozone's banks are.

The ESM is now a permanent bailout fund for private banks, a sort of permanent "welfare for the rich." There is no ceiling set on the obligations to be underwritten by the taxpayers, no room to negotiate, and no recourse in court. Its daunting provisions were summarized in a December 2011 YouTube video originally posted in German, titled "The shocking truth of the pending EU collapse!"

The treaty establishes a new intergovernmental organization to which we are required to transfer unlimited assets within seven days if it so requests, an organization that can sue us but is immune from all forms of prosecution and whose managers enjoy the same immunity. There are no independent reviewers and no existing laws apply. Governments cannot take action against it. Europe's national budgets [are] in the hands of one single unelected intergovernmental organization.

Here are some of the ESM's key provisions:

[Article 8] "The authorised capital stock shall be EUR 700,000 [700 billion Euros]."

[Article 9]: "ESM Members hereby irrevocably and unconditionally undertake to pay on demand any capital call made on them…such demand to be paid within seven days of receipt."

[Article 10]: "The Board of Governors… may decide to change the authorised capital and amend Article 8…accordingly."

[Article 32, paragraph 3]: "The ESM, its property, funding, and assets…shall enjoy immunity from every form of judicial process…."

[Article 32, paragraph 4]: "The property, funding and assets of the ESM shall…be immune from search, requisition, confiscation,

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Coup d'état *from page 1*

expropriation, or any other form of seizure, taking or foreclosure by executive, judicial, administrative or legislative action."

[Article 30]: "…Governors, alternate Governors, Directors, alternate Directors, as well as the Managing Director and other staff members shall be immune from legal proceedings with respect to acts performed by them in their official capacity and shall enjoy inviolability in respect of their official papers and documents."

And that was before Merkel's recent concessions, which allow this open-ended indebtedness to be funneled directly to the banks.

Why Did Merkel Cave?

"Reactions back home were devastating," reported *der Spiegel*. "[T]he impression was that [Merkel] had been out-manoeuvred by Italian Prime Minister Mario Monti and Spanish Prime Minster Mariano Rajoy."

As of June 21, 13 of 17 countries still had not ratified the ESM; and the most important ratification needed was Germany's, the largest economy in the Eurozone. Earlier, Angela Merkel had opposed using the bailout fund to pump money directly into struggling European banks. But at the EU summit that began on Thursday and dragged on well into the night, she finally relented. Late Friday evening, German lawmakers voted 493-106 in favour of the €700 billion ($890 billion) permanent bailout fund.

What caused Merkel to back down? According to an article in *The Economist*, the late night was "filled with bluff and bluster," in which Mariano Rajoy, the Spanish prime minister…, along with Italy's Mario Monti, had threatened to block any agreement at the summit unless their demands were met. Mr Rajoy obtained satisfaction, but the same is not quite true of Mr Monti, who had been the most adamant of the two.

Mr Monti declared himself satisfied, but caused considerable irritation to partners. Among the deals he had blocked was the "growth pact," a mixture of stimulus measures. What Monti achieved by this manoeuvre was not clear:

"Who needs the growth pact? Not Germany," said one bemused participant. The euro zone's fiscal hawks say the bond-buying mechanism will be little different from the existing system. "Mario Monti raised a gun to his head and threatened to shoot himself. In the end he wounded himself in the shoulder," said one scornful diplomat.

Maybe. Or maybe the bond-buying mechanism was not what he was really after.

The Italian Coup d'Etat

There is reason to suspect that "Super Mario" Monti may be representing interests other than those of his country. He rose to power in Italy last November in what critics called a "'coup d'etat' engineered by bankers and the European Union." He was not elected but stepped in after Prime Minister Silvio Berlusconi resigned under duress.

Monti is not only an "international advisor" to Goldman Sachs, one of the most powerful financial firms in the world, but a leader in the Bilderberg Group and the Trilateral Commission. In an article in *The New American*, Alex Newman calls these clandestine groups "two of the most influential cabals in existence today." Monti is listed as a member of the steering committee on the official Bilderberg website and as the European Group chairman on the Trilateral Commission website.

The Trilateral Commission was co-founded in 1973 by David Rockefeller and Zbigniew Brzezinski, also Bilderberger attendees. The Trilateral Commission grew from the thesis in Brzezinski's 1970 piece *Between Two Ages: America's Role in the Technetronic Era* that a coordinated policy among developed nations was necessary to counter global instability erupting from increasing economic inequality. He wrote in his 1997 book *The Grand Chessboard* that it would be difficult to get a consensus on these issues "except in the circumstance of a truly massive and widely perceived direct external threat."

Naomi Klein calls it "the shock doctrine" – an induced disaster forcing austerity measures on sovereign nations. In desperation, they would come to heel, relinquishing the sovereign right of governments to an unelected body of technocrats. And that is what the ESM seems to achieve.

Rockefeller notoriously wrote in his 2002 autobiography, "Some even believe we are part of a secret cabal working against the best interests of the United States, characterizing my family and me as 'internationalists' and of conspiring with others around the world to build a more integrated global political and economic structure – one world, if you will. If that's the charge, I stand guilty, and I am proud of it."

Implementing the Shock Doctrine

In another bankers' coup last November, former Goldman Sachs executive Mario

Draghi replaced Jean-Claude Trichet as head of the European Central Bank. The European Stability Mechanism quickly followed. It was a permanent rescue facility intended to replace certain temporary facilities as soon as the member states had ratified it, slated to occur by July 1, 2012. The ESM came to an initial vote in January 2012, when it was passed in the dead of night with barely a mention in the press.

The recent modifications were also agreed to in the dead of night, ostensibly because Italy and Spain were afflicted with onerously high interest rates. But there are other ways to bring down interest rates on sovereign debt besides forcing whole countries into open-ended pacts to bail out private banks for unlimited sums in perpetuity, in the hope that the banks might bail the governments out in return.

The US 2012 budget deficit is significantly worse than either Italy's or Spain's, yet somehow the US has managed to keep interest rates on its debt at record lows. How has it pulled this off?

One theory is that JPMorgan's $57 trillion in interest rate swaps have something to do with it. Another explanation, however, is that the Fed has simply stepped in as lender of last resort and bought up any debt not sold at the low rate set by the Treasury, using "quantitative easing" (money created on a computer screen). Between December 2008 and June 2011, the Fed bought a whopping $2.3 trillion of US bonds in two rounds of quantitative easing. Why can't the European Central Bank do the same thing? The answer is that there are rules against it, but rules are just arbitrary agreements. They can be changed by agreement – and often have been, to save the banks.

As the cynic quoted in *The Economist* article above observed, the bond-buying mechanism for countries under the ESM will be little different from the existing system. Mario Monti said the plan will support government bond prices only in countries that comply with fiscal targets, and that it will act as an incentive for governments to follow virtuous policies. That means avoiding deficits, even it if requires further austerity measures and selling of assets. On the public level, that could mean national treasures like the Acropolis. On the private level, *The New York Times* reported Friday that some desperate out-of-work Europeans were going so far as to sell their kidneys to pay household bills. The shock doctrine, it seems, has come to the doorsteps of privileged Westerners.

The German diplomats negotiating the ESM did leave open some escape hatches, including a request by Germany's highest court to the country's president not to sign the treaties into law until a legal review can be completed. At least 12,000 complaints are expected to be filed with the Federal Constitutional Court regarding the ESM and the fiscal pact. The legal review could well conclude that the ESM illegally hijacks taxpayer funds for private bank profit.

It is one thing to pool national resources to bail out other sovereign governments, quite another to write a blank check to bail out the profligate private banks that precipitated the global downturn. Europe has a strong tradition of publicly-owned banks. If the people must bear the costs, the people should own the banks and reap the benefits.

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Our Comment. It is, of course, speculative banks that must be controlled. Ordinary banks that limit their investment to short-term trading for the convenience of say a grocers and another small traders would still be essential for the convenience of the public. *W.K.*

The French Still Flock to Bookstores

By Elaine Sciolino, The New York Times, June 21, 2012

Paris – The French, as usual, insist on being different. As independent bookstores crash and burn in the United States and Britain, the book market in France is doing just fine. France boasts 2,500 bookstores, and for every neighborhood bookstore that closes, another seems to open. From 2003 to 2011 book sales in France increased by 6.5 percent.

E-books account for only 1.8 percent of the general consumer publishing market here, compared with 6.4 percent in the United States. The French have a centuries-old reverence for the printed page.

"There are two things you don't throw out in France – bread and books," said Bernard Fixot, owner and publisher of XO, a small publishing house dedicated to churning out best sellers. "In Germany the most important creative social status is given to the musician. In Italy it's the painter. Who's the most important creator in France? It's the writer."

A more compelling reason is the intervention of the state. In the Anglophone book world the free market reigns; here it is trumped by price fixing.

Since 1981 the "Lang law," named after its promoter, Jack Lang, the culture minister at the time, has fixed prices for French-language books. Booksellers – even Amazon – may not discount books more than 5 percent below the publisher's list price, although Amazon fought for and won the right to provide free delivery.

Last year as French publishers watched in horror as e-books ate away at the printed book market in the United States, they successfully lobbied the government to fix prices for e-books too. Now publishers themselves decide the price of e-books; any other discounting is forbidden.

There are also government-financed institutions that offer grants and interest-free loans to would-be bookstore owners.

The contrast between the fate of English- and French-language bookstores is playing out in Paris these days.

Next month, after 30 years in business, the leading English-language Paris bookstore will close. For a generation authors like David Sedaris, Susan Sontag, Raymond Carver and Don DeLillo gave talks and readings at the store, the Village Voice, on one of the chicest streets of St.-Germain-des-Prés.

"When Stephen Spender gave a talk, Mary McCarthy was in the audience," Hazel Rowley wrote in a 2008 essay on the bookstore. "One evening Edmund White introduced Jonathan Raban, with Bruce Chatwin among the audience." But the Village Voice could not survive the deep discounting of Amazon and sellers of e-books.

The spectre of loss hovered over a party there Saturday night, when hundreds of well-wishers crammed into the store and spilled out onto the narrow street to mourn its passing.

"I want you to know what a privilege it was to have you come and sit with me in my dark and cramped little den at the back of the bookshop, to chat, talk about books, about your own work and about life," said Odile Hellier, the founder and owner. "I will dearly miss those moments and can only hope that there will be another dark little den where I can sit and share ideas, and all the rest."

It may have to be in a French-language bookstore like L'Usage du Monde across town in the heart of a gentrifying neighbourhood of the 17th Arrondissement, which will celebrate its first anniversary in August.

The owners, Katia and Jean-Philippe Pérou, received grants from the National Center of the Book in the Culture Ministry and the Paris regional government and an interest-free loan from a group with the unwieldy name the Association for the Development of the Bookstore of Creation.

"We couldn't have opened our bookstore without the subsidies we received," Ms. Pérou said. "And we couldn't survive now without fixed prices."

Beneath the surface there are predictions that France is only delaying the inevitable, and that sooner or later market forces will prevail. Despite the appeal of the neighbourhood bookstore 13 percent of French books were bought on the Internet in 2011.

An agreement that Google announced this month with the French Publishers Association and the Société des Gens de Lettres, an authors' group, should allow publishers to offer digital versions of their works for Google to sell. Until now sales of e-books have lagged in France and much of the rest of Europe in part because of disputes over rights.

"We are in a time of exploration, trial and error, experimentation," Bruno Racine, president of the French national library, wrote in his 2011 book, *Google and the New World*. "Many scenarios are envisioned. The least probable is certainly that of a victorious resistance of the paper book."

A 59-page study by the Culture Ministry in March made recommendations to delay the decline of print sales, including limiting rent increases for bookstores, emergency funds for booksellers from the book industry and increased cooperation between the industry and government.

"Running a bookstore is a combat sport," the report concluded.

One tiny operation determined to preserve the printed book is Circul'livre.

On the third Sunday of every month this organization takes over a corner of the Rue des Martyrs south of Montmartre. A small band of retirees classify used books by subject and display them in open crates.

The books are not for sale. Customers just take as many books as they want as long as they adhere to an informal code of honour neither to sell nor destroy their bounty. They are encouraged to drop off their old books, a system that keeps the stock replenished.

"Books are living things," said Andrée Le Faou, one of the volunteer organizers, as she hawked a three-volume biography of Henri IV. "They need to be respected, to be loved. We are giving them many lives."

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Our Comment. The same must be said of any aspect of human history – good or bad. It is only by assessing and remembering our past experiences that humanity can hope to survive. In a very real sense we must consider any aspect of our past as a critical tool contributing to the human race having a future. *W.K.*

Secret EU Summit Document Shows First Step to Banking Union

A classified draft of [the June] EU summit conclusions is the first step on an emerging "roadmap" to a banking union, pooling debt via Eurobonds and political union via EU treaty change over the next 10 years.

By Bruno Waterfield, The Telegraph, June 17, 2012

The "limite" text – published exclusively by *The Daily Telegraph*, is secret, restricted for the "eyes only" of diplomats and officials preparing for the 28 and 29 June European Council in Brussels.

Most of the text, the annexed "Compact for Growth and Jobs," are deals on project bonds and other small scale EU initiatives that François Hollande is trumpeting as a €120 billion "growth pact."

The first draft is relatively uncontroversial because the Eurobond and "banking union" issues are currently all too sensitive to be committed to paper for officials.

Other so-called "non-papers" are circulating at a top secret level between national capitals and Brussels.

The difficult issues not included in the draft are the "p.m." items in the draft: "other financial stability measures" and "PEC report on EMU."

Translated from the Brussels jargon, the PEC – president of the European Council – report will be Herman Van Rompuy's preliminary text of the future of "Economic and Monetary Union." This will be circulated in sealed envelopes next week.

The separate text will set out a "roadmap" to a banking union, polling debt via some kind of Eurobonds and political union via EU treaty change over the next 10 years.

Also important and controversial will be the "other financial stability measures" paper, including a financial transition tax proposal and moves towards a banking union that can be taken by the EU before the end of the year.

Britain faces a major fight over an FTT, or some other banking levy, at a meeting of EU finance ministers on Friday ahead of the summit next week.

The UK – which has no veto under current proposals on deepening EU banking regulation – also faces the ECB becoming Europe's main banking regulator and the creation of national bank resolution funds that can be asked to contribute to European bank bailouts on a "compulsory" basis.

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Our Comment. What is emerging ever more clearly is this: modern Greece remains increasingly cut off from its great historic achievements precisely because speculative banking throughout the world could not survive humanity's unique heritage from ancient Greece.

Developed above all by Plato, pupil of the sacrificed Socrates who "merely" asked the key questions that made inevitable the answers of Plato, and others of that portentous school of great keys. In a sense today it is Greece's great misfortune that it is *verboten* to claim its unique historic heritage because, when it does, speculative banking will be attacking throughout the world.

Human capital would be recognized not as something that *can* be recognized but that *must* be recognized. Governments would no longer be allowed to consider investment in human capital as something they cannot afford.

On the contrary it is becoming ever clearer that the great heritage of which Greece is being deprived is essential to bringing in the most elementary basic accounting in government books in every country in this misgoverned world.

W.K.

Worried Banks Resist Fiscal Union

By Landon Thomas Jr., The New York Times, June 18, 2012

The seemingly endless series of euro zone crises has European officials pushing for a banking union that would watch over and bind together the currency group's faltering financial institutions.

But for Europeans, there seems to be little appetite for such a compact right now. In fact, banks and their national regulators, anxious about the Greek elections and Spain's hastily arranged bailout, are behaving more parochially than ever.

That poses a threat to the interbank lending across borders that is crucial to maintaining liquidity – the free flow of money that is the lifeblood of the global financial system.

French and German banks have clamped off much of the lending to their counterparts in Italy and Spain, which in turn are primarily giving loans to their own debt-laden governments.

And in Madrid, even after European finance ministers agreed to a 100 billion euros, or $125 billion, rescue of Spain's failing banks, the always proud Spanish government is insisting that it – and not Brussels bureaucrats – will take charge of how and where the funds are deployed.

With interbank cooperation at perhaps its lowest level since the creation of the euro currency union, European officials say they are moving toward a broader solution.

Experts warn, though, that what is needed now is not another working paper proposing new levels of euro bureaucracy, but a clear action plan that addresses the root issue: markets and investors have lost faith in Europe's ability to regulate its banks.

"Why do you think European banks won't lend to Spanish banks?" asked Karel Lannoo, chief executive of the Brussels-based Center for European Policy Studies and an expert on bank regulation in Europe. "Because they do not trust Spanish regulators. Has Citigroup stopped lending to California? No. What we need is a single banking supervisor and a single settlement system like in the United States. And we have no time to lose."

Top officials at the United States Treasury and the International Monetary Fund have also been warning for more than a year that there can be no easy resolution to the euro crisis until Europe solves its banking problem.

Mario Draghi, the head of the European Central Bank in Frankfurt – right now the closest thing the euro zone has to a banking coordinator – said Friday that he and top European Union officials in Brussels would present a master plan for the euro project in a matter of days.

A blueprint is only that, however. Substantial changes that would affect banks and national budgets would probably require treaty changes and voter approval. That process could take many months and there is no guarantee of success.

As part of the push, the European Commission published proposals this month that would include creation of a Europe-wide banking supervisor whose oversight powers would trump those of local regulators.

And to discourage the flight of bank deposits from weaker countries, a problem that has plagued Greece and now Spain, the European Commission proposed a deposit insurance fund for the entire euro zone, analogous to the Federal Deposit Insurance Corporation in the United States. Individual euro zone member nations already have deposit insurance. But the Spanish fund, for one, is nearly insolvent.

Under the Brussels proposal, a new banking regulator would also have the authority to share the financial pain of bank bailouts by forcing some holders of the bonds of bailed-out banks to absorb losses.

Hoping to impose such changes sooner than formal treaty revisions would allow, Mr. Lannoo of the Center for European Policy Studies proposed an elegant solution in a recent paper.

He says there is already an article in the European Union treaty (Article 127.5, to be exact) that would let the European Central Bank take on supervision of euro zone members' banks, provided that the finance ministers of the 17 countries that use the euro approve such a step unanimously. That would be faster than getting the approval of 17 national governments.

And it would be in tune with a global trend of giving central banks ultimate responsibility for bank safety, while giving the European Central Bank the ability to spot and address banking disasters in countries like Ireland and Spain before they become a Europe-wide threat.

But even if support was gathering for greater banking consolidation in Europe, there would be political obstacles.

For one thing, putting the European Central Bank in charge would neuter the London-based European Banking Authority, which was set up by Brussels to oversee European banks. Although the authority has been widely ridiculed for its toothless stress tests that missed banking fiascos in Ireland and Spain, entrenched bureaucracies are seldom easy to eliminate.

Even as the policy debate proceeds, nervous European banks have been slashing their short-term loans to Italy and Spain at a time when those banks, which depend largely on such loans to survive, are desperate for capital.

French loans to Spanish banks plunged 34 percent in the fourth quarter of 2011 compared with the previous quarter, according to the latest data from the Bank for International Settlements.

For Italian banks, French bankers cut their exposure by 16 percent. German banks have also been increasingly wary of their Italian and Spanish peers, reducing lending to them by about 19 percent last year.

More recent data, once available, are almost certain to show even tighter purse strings, analysts say.

In the last six months, as fears about Spain and Greece have intensified, Spanish and Italian banks have been by far the biggest users of the European Central Bank's program of cut-rate, three-year loans to banks that cannot find money elsewhere.

But instead of funneling that money back into the Spanish and Greek economies as loans to cash-starved businesses and individuals, these banks have become the primary buyers of their governments' bonds. That has perpetuated a nasty cycle in which the problems of the government become the problems of its banks, and vice versa.

"What we are seeing is a localization of risk in Europe," said Alberto Gallo, a senior credit strategist at the Royal Bank of Scotland in London. "Or, a reverse integration of financial and banking markets. And as

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this continues, it will be much harder to go back to normal."

In many ways, the extent to which Brussels is committed to going beyond words and working papers will be tested soon in Spain. Even though Europe has agreed to lend Spain money to fix its banks, Spanish government officials continue to resist European advice on how to proceed.

For example: When Joaquín Almunia, the Spanish-born European Union commissioner for competition, said recently that at least one Spanish bank might need to be shut down, officials in Madrid rejected his suggestion. In some quarters, Mr. Almunia's patriotism was even questioned.

Most delicate will be whether the Spanish banks receiving the largest cash injections, like the nationalized mortgage giant Bankia, will be forced to impose losses on holders of their subordinated bonds. Those are the investors whose bonds are not backed by collateral and are thus considered more risky.

Such a "bail-in" feature is a central plank of Brussels's banking union plan, and it is widely supported by industry experts because it would punish investors for taking undue risks. In Ireland, those types of bondholders were wiped out when Irish banks were recapitalized.

In Spain, though, the problem is that 62 percent of the holders of Bankia's subordinated debt are Spanish individual investors, not overseas hedge funds and investment banks. It is not likely that Madrid will be willing to hit those citizens with a 65 percent loss – the loans are currently priced at about 35 cents on the dollar – at a time of 25 percent unemployment in the country.

It is too early to know whether Brussels will override Spanish political considerations and force such a write-down as a condition for lending bailout money. If it does not, doubts will continue over Europe's ability to deliver a banking union plan with real authority.

"There are compelling reasons for the euro zone to insist on losses for subordinated and even senior bondholders, the least of which is a reduction in moral hazard," said Adam Lerrick, an expert on banking and sovereign debt at the American Enterprise Institute. "Losses for bondholders is now euro zone policy, so Europe's credibility is also at stake."

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Our Comment. At a time when unemployment in Spain is running at about 25 percent, it would be political suicide to hit citizens with losses dictated by the theoretical calculations that disregard the survival needs of its jobless citizens. Unless such survival needs of its unemployed are given crucial attention, they are playing hopeless games with meaningless numbers. Persisted, in the end the result could be utter social collapse. *W.K.*

Demonstration of Support from Canada

William Krehm, economist, 98 years old, traveled from Canada to Athens [in June], with one purpose in mind: to encourage and support the struggle of SYRIZA. That was the reason he met with the head of the parliamentary group, Alexi Tsipras.

"The message I want to send is really a complaint: to denounce the dominance of the speculative commands of the banks against politics. Commands like these, such ordinates, aim at ignoring human capital. To transform this, too, into a component of the betting game."

And he went on: "This deadly condition concerns not only Greece, but the entire world. The loop they have passed on the neck of Greece today applies to the global economy as a whole. Mankind is not able to reverse its course toward self-destruction without recognizing the critical importance of the ancient Greek heritage."

A heritage that today is threatened, as the lush Krehm recognizes, from the austerity policies directed against the cultural infrastructure. "To address these as a liability is what Is leading humanity towards self-destruction."

William Krehm, who took part in the Spanish Civil War ("I must say that anarchists behaved wonderfully"), an influential member of the Committee on Monetary and Economic Reform, which publishes a business magazine in Canada, decided to make this journey to Athens in solidarity and support for the struggle of SYRIZA. "Age is irrelevant," he laughs. "Nothing could deter me from this trip…."

This is the translation form an article that appeared in the Greek newspaper Synentexy *on June 16, 2012.*

China Joins Effort to Spur Growth

Decisions by three of world's five key banks the most dramatic dose of collective action since the financial crisis.

By Kevin Carmichael, The Globe and Mail, July 6, 2012

Washington – An economic slowdown is causing alarm in China and Europe, forcing central banks in both regions to cut borrowing rates.

The People's Bank of China dropped its main lending rate to 6 percent from 6.31 percent on Thursday, surprising investors because Governor Zhou Xiaochuan had cut interest rates only a month earlier. In Frankfurt, the European Central Bank reduced its benchmark rate by a quarter of a percentage point to 0.75 percent, the lowest in the history of the euro zone. The Bank of England also took measures to inject money into the financial system to give a lift to the flagging UK economy.

While the European moves were anticipated, the unexpected addition of China introduced a sense of drama, as together, the three decisions represented the most dramatic dose of collective action by central banks since the financial crisis of 2008-09.

"There seems to be some kind of co-ordination going on" among policy makers, said Daniel Bain, chief investment officer at Toronto-based Thornmark Asset Management Inc., which oversees investments worth $500 million. "That co-ordination is required because the global economic fundamentals are weak."

While Europe's economy has been struggling for some time, it is China that is causing much of the concern lately. After leading the world economy out of the recession in 2009, the world's second-largest economy is struggling to generate enough domestic demand to make up for diminished exports to Europe, where growth has all but stalled because of the region's sovereign debt crisis.

Two weeks ago, the Federal Reserve also took action, extending a stimulus measure that was set to expire; Chairman Ben Bernanke said the US central bank was prepared to do more if the job picture failed to improve. The US unemployment rate is 8.2 percent, compared to 5 percent at the start of 2008, and is not expected to change much when the latest data on the labour force are released today.

A deteriorating global economy could force the Bank of Canada to further delay its plans to raise its benchmark lending rate back to a more typical level. Earlier this week, economists at BMO Nesbitt Burns in Toronto said they don't expect the bank to raise short-term rates until July 2013; previously, they had expected a rate hike in January. As long as US rates stay low, the Bank of Canada's room to manoeuvre is limited because significantly higher interest rates in Canada would put upward pressure on the Canadian dollar. At a time when global trade is weak, a stronger currency would represent an additional blow to Canadian exporters.

It's unclear whether the measures announced Thursday will have much impact. Equity markets were little changed, a signal that investors were either spooked that the global economy is deteriorating, or doubtful of policy makers' ability to turn things around.

China could be in a new phase of reducing borrowing costs, after spending much of last year making money more expensive in order to deflate a real-estate bubble. Anything that encourages China's middle class to spend will be good for the global economy in the short term, although the country's recent slowdown in growth suggests its consumers are a long way from spending like Europeans and North Americans.

The ECB's benchmark interest rate now is lower than it was during the financial crisis. The central bank also said it would stop paying interest on the money private lenders stash at the ECB, a measure meant to encourage banks to take some risks by lending more to consumers and businesses.

Yet some analysts said the ECB was too timid, and could have cut its key rate by half a percentage point to 0.5 percent. Many observers of the situation in Europe, including Mr. Bain, say the central bank must commit to buying the debt of countries such as Italy and Spain to keep borrowing costs in these countries under control. Only then will such economies have the breathing room necessary to grow, Mr. Bain said.

ECB president Mario Draghi conceded that one the biggest issues in Europe is that there is little demand for loans, no matter the price. Yet he argued the ECB's latest measures would have an important psychological effect by boosting confidence.

Even though economic growth in the euro zone "is hovering around zero, basically," the ECB continues to expect a "gradual, slow recovery around the end of the year," Mr. Draghi said.

The ECB says that rebound will come from improved sentiment in financial markets and a stronger demand for European goods and services from other parts of the world. It's a shaky promise, and quite possibly depends on how Mr. Draghi and other policy makers react over the next few months. Best-case scenarios have tended to fall apart in recent years, just as they are now. "Downside risks are materializing," Mr. Draghi said.

Our Comment

Our private shock at finding that after our dependence on "the market" to support the currency that we were counting on, so that we could brace our courage to support an alleged miracle drug, that actually required such support has actually come from Beethoven himself in the piano part of his great *Tenth Sonata for Violin and Piano*.

That was no small detail since it was no longer possible with sources debunked in Beethoven's masterful score of this work. Communications by the previous rules upon which my medical doctors had counted in other cautious prescriptions, no longer made sense. That left neither nook nor cranny unexplored.

Small enough chance indeed, for relationships hidden from the analytical powers of genius, no matter what the medium!

W.K.

The Bookstore on page 6 lists other titles. Note the special Combo Offers.

Quantum Mechanics: The Physics of the Microscopic World

Course guidebook by Professor Benjamin Schumacher, Kenyon College. Published by The Great Courses, Chantilly, Virginia, 2009.

Editor: This undoubtedly is amongst the most important books I have set eyes on. The following is an extended excerpt.

Quantum mechanics is the fundamental physics of the microscopic world, the domain of atoms and photons and elementary particles. The theory was developed in the early 20th century by Planck, Einstein, Bohr, Heisenberg, and others. Though physics has advanced quite far in the decades since quantum mechanics was born, it remains the basic framework for our deepest insights into nature.

Yet although it is a cornerstone of modern physics, quantum mechanics remains a profoundly strange picture of reality. The quantum world confronts us with mind-bogging questions. How can light be both wave and particle? What does it mean when 2 quantum particles are "entangled" – a relationship so weird that Einstein called it "spooky"? Is there really a vast amount of energy in empty space? Can the laws of quantum physics someday make our computers faster and our messages more private?

This course is an introduction to the fundamentals of quantum mechanics, accessible to students without any previous preparation in math and physics. In 24 lectures, using a small toolkit of simple concepts and examples, we will trace the origins of the theory of quantum mechanics, describe its basic principles, and explore some of the most remarkable features of the quantum world.

After surveying the way ahead, the course begins by describing the theories of physics that prevailed before the quantum revolution. We will see how Max Planck and Albert Einstein introduced quantum ideas to explain certain mysterious properties of light. These ideas soon spread to all of physics, affecting our understanding of all types of matter and energy. A central idea is the notion of "wave-particle duality," in which the entities of nature (electrons and so on) can exhibit the characteristics of both waves and particles. This will lead us to Werner Heisenberg's famous uncertainty relation. The new physics posed many puzzles for its founders. This was nowhere better exemplified than in the great debate between Einstein and Niels Bohr over the validity and meaning of quantum mechanics.…

Next we will turn to the task of presenting quantum theory in its clearest and simplest form. We will do this through a careful analysis – a thought experiment involving a single photon traveling through an apparatus called an "interferometer." We will see how this distinction plays a role in phenomena including lasers, superfluids, the structure of atoms, and the property of solids.

This will lead us to our next topic, the riddle of quantum entanglement. As we will show, the behavior of entangled particles challenges some of our most deeply held intuitions about the physical world. Almost as bizarre is Richard Feynman's startling idea that a quantum particle moves from point A to point B by following *every possible path* from A to B, each path making its own contribution. By applying Feynman's principle and the uncertainty principle to "empty space." We find even the vacuum is a realm of ceaseless quantum activity.

Quantum information theory is a relatively new branch of quantum physics. In our lectures, we will describe some of its remarkable concepts. Unlike ordinary information, quantum information cannot be perfectly copied. It can, on the other hand, be used to send perfectly secret messages and to perform "quantum teleportation." It may even be possible to use quantum physics to construct a quantum computer, a novel and extremely powerful machine for solving mathematical problems.

Our course concludes with a discussion of some philosophical questions. What is the real meaning of quantum mechanics? What does it tell us about the nature of our world? Do our choices and observations help to bring reality into being? Does the randomness of the quantum realm disguise a deeper, universe-spanning order? Or are the myriad possibilities of quantum physics all parts of a complex "multiverse" beyond our imaging? What deep principle links together the many mysteries of the quantum world?

A note about mathematics: quantum mechanics is often named in highly abstract mathematical terms. (Open any advanced textbook on the subject and see for yourself!) Yet the central ideas of quantum mechanics are not at all complicated and can be understood by almost anyone. With a few careful simplifications and very little math, it is possible to embark on a serious exploration of the quantum world.…

Lecture 1

In this course, we are embarking on a journey to a distant world, a world governed by strange and unfamiliar laws… By distant, I mean a world far from our everyday experiences, a world distant not in space, but in size. It's the world of the microscopic world.

What is quantum mechanics? "Mechanics" is the branch of physics – the way things in the universe evolve over time. "Classical mechanics" is based on Newton's laws of motion.

That studies force and motion. This was the prevailing view of the world before about 1900. It is a branch of classical physics, which also includes thermodynamics and electromagnetism. "Quantum mechanics" is a new theory developed between 1900 and 1930 to replace Newton's laws, especially to account for the behavior of microscopic pieces of matter. "Quantum theory" is a more encompassing term, including a wider general application of quantum ideas. "Quantum physics" is the most general term for the physics of the microscopic real.

Quantum mechanics is the most successful physical theory ever devised. It explains the structure of atoms, their combination into molecules, the interaction of light with matter, the behavior of solids and liquids near absolute zero, and many other phenomena. Quantum theory remains the general framework within which modern theories of physics are formed. For example, superstring theory (an exciting but speculative theory of elementary particles and forces) is a quantum theory.

Quantum physics challenges our imaginations in new and unexpected ways. First, quantum theory has a number of surprising implications for probability, the motion of particles, the properties of energy, the strange connectedness of separated systems, and the behavior of information at the smallest scales. The "weirdness" of quantum theory is not an incidental feature. It is at the center of the theory, required to make a consistent, accurate physical theory of the microscopic world.

Second, quantum physics has inspired profound philosophical discussions about the basic nature of the physical world. These will also be part of our story. Albert Einstein and Niels Bohr carried on a famous debate on the new physics in the early years of quantum mechanics. Also, the phenomenon of quantum entanglement has led us further and further away from a "commonsense" view of the microscopic realm, Even today, there are several competing ideas about how to interpret the mathematical theory of quantum mechanics.

Before we start off, we need to set some ground rules.… First, we will simplify our discussion to highlight the fundamental principles, and we will try to note when this happens. Don't be too worried about this. The course explains the real theory, in simplified form. Also, we will often consider "thought experiments" – highly idealized experiments that might be possible in principle, although they may be impractical. In most cases, a more complicated and realistic version can actually be done in a lab.

How will we use mathematics? We will sometimes express the ideas of quantum mechanics symbolically, and we will learn a few simple rules for manipulating and interpreting the symbols.…Venturing a short way into the abstract mathematics of quantum theory will allow us to explore the quantum world in a much deeper way.

Questions to consider:

1. In the remarkable short film, *Powers of Ten,* Charles and Ray Eames "zoom in" on a scene by a magnification of x10 every few seconds. Imagine creating such a film of your own. You'll needs 8 of these x10 stages to go from a 1-inch aluminum cube down to a single aluminum atom. What sorts of common things (bugs, dust specks, cells, molecules) would you show at each stage from cube to atom?

2. In the lecture, we described several conceptual puzzles posed by quantum theory. Which of these seems most intriguing to you?

The View from 1900, Lecture 2

Throughout the history of human thought, there have been essentially 2 ideas about the fundamental nature of the physical world.… In a nutshell, those 2 ideas are whether the world is made out of things [discrete, indivisible units] or the world is made out of stuff [smooth continuous substances].

In modern terms, you can think of things as digital and stuff as analog. But if we travel back to a much earlier historical period, we can find a version of this debate among the Greek philosophers. The atomists, led by Democritus, considered the world to be composed of discrete, indivisible units called "atoms." Everything is made of atoms, with empty space between them. All phenomena are due to the motions and combinations of atoms. Other philosophers, including Aristotle, believed on the contrary that the basic substances of the world are continuous and infinitely divisible.

The debate resurfaced in the 17th century as early physicists tried to understand the nature of light. Isaac Newton believed that light is a stream of discrete corpuscles that move in straight lines unless their paths are deflected. Different colors of light correspond to different types of corpuscles. Christian Huygens believed that light is a continuous wave phenomenon analogous to sound. These waves propagate through space, and different colors correspond to different frequencies of the waves. Waves are characterized by their speed v, their wavelength λ, and their frequency f. These are related by the equation $v = \lambda f$.

In the 19th century, classical physicists arrived at a very successful synthesis of these ideas to explain the physical world. Matter is discrete, they said, while light is composed of continuous waves. In the 1800s John Dalton realized that chemical compounds could be explained by assuming that elements are composed of atoms of differing weights, which can combine into molecules. This became the fundamental idea of chemistry. Also in the 1800s, James Clerk Maxwell and Ludwig Boltzmann showed how the properties of a gas (pressure, temperature and viscosity) can be explained by viewing the gas as a swarm of huge numbers of tiny molecules, moving according to Newton's laws. Heat energy is just the random motion of these molecules. The theory of heat became unified with the theory of mechanics.

Also in the 19th century, scientists conducted experiments that indicated that light is made of waves. Thomas Young devised his famous 2-slit experiment, in which light shows constructive and destructive interference. This demonstrated that light travels in waves. Young measured the wavelength of visible light, which is less that 1 millionth of a meter. Maxwell showed that light is a traveling disturbance in electric and magnetic fields – in short, an electromagnetic wave. The theory of optics became unified with the theory of electromagnetism.

In 1900, Lord Kelvin gave a lecture at the Royal Institution in which he pointed out "two dark clouds" on the horizon of classical physics. Each dark cloud would turn out to be a hurricane. The first dark cloud was the curious result of an experiment by Michelson and Morley, who tried to detect the presence of the ether (the medium of light waves). This experiment later led to the development of Einstein's theory of relativity, revolutionizing our ideas of space and time. The second dark cloud was the thermal radiation ("blackbody radiation") given off by a warm object. If we try to explain this using classical physics, we get a very wrong result. This problem became the origin of quantum physics.

Questions to consider:

1. In 1900, no one had ever "seen" an atom or even knew exactly how large they were. Why, then, was it reasonable for physicists and chemists to believe in the existence of atoms?

2. The speed of sound is about 343 m/s. The human ear can detect sounds with a frequency range of 20 to 20,000 cycles/s. What range of wavelengths can the ear detect?

3. In the 2-slit experiment, imagine that 1 slit is somewhat larger than the other, so that light waves coming from the 2 slits are not equal in intensity. What would the interference pattern look like?

Two Revolutionaries — Plank and Einstein, Lecture 3

At the beginning of the 20th century, 2 revolutionary thinkers, Max Planck and Albert Einstein, began to question the 19th-century synthesis, and to introduce quantum ideas into physics.… There were just a few leftover experimental puzzles about light and matter, and to solve them, they needed to change the entire structure of physics.

The first puzzle was the problem of thermal radiation. When a solid object is heated, like the filament of an incandescent light bulb, it gives off radiation. The details are hard to reconcile with classical physics. This is sometimes called "blackbody radiation," since the simplest case occurs when the object is black in color. At a given temperature, all black bodies radiate in the same way. When the classic theory of heat is applied to the radiation, it predicts the low-frequency radiation (infrared) pretty well. But it predicts a lot more high-frequency radiation (ultraviolet) than is actually observed or even possible. This is called the "ultraviolet catastrophe."

In 1900, Planck made a strange hypothesis. He supposed that light energy can only be emitted or absorbed by a black body in discrete amounts, called "light quanta." The energy of a light quantum is related to the light frequency by $E = hf$. Where h is called "Planck's constant." Because the value of is so tiny (6.6×10^{-34} J·s), the individual quanta are extremely small. An ordinary light bulb emits around a billion trillion (10^{20}) quanta each second. Since higher frequencies mean higher-energy quanta, groups of atoms cannot emit high-frequency. A wave cannot have any intensity and therefore can carry any amount of energy. Planck's quantum hypothesis (a radical change) emits high-intensity light as readily. Planck's quantum hypothesis is a radical change in the way we look at light.

Einstein examined the problem of the "photoelectric effect." This problem arises from the fact that, when light falls on a polished metal surface in a vacuum, electrons can be emitted from the metal, and this process has several features that are hard to explain if light is a wave. The energy of the electrons does not depend on the intensity of the light. If we use a brighter light, we get more electrons, but each one has the same energy as before. Instead, the electrons' energy depends on the frequency of the light. If the frequency is too low, no electrons are produced. The higher the frequency, the higher the electron energy.

In 1905, Einstein realized that Planck's quantum hypothesis amounts to assuming that light comes in the form of discrete particles, later called "photons." This is the key to understanding the photoelectric effect. Each photoelectron gets its energy from a single photon. Some of this energy goes into "prying it loose" from the metal; the electron flies away with the rest. Photons in bright light or dim light have the same energy, so the electron photons of higher energy and therefore electrons of higher energy are produced.

This third puzzle is the problem of heat capacities. There was a long-standing puzzle about the heat capacities of pure solids – that is, solids made from 1 type of atom. We will consider the examples of platinum and diamond (carbon). The "heat capacity" is the heat energy needed to raise the temperature of the solid by 1°C. Classical heat theory predicts that all pure solids should have the same heat capacity for the same number of atoms. This is because at a given temperature T all vibrating atoms should have the same energy on average. Carbon atoms, being less massive, would vibrate more times per second than platinum atoms, but they would have the same average energy, Experimental results, however, are quite different at 1000°C, both platinum and diamond have about the expected heat capacity. At room temperature, around 20°C, platinum behaves as expected but diamond's heat capacity is too small. At –200°C, both platinum and diamond have unexpectedly low heat capacities.

In 1908, Einstein applied quantum ideas to the vibration of atoms. He proposed that atomic vibration energy only comes in discrete quanta of size $E = hf$. This is the first application of quantum physics to matter rather than to light. It directly challenges Newton's mechanics in which a vibrating atom can have any amount of energy. For any pure solid, at high T there is enough heat energy for all the atoms to vibrate, so the heat capacity is lower than expected. For diamond (carbon atoms), higher vibration f means that the energy quanta are larger. Both –200°C and 20°C count as "low" T. For platinum, only –200°C is a "low" T. Einstein's idea, with a few refinements of detail, explains the heat capacities of pure solids at all temperatures.

Questions to consider:

1. In the phenomenon of photoluminescence, atoms absorb light of one frequency, then reemit light of a different frequency. According to Stock's rule, the emitted light has a lower frequency than the absorbed light. Explain why this fact makes sense given the photon theory. (Einstein discussed Stokes's rule in his photoelectric effect paper).

2. "The quantum discoveries of Planck and Einstein tell us what we once supposed to be continuous is actually discrete" Discuss how this statement applies (if it does) to each of the 3 problems we have described.

Particles of Light, Waves of Matter, Lecture 4

Young's 2-slit experiment demonstrates that light is a wave. On the other hand, Einstein's analysis of the photoelectric effect demonstrates that light is composed of discrete particles…. Our understanding of light must somehow encompass both the wave and the particle ideas.

The quantum view can be summed up as a wave-particle duality. The true nature of light cannot be described in simple terms. Both particle and wave pictures are required to explain the behavior of light. The rule of thumb is this: Light travels in the form of waves, with frequency, wave length, interference effects, etc. De Broglie's idea was rapidly confirmed for electrons, which exhibit interference effects when they pass through the regularly spaced atoms in a crystal. Electron waves constructively interfere in some directions, and destructively in others. Modern experiments have demonstrated the wave properties of even larger pieces of matter, including neutrons and entire atoms. In one recent experiment, a 2-slit experiment was done with C_{60} molecules, which are more than a million times more massive than electrons.

There is a connection between wave and particle properties The Planck-de Broglie relations connect the mechanical properties of waves and particles. A particle of mass m moving at a speed of v has a momentum $p = mv$ and an energy $E = \frac{1}{2}mv^2$. Waves on the other hand are characterized by their wavelength λ and frequency f. Particle properties are connected to wave properties by Planck's constant (h): $E = hf$ and $p = h/\lambda$. The typical wavelength of electrons in atoms is extremely small, <1 nm (10^{-9} m).

The Born rule, named after physicist Max Born, provides another connection between wave and particle properties. A particle has a definite position, but a wave is spread out all over the place. How can we reconcile this? The Born rule states that the intensity of a wave given by the by the square of its amplitude, tells us the probability of finding the particle at any given location. We illustrate the Born rule by examining an electron 2-slit experiment, one particle at a time. Each particle lands randomly, but after billions of particles arrive a statistical pattern emerges. Constructive interference enhances the probability of a particle being found in a given location, while destructive experiences suppress it.

Questions to consider:

1. Let's put some numbers to wave-particle duality. The value of Planck's constant is about 6.6×10^{-34} kg·m²/s. An electron has a mass of 9.1×10^{-31} kg. (This might seem fast. But it is actually a typical speed for an electron in an atom.) First find the electron's energy and momentum, then calculate its quantum frequency and wavelength.

2. In a 2-slit experiment, if we open only 1 slit or the other, suppose the probability that a photon reaches a given point is P the same in either case? Now we open both slits and repeat the experiment. Explain why the probability that a photon reaches the given point might be anything between 0 and $4P$.

3. In "classical" wave physics, the intensity of a light wave gives the amount of energy it carries. The Born rule tells us that in quantum physics, the intensity gives the probability of finding a photon in that region. How are these 2 ideas related?

Standing Waves and Stable Atoms, Lecture 5

In the last lecture, we saw and explored the strange quantum idea of wave-particle duality, an idea that applies both to light and to matter. Everything has both wave properties and particle properties.… This time we're going to see how the wave characteristics matter explain the structure of atoms.

In 1909, Ernest Rutherford supervised experiments to scatter fast-moving particles from gold foil. These experiments led him to propose a "solar system" model of atomic structure. In this model, most of the atom's mass lies in the heavy, positively charged nucleus at its center. Electrons, with a negative charge and relatively low mass, orbit the nucleus, held in place by the attractive electric force between positive and negative charges. This leads to a puzzle: in classical mechanics, an orbiting electron should emit electromagnetic radiation. It should therefore lose energy and spiral inward towards the nucleus. Rutherford's atom should implode in less than 1 microsecond.

In 1913, Niels Bohr, a postdoctoral student in Rutherford's lab, used the new quantum ideas to explain atomic structure. Bohr proposed that only certain discrete orbits are possible for the electron in the atom. If the electron is in the innermost possible orbit, it can no longer spiral inward. Thus atoms can be stable. When an electron "jumps" from one orbit to another, it absorbs or emits a photon. We can also imagine more abstractly: Different Bohr orbits are "rungs" on an "energy ladder" for the electron. To climb up to a photon higher rung, the electron must absorb a photon; to descend, it must emit a photon. The photon energies are determined by the spacing of these energy levels. Bohr was able to predict the pattern of energy levels in hydrogen atoms, which only have a single electron. His pattern accounts for the discrete colors of light (photon energies) produced by hot hydrogen gas. This is called the "emission spectrum" of the element.

Bohr's orbits correspond to "standing wave patterns" of electrons moving around the nucleus. The can be nicely explained by de Broglie's electron waves, although this was not Bohr's original explanation. In de Broglie's version of Bohr's model, in any wave system enclosed in space, only certain wave patterns are possible. An easy example of this is a stretched piano wire. The wave must "fit" between the fixed ends of the wire. Only certain wavelengths and frequencies (or combination of these) can occur, which is why the piano wire vibrates with a definite note when struck. As an electron orbits an atom, only certain wave patterns and frequencies are possible. These standing wave patterns determine the possible Bohr orbits.

In 1926, Erwin Schrödinger provided a detailed mathematical description of de Broglie's waves. His description is embodied in the famous Schrödinger equation, which is one of the fundamental equations in all of physics. Here is one form of the equation:

$$-(^{h^2}/_{2m})\nabla^2\Psi + U(x,y,z)\Psi = i\hbar(^{\partial\Psi}/_{\partial t})$$

The Ψ in this equation is the "wave function" of the electron. The wave intensity $|\Psi|^2$ gives the probability of finding the electron at any given point in space. Solving the Schrödinger equation gives 3-dimensional standing wave patterns for an electron in an atom. Each wave pattern corresponds to a different energy level. The wave patterns are changed by the emission or absorption of photons. In an ordinary advanced quantum mechanics course, students spend at least 90% of their time learning methods for solving the Schrödinger equation. This can be a very hard task, especially when the situation is complicated.

The Schrödinger equation and quantum mechanics do a good job of explaining energy levels for atoms and molecules, the emission and absorption of light by atoms, and the way atoms are affected by outside forces (e.g., stretched by electric fields or twisted by magnetic fields). All of these can be calculated from the standing wave patterns of de Broglie waves, determined by the Schrödinger equation.

Questions to consider:

1. Before Rutherford's scattering experiment, a leading idea of atomic structure was J.J. Thomson's "plum-pudding" theory. In this model, negatively charged electrons were embedded in a diffuse, positively charged "pudding." If Thomson's model had been correct, how would the scattering experiment have turned out differently?

2. A piano wire can vibrate at a certain fundamental frequency f and also at higher "overtone" frequencies $2f$, $3f$, and so on. If you have access to a piano, try the following experiment. Hold down the key for middle C (262 cycles/s) without playing the note. Now briefly play each of the following notes and listen to how the open C string responds: C (1 octave up, or 524 cycles/s), G (1.5 octaves up, or 784 cycles/s), and C (2 octaves up, or 1048 cycles/s). Also try this with other notes. What do you observe?

3. Excited hydrogen atoms emit violet, blue-green, and red light. These correspond to electrons dropping to the second energy level from the ones above it: $3 \Rightarrow 2$, $4 \Rightarrow 2$ and $5 \Rightarrow 2$. Which jumps correspond to which emitted colours and why? (Recall that violet light as a higher frequency than red light).

Uncertainty, Lecture 6

Our business today is to explore the implications of [the quantum idea of wave-particle duality], to say what it means for the wave to spread out, and to say what it means for the quantum wave describing a quantum particle to spread out in space. Today we're going to talk about the uncertainty principle.

Particles and waves have contrasting properties. In classical physics, a particle like an electron has both an exact location in space and a definite velocity or momentum at every moment. In other words, the particle has an exact "trajectory" through space. On the other hand, we have the basic wave phenomenon of diffraction of waves through a single slit. After passing through the slit, the waves spread out into the space beyond. The diffraction effect depends on the ratio λ/w, the wavelength divided by the width of the slit. A narrow slit (large ratio) produces a wide pattern of waves, while a wide slit (small ratio) produces a narrow pattern. This allows waves to "go around corners." A thought experiment illustrates this: A friend behind a wall speaks to us through an open door. We can hear the friend because the wavelength of the sound waves is large, and the sound waves passing through the door spread out. But we do not see the friend because light waves have very short wavelengths, and diffraction through the door is negligible.

Diffraction and wave particle duality set a basic limit on how well a particle's properties are defined. We consider an electron, described by de Broglie waves, passing through a barrier with a single slit. If the electron passes through the slit, this means that we know the particle's position (x), though not exactly. Our uncertainty in the particle position is just the slit width: $\Delta x \approx \Delta w$. Because of diffraction, the de Broglie wave spreads out past the split. The lateral velocity of the particle is not exactly known, which means we cannot tell exactly where the particle will be found. It turns out to be easier to consider the particle's lateral momentum p. The spreading of the wave pattern means that there is an uncertainty Δp in this momentum. A wide pattern means a larger Δp. The relation between slit width and diffraction spreading means there is a trade-off between Δx and Δp. The smaller one is, the larger the other must be.

Werner Heisenberg realized that this represents a basic trade-off in nature, which is the famous "uncertainty principle." Suppose Δx and Δp are our uncertainties in a particle's position and momentum. Then it must be true that $\Delta x \Delta p \geq h$ (where h is Planck's constant).

There are some important things to note. First, this is an inequality. We can always be less certain about x and p than this, but never more certain. second, our definitions of uncertainty. Second, our definitions of uncertainty here are informal or "fuzzy." With more careful technical definitions, there may be a factor of 2 or 4 (or 4π!) in the right-hand side. This does not change the basic point. Additionally, Planck's constant is extremely small, so a large-scale object can have a pretty well-defined location and momentum. This is part of the reason why large-scale objects can behave like classical particles. Lastly, for microscopic particles like electrons, the uncertainty principal can be very important. An electron confined to an atom has Δx no larger than the diameter of the atom. The resulting momentum uncertainty Δp is large enough that we do not even know which direction the electron is moving in the atom!

Heisenberg argued that the uncertainty principle is actually an "indeterminacy principle." The point is not that we do not know the exact values of x and p for an electron; the electron in fact does not have exact values of x and p.

Another uncertainty principle relates time and energy. If a process happens over a period of time Δt, and the energy involved in the process is uncertain by an amount ΔE, then $\Delta E \Delta t \geq h$.

Questions to consider:

1. Heisenberg used several different terms to describe his basic idea. He said that a particle's position might have "uncertainty" or "indeterminacy" or "imprecision" or "latitude" or "statistical spread." Remark on the different shades of meaning that these various terms suggest.

2. There is a classical "uncertainty principle" for any sort of wave, including sound. A musical note is a mixture of a range of frequencies Δf. If the note lasts for a time period Δt, it turns out that the spread of frequencies must satisfy $\Delta f \geq {}^{1}/_{\Delta t}$. (This means that very short notes do not have a very definite pitch.) What version of the quantum uncertainty principle is most closely related to this fact?

Complementary and the Great Debate, Lecture 7

This lecture is about an argument. The protagonists are 2 giants of 20th century science, Albert Einstein and Niels Bohr, They're 2 of the founders of quantum theory and the subject of their argument is the meaning of quantum mechanics. At stake, are our most fundamental ideas about the nature of nature.

Albert Einstein was the father of the idea of wave-particle duality, but he found much to criticize in quantum mechanics. In his view, one key flaw was that quantum mechanics failed to answer the question of why a particle ended up in one place rather than another. The theory only predicts probabilities. Einstein believed this to be a flaw – he thought a theory should explain individual events, not just tendencies. Also, he was predisposed to "determinism," the idea that the future of the universe is completely determined by the present. He said, "God does not play dice with the universe." Additionally, he at first thought that quantum Mechanics was not logically consistent.

Niels Bohr was a deeply philosophical thinker and a powerful personality. Much of quantum mechanics was developed by his followers and worked out at his theoretical physics institute in Copenhagen. Bohr believed that the new quantum theory required physicists to abandon old concepts, including determinism. He said, "Einstein, stop telling God what to do." Bohr worked out a sophisticated framework of concepts for using quantum ideas without contradictions. This framework came to be called the "Copenhagen interpretation" of quantum mechanics and has been the principal way that physicists have made sense of quantum theory. (We will see other approaches later.)

The Copenhagen interpretation rests on Bohr's "principle of complementarity." This is a subtle idea that requires a careful explanation. Bohr says that we must consider 2 physical realms. There is a microscopic realm of electrons, photons, etc., that cannot be described in "ordinary language." There is also a microscopic realm of large objects, people, etc., that can be described in "ordinary language." There is also a macroscopic realm of large objects, people, etc., that can be described in "ordinary language" and in which classical physics is approximately valid. To make a measurement of the quantum realms, we must always "amplify" the result to the macroscopic realm, so that we can accord it and communicate it in ordinary language. This act of amplification is crucial!

Every experiment on a quantum particle is an "interaction" between the experimental apparatus and the particle, not just a passive observation. Interaction goes both ways, and the particle is always affected in some way. How the quantum particle responds depends on what interaction occurs. Different types of experiments are logically exclusive – we can do one or the other, but not both at the same time. The uncertainty principle tells us that we cannot exactly measure the position and momentum of a particle at the same time. Why not? The interaction needed for a position measurement is not the same as that needed for a momentum measurement. They are complementary. Measuring one logically excludes measuring the other at the same time. Consequently, when we try to use ordinary language to describe the quantum world, we must use different complementary descriptions in different situations – but the mathematics of quantum mechanics guarantees that we can do this without contradiction.

Bohr and Einstein engaged in a long-running debate about the validity and meaning of quantum mechanics. Einstein proposed several puzzles and paradoxes designed to show some loophole in quantum mechanics. Bohr responded to them one by one, in each case trying to expose the flaw in Einstein's thinking and defend quantum mechanics. This might appear a debate about details and examples, but it was really a profound argument about basic principles.

The debate reached its crescendo at the Solvay Conference of 1927 and 1930. Einstein proposed several clever thought experiments to try to prove that the uncertainty principle could be beaten. We will examine one of these.

Einstein asked us to suppose a particle passes through a barrier with 1 slit. This gives us a lateral position uncertainty Δx, which implies a minimum lateral momentum uncertainty Δp. But if the barrier is moveable, then the deflection of the particle will cause a sideways recoil of the barrier. By measuring this recoil, we should be able to determine the particle's new momentum. We can violate the uncertainty principle!

Not so fast replied Bohr, We must also consider how the uncertainty principle applies to the moveable barrier, which has position X and momentum P. To measure the recoil precisely, then our uncertainty ΔP in the barrier's momentum must be extremely small. But then the barrier's position is uncertain by a large ΔX. The uncertainty Δx in the particle's position cannot be smaller than our (large) uncertainty ΔX in the location of the slit. The uncertainty principle is not violated.

After 1930 Einstein was forced to accept that quantum mechanics was a consistent theory of nature. Nevertheless, he was still dissatisfied and kept looking for clues to a deeper view. The Bohr-Einstein debate shifted but did not end.

Questions to consider:

1, De Broglie's original view was that both waves and particles existed at the same time and that the wave exerted quantum forces that guided the particle through space. The particle thus had a definite trajectory, though the trajectory would be complicated and difficult to predict. Would this idea have appealed more to Einstein or to Bohr?

2. In a 1928 letter to Schrödinger, Einstein referred to complementarity as a "tranquilizing philosophy" that merely allowed quantum physicists to avoid uncomfortable questions. Is this fair? How would you respond to – or defend – Einstein's remark?

3. Should we think of Einstein's sharp critique of quantum theory as an obstacle or a spur to its development? What is the role of criticism in the creation of new ideas?

Paradoxes of Interference, Lecture 8

In the first section of the course, we've been tracing how a generation of the most brilliant scientists in human history created the theory of quantum mechanics and wrestled with its perplexities…. In the second section, we embark on the task of introducing the theory itself, quantity theory in a simplified form.

To begin to look at quantum mechanics, we will use an interferometer as a simple conceptual "laboratory." An interferometer is an optical apparatus made up of several components. A light source generates a beam of light with a definite wavelength as input to the apparatus. The intensity of the light can be reduced so that only 1 photon is traveling through the apparatus at a time. Photon detectors can be placed to register any photons that strike them. (Our detectors are somewhat idealized.) Mirrors are used to guide the light beams in various directions.

The crucial components of an inferometer are "half-silvered mirrors." A half-silvered mirror splits a beam of light into 2 beams of equal intensity. These mirrors are also sometimes called "beam splitters." It's important to note that light waves that reflect from the silvered side of the mirror are inverted – that is, the electromagnetic fields are reversed in the reflected waves. If we send a single photon through a beam splitter, photon detectors do not both register "half a photon." Instead, the entire photon is registered in one place or the other, each with probability ½.

Our apparatus is a Mach-Zehnder interferometer. An incoming light beam is split at a half-silvered mirror. The two beams are then recombined at a second half-silvered mirror, and the output beams are observed. If everything is set up properly, all of the light emerges in 1 beam. This is because the light constructively interferes in that direction but destructively interferes in the other. If we send 1 photon at a time through the interferometer, the photon is always registered in 1 beam rather than the other. The probabilities exhibit constructive and destructive interference!

We can explore quantum ideas by thought experiments using the single-photon version of the Mach-Zehnder interferometer. Interference can only happen if the photon travels "both ways" through the interferometer. Suppose we introduce a non-absorbing detector into 1 beam. This tells us which beam the photon traveled, but in so doing we completely lose the interference effect. Each detector registers the photon 50% of the time. For interference to occur, the photon must leave no "footprints" behind that would tell which way it went.

"Both ways" and "which way" experiments illustrate the principle of complementarity. With the second half-silvered mirror present, we find interference effects. The photon must have traveled 'both ways" through the interferometer. If we remove the half-silvered mirror, the photon detectors tell us "which way" the photon traveled. Through the interferometer. We must choose which experiment to do, and we cannot later say what would have happened if we had done the other one. Keep in mind Asher Peres's quantum motto: "Unperformed experiments have *no* results." In 1978, John Wheeler proposed the "delayed-choice experiment." We decide whether to leave the mirror in or take it out when the light has already traveled 99% of the way through the apparatus. We decide whether the photon went "both ways" or "one way" after it has almost completed its journey! Wheeler's quantum motto is "No phenomenon is a phenomenon until it is an *observed* phenomenon."

The Elizur-Valdman bomb problem leads us to even stranger conclusions. In this scenario, a factory produces bombs with extremely sensitive light triggers. Some bombs are "good" and some are defective. We want to test them. A good bomb will explode if even 1 photon hits the trigger. But a defective bomb lacks the trigger mechanism and photons pass through. Suppose we send just 1 photon into a bomb to test it. A good bomb will explode and a defective one will not. This tests the bomb, but only by blowing it up. Can we ever find out that a bomb is good without exploding it? This seems impossible!

A quantum trick solves the puzzle. Elitzur and Vaidman suggested that we put the bomb in 1 beam of a Mach-Zehnder interferometer and send 1 photon through. If the bomb is defective, then the light shows interference. The photon always winds up in one detector and never in the other. If the bomb is good, then 50% of the time it will explode. But other 50% of the time, the photon travels the other beam to the second beam splitter. Thus 25% of the time it will strike a detector that would be impossible if the bomb were defective. We can certify some good bombs without exploding them!

Questions to consider:

1. In our interferometers experiment, suppose we flip the second beam splitter so that its metal coating is on the other side. How would his affect the constructive and destructive interference? What is we flip both beam splitters?

2. In the bomb-testing experiment, one possible outcome is inconclusive. Since both working and defective bombs can produce it. Suppose we repeat the test once more if this happens. What percentage of working bombs are (a) blown up, (b) certified as working, and (c) still undetermined in this double test? Suppose we repeat the test as many times as necessary to achieve a conclusive result? What percentage of the working bombs are blown up?

States, Amplitudes and Probabilities – Lecture 9

Now we want to formulate symbolic ways of working with quantum ideas. We want to introduce a kind of mathematical language. I mean, after all, if we want to explore Mongolia, it's a good idea to learn some Mongolian, especially if the best maps are all written in Mongolian. Our destination is a place that's even more exotic than Mongolia, Our destination is the microscopic world.

Our aim here is to introduce a formal language to describe quantum ideas. First we introduce a few terms and abstract symbols. A "system" is any piece of the quantum world that we wish to consider. For example, we might consider a single photon in an interferometer. A "state," on the other hand, is a physical situation of some system. We represent a state by a "ket," like so: $|state\rangle$. What we put inside the ket $|\ldots\rangle$ is just a convenient label for the state. A "basis" is a set of distinct states that cover all of the outcomes of some measurement. For example, the photon in the interferometer would be found in one beam or the other, so the 2 states $|\text{upper}\rangle$ and $|\text{lower}\rangle$ make up a basis. There can be different possible measurements, as there can be different possible basis sets for a quantum system.

Besides basis states, there are also "superposition" states. The term superposition is meant to suggest a composite, like 2 pictures "superimposed" on one another in a double exposure. We represent a superposition as an abstract sum:

$|state\rangle = a|\text{upper}\rangle + b\,|\text{lower}\rangle$

The numerical factors a and b are called "amplitudes." In full quantum mechanics, these are amplitudes might include imaginary numbers (like $\sqrt{-1}$). We can omit this complication, but we will use both positive and negative amplitudes. We define number $s = 0.7071\ldots$, for which $s^2 = ½$. (We will give this number a special name for convenience because we will use it a lot in examples.)

Next, we need rules for working and interpreting the abstract quantum symbols. The "rule of superposition" says that a superposition of 2 or more basics states is also a quantum state. This means that a quantum system has more possibilities than we might expect. For the photon in the interferometer, besides $|\text{upper}\rangle$ and $|\text{lower}\rangle$ states, we also have lots of superposition states $a|\text{upper}\rangle + b|\text{lower}\rangle$ for many different choices of amplitudes a and b. A superposition state represents the photon divided among the beams in some way, as happens in a interferometer. The amplitudes determine the details.

The "rule of probability" (also called the Borne rule) says that if we make a measurement, the probability of any result is determined by the amplitude of that result:

probability = $|\text{amplitude}|^2$

Quantum mechanics only predicts probabilities, not definite results. What is probability? For any event, it's probability P is a number between 0 and 1. The value $P = 0$ means the event is impossible and $P = 1$ means that it is certain. An intermediate value like $P = 0.37$ means that if we tried the same experiment many times, the event would happen about 37% of the time. Probabilities predict statistics. Both positive and negative amplitudes give positive probabilities.

Suppose our photon is in the state $a|\text{upper}\rangle + b|\text{lower}\rangle$. If we make a measurement to find which beam the photon is in, we will get results with probabilities:

$P(\text{upper}) = |a|^2$ and $P(\text{lower}) = |b|^2$

This means we must have $|a|^2 + |b|^2 = 1$, since probabilities must always add up to 1.

In the state $s|\text{upper}\rangle + s|\text{lower}\rangle$, each beam has probability $|s|^2 = ½$. The same thing is also true for the different quantum state $s|\text{upper}\rangle - s|\text{lower}\rangle$, because:

$|s|^2 = |-s|^2 = ½$.

There are 2 "update rules" that tell how the state changes when something happens to the system. Update rule I says that when there is no measurement, the state changes in a definite way that maintains any superposition. If we know how to update the basis states, we can determine how to update superposition states. Update rule II says that when there is a measurement, we use the results to find the new state. In this case, the state is updated randomly….

In the interferometer, we keep tracks of the quantum state at each stage to figure out what happens to the photon. The photon starts out in the upper beam, so its state is $|\text{upper}\rangle$. At the first beam splitter, the state changes: $|\text{upper}\rangle \Rightarrow s|\text{upper}\rangle + s|\text{lower}\rangle$. The beams recombine at the second beam splitter. We apply the beam splitter state change to each part of the superposition, according to update rule I:

$s|\text{upper}\rangle + s|\text{lower}\rangle$

$\Rightarrow s(s|\text{upper}\rangle + s|\text{lower}\rangle) + s(s|\text{upper}\rangle - s|\text{lower}\rangle)$

We now multiply amplitudes and combine terms as we would in an ordinary algebraic expression. This gives us the final state:

$(s^2+s^2)\,|\text{upper}\rangle + (s^2-s^2)\,|\text{lower}\rangle = |\text{upper}\rangle$

At the end, the photon is certain to be in the upper beam. Constructive and destructive interference take place in the amplitudes. The quantum amplitude keeps track of the wave properties of the photon.

Questions to consider:

1. One of the questions for the last lecture asked what happens when the second beam splitter is flipped so that its metal coating is on the other side. Write down how a nipped beam splitter affects the $|\text{upper}\rangle$ and $|\text{lower}\rangle$ basis states, and work out the final quantum state for the final quantum for the photon. Does this agree with your previous answer? (It should.)

2. If we simply allow the 2 beams to cross without a beam splitter, this simply exchanges the basic states: $|\text{upper}\rangle \Rightarrow |\text{lower}\rangle$ and $|\text{lower}\rangle \Rightarrow |\text{upper}\rangle$. Use this fact to find the final quantum state if the second beam splitter is removed (as in Wheeler's delayed-choice experiment).

3. Suppose we place a non-absorbing detector in one of the beams of the interferometer. Using both update rules, explain what happens to the quantum state at various stages of the apparatus.

Particles that Spin, Lecture 10

This time we're going to take up a new example. We are going to use lots of 3-dimensional geometry, lots of angles and directions. We'll get to practice our spatial skills. This time we're going to talk about the physics of spin.

The physics of "spin" offers us another example of the quantum rules. An electron in orbit is analogous to a planet moving around the sun. Each planet moves through space and rotates on its axis. Something similar is true for quantum particles like electrons. They not only move through space – they also have internal spin. Spin is a kind of angular momentum, a physical measure of the amount of rotation in a particle.

Classical spins can have any value for any component. A "spin component" is the degree of spin a particle has along a particular axis. Classically, this depends on (1) the total amount of spin, and (2) the angle between the rotation axis and the axis we are interested in. For a classical spinning object, a given spin component can have any value, and all spin components have definite values at the same time.

Quantum spins have quite different characteristics. We can measure any component of a particle's spin by a "Stern-Gerlach apparatus," which measures the deflection of the particle in a non-uniform magnetic field. The orientation of the apparatus determines which spin component we measure. For electrons, the measurement of any spin component only can give 2 possible results, the values ±½ (in units of $h/2\pi$). Electrons are said to be spin-½ particles, as are protons and neutrons. Other quantum particles can be spin 0 (no spin at all), spin 1, spin $^3/_2$, etc.

Let's look at measurements and state for the spin-½ particle. We can measure an electron's spin along any axis in space. Two axes that we are especially interested in are the perpendicular axes z and x. A z measurement gives us 2 basis states $|\uparrow\rangle$ and $|\downarrow\rangle$, corresponding to the results $z = +½$ and $z = –½$, respectively. We call these "spin up" and "spin down." An x measurement gives us different basis states $|\rightarrow\rangle$ and $|\leftarrow\rangle$, corresponding to the results $x = +½$ and $x = –½$ respectively. We call these "spin right" and "spin left." We can write the x basis states as superpositions of z basis states and vice versa:

$|\rightarrow\rangle = s|\uparrow\rangle + s|\downarrow\rangle$

$|\leftarrow\rangle = s|\uparrow\rangle - s|\downarrow\rangle$

and

$|\uparrow\rangle = s|\rightarrow\rangle + s|\leftarrow\rangle$

$|\downarrow\rangle = s|\rightarrow\rangle - s|\leftarrow\rangle$

We call x and z "complementary quantities" for the electron. The x and z measurements are mutually exclusive-the Stern-Gerlach apparatus must be aligned one way or the other. There is an uncertainty principle for spin. A particle cannot have definite values for both x and z at the same time. For z basis states, z is definite but x is indeterminate; for x basis states, x is definite but z is indeterminate. The complementarity of different spin components for large-scale spinning objects (baseballs, planets) is negligible because h is so small.

From here we can extend the theory of spin ½. There are other spin components besides z and x. Consider the spin component at an angle α from the z-axis (in the z-x plane). The basis vectors for this spin component can be called $|\alpha+\rangle$ and $|\alpha+\rangle$. For instance, $|\rightarrow\rangle = |90°+\rangle$. Suppose we prepare $|\alpha+\rangle$ and measure spin component z. What is the probability P that we obtain the result $z = +½$? Here is a table:

α	0°	45°	90°	135°	180°
P	1.00	0.85	0.50	0.15	0.00

(The values for 45° and 135° are rounded off here.) This table helps us calculate the probabilities if we have a spin with a definite component along any axis and then measure it along another axis at an angle α.

What happens to the spin of a particle if we rotate it in space? We can rotate an electron spin (or the spin of a proton or neutron) by using magnetic fields. Since no measurement is involved, the spin state should change according to update rule I. Suppose we rotate around the y-axis by 90°. How do basis states change?

$|\uparrow\rangle \Rightarrow s|\uparrow\rangle + s|\downarrow\rangle = |\rightarrow\rangle.$

$|\downarrow\rangle \Rightarrow -s|\uparrow\rangle + s|\downarrow\rangle = -|\leftarrow\rangle.$

From this, we can also find the following:

$|\rightarrow\rangle \Rightarrow |\downarrow\rangle$ and $|\leftarrow\rangle \Rightarrow |\uparrow\rangle$.

Why the minus sign in the rotation of $|\downarrow\rangle$? We cannot work things out consistently without it. But it should not matter. Because of the rule of probability, the states $|\leftarrow\rangle$ and $-|\leftarrow\rangle$ will yield exactly the same probabilities in any measurement. The kets $|\text{state}\rangle$ and $-|\text{state}\rangle$ describe equivalent physical situations.

To rotate the spin by 360°, we can do it 90° at a time:

$|\uparrow\rangle \Rightarrow |\rightarrow\rangle \Rightarrow |\downarrow\rangle \Rightarrow -|\leftarrow\rangle \Rightarrow -|\uparrow\rangle$

This curious minus sign does not worry us – but we will remember it. It turns out to be very interesting and significant later on!

Questions to consider:

1. In a Stern-Gerlach experiment, a beam of particles with spin is deflected by a magnetic field. The amount of deflection depends on the z component of the spin. In the real experiment, quantum particles emerge in just 2 different directions, corresponding to spin components +½ or –½. But imagine a world in which these particles had a "classical" spin, like the spin of a top. How would the experiment turn out?

2. Here is an algebraic exercise suggested in the lecture. We gave formulas for the x basis states written in terms of the z basis states: $|\rightarrow\rangle = s|\uparrow\rangle + s|\downarrow\rangle$ and $|\leftarrow\rangle = s|\uparrow\rangle - s|\downarrow\rangle$. Starting only with these, figure out the formulas that give the z basis states in terms of the x basis states. (You will need to remember that $s^2 = ½$.)

3. Show that we cannot "do without" the funny minus signs in the rotation rule for spins. It would be nicer if 90° rotation worked something like this: $|\uparrow\rangle \Rightarrow |\rightarrow\rangle \Rightarrow |\downarrow\rangle \Rightarrow |\leftarrow\rangle \Rightarrow |\uparrow\rangle$, with no minus signs at all. Show that this "nice rule" is inconsistent with update rule 1. (Hint: write $|\rightarrow\rangle$ and $|\leftarrow\rangle$ as superpositions of the basis states $|\uparrow\rangle$ and $|\downarrow\rangle$.)

Quantum Twins, Lecture 11

Now we'll be moving into…several different particular topics in quantum theory. We'll begin…with…the theory of identical particles. All electrons are identical. All photons are identical. What does this mean? How can quantum theory describe that? What are the implications? This is an amazing story that we'll be telling.… Here's our essential point: Macroscopic classic objects and microscopic quantum particles have a different sense of identity.

Macroscopic objects obey the "snowflake principle": no 2 are exactly alike. Every object can be uniquely identified, at least in principle. No 2 snowflakes are alike (though some appear quite similar). Even identical twins have lightly different fingerprints. If we put 2 pennies in a box and then draw 1 out, it makes sense to ask which penny we have. There are always microscopic differences that can be used as identifying marks, like a serial numbers on currency.

In contrast, quantum particles do not obey this snowflake principle. All electrons are exactly identical to each other. They may differ in location and spin, but they are otherwise exactly the same if we put 2 electrons in a box and then draw 2 out, it does not make sense to ask which electron we have. There are no microscopic differences to be used as serial numbers. The same is true for 2 photons, or 2 protons, or even 2 atoms of the same type.

The point here is not simply a philosophical one; it changes how we apply the quantum rules. We already know the quantum rules for a single-particle system. We imagine 2 "boxes," A and B. A quantum particle can be in either of the 2 boxes. Thus 1 particle has basis states $|A\rangle$ and $|B\rangle$ (and could be in any superposition of these).

"Distinguishable" quantum particles have simple rules. These particles can be discriminated in some way. For example, in a 2-particle system, our first particle might be a proton and the second one an electron. The 2-particle states $|AB\rangle$ and $|BA\rangle$ are distinct physical situations. In $|AB\rangle$, the first particle is in box A and the second in box B; in $|BA\rangle$, they are reversed. We can tell these situations apart. Distinguishable particles might also be in the same box, as in the states $|AA\rangle$ and $|BB\rangle$.

"Identical" particles force us to re-examine our assumptions. For 2 electrons, the states $|AB\rangle$ and $|BA\rangle$ do not represent distinct physical situations. We can express this by using the "SWAP" operation, which exchanges the 2 particles. For instance, $\text{SWAP}|AB\rangle = |BA\rangle$. (If we had more particles, we would have a SWAP operation for each possible pair). For any state of 2 identical particles, $|\text{state}\rangle$ and $\text{SWAP}|\text{state}\rangle$ must be physically equivalent. If we swap twice, we must return to the original situation: $\text{SWAP}^2|\text{state}\rangle = |\text{state}\rangle$.

Quantum particles come in 2 possible types, depending on how the SWAP operation works. First we will consider Bose-Einstein particles or "bosons," named for Satyendra Bose and Albert Einstein, who did ground-breaking work related to them. The boson rule says that for a pair of identical bosons, $\text{SWAP}|\text{state}\rangle = |\text{state}\rangle$. The quantum state is completely unchanged when we swap the particles. Examples of bosons include photons and helium atoms.

Next we will consider Fermi-Dirac particles, or "fermions," about which Enrico Fermi and Paul Dirac did important work. The fermions rule says that for a pair of identical fermions, SWAP$|\text{state}\rangle = -|\text{state}\rangle$. Two swaps still cancel out:

SWAP$^2|\text{state}\rangle = -(-|\text{state}\rangle) = +|\text{state}\rangle$.

Examples of fermions include electrons, protons, and neutrons. Notice that the basic constituents of ordinary matter are all fermions.

Consider the 2 boxes again, with 1 particle in each. For distinguishable particles, we have distinct states $|AB\rangle$ and $|BA\rangle$. For bosons, there is only 1 distinct state, which is $s|AB\rangle + s|BA\rangle$. This is called a "symmetric" state because it is unchanged if we swap the particles. For bosons there is also only 1 distinct state, which is $s|AB\rangle - s|BA\rangle$. This is called an "anti-symmetric" state because it acquires a minus sign is we swap the 2 particles:

$$\text{SWAP}(s|AB\rangle - s|BA\rangle) = s|BA\rangle - s|AB\rangle = -(s|AB\rangle - s|BA\rangle)$$

If 2 (or an even number) of identical fermions combine to make a "composite" particle, then the result is a boson, because swapping 2 fermions yields 2 minus signs. This way ordinary helium atoms (with 2 electrons + 2 protons + 2 neutrons are bosons.

Questions to consider:

1. Think of the 2 most nearly identically macroscopic objects in your house. How could they in fact be distinguished?

2. If we have 3 identical particles (labelled 1, 2 and 3), then there are at least 3 different SWAP operations: SWAP(12), SWAP(13) and SWAP(23). Show how SWAP(23) can be created out of a combination of SWAP(12) and SWAP(13). Also show how to use these pairwise SWAPs to create the "cyclic" swap that takes $1 \Rightarrow 2 \Rightarrow 3 \Rightarrow 1$.

3. A composite particle of several fermions can act like a boson. Can we have the opposite – a composite of bosons that acts as a fermion? If so, how? And if not, why not?

The Gregarious Particles, Lecture 12

We're going to consider bosons, the symmetric ones, and examples of bosons include photons, the particles of light, helium atoms…. Where did all the boson stuff come from originally? It's actually rooted in the same thing that quantum theory itself is rooted in; remember the original impetus for quantum theory was to explain black body radiation.

Because of the boson rule, 2 identical bosons can exist in the same state. In fact, they prefer it that way. We consider a pair

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of particles in 3 boxes: A, B, and C. A single particle has basis states $|A\rangle$, $|B\rangle$, and $|C\rangle$. A pair of distinguishable particles has 9 basis states:

$|AA\rangle, |AB\rangle, |AC\rangle, |BA\rangle, |BB\rangle, |BC\rangle, |CA\rangle, |CB\rangle, |CC\rangle$

In $1/3$ of these states ($|AA\rangle, |BB\rangle, |CC\rangle$), the particles will be found in the same box. Just by chance, we would expect to find the particles together $1/3$ of the time.

If the 2 particles are bosons, there are fewer basis states, since the states must be symmetric under a particle swap. A pair of identical bosons has 6 symmetric basis states:

$|AA\rangle, s|AB\rangle + s|BA\rangle, s|AC\rangle + s|CA\rangle, |BB\rangle, s|BC\rangle + s|CB\rangle, |CC\rangle$

In ½ of these states, the particles are found in the same box. Just by chance, we would expect to find the particles together ½ of the time, more often than we would a pair of distinguishable particles. Bosons have a "gregarious" streak, not because of some special force but simply because they are bosons. This effect gets stronger when more bosons are together.

The boson rule explains how a laser works. Einstein identified 3 ways that an atom can interact with a photon. An atom can absorb a photon, if one is present with the right energy. The atom jumps to an excited state. Alternatively, an atom already in an excited state can emit a photon spontaneously, which then emerges in some random direction. Another possibility is stimulated emission: Suppose we have an excited atom, and there are already some photons present that are moving in a particular direction. Because photons are bosons, the atom has a greater probability of adding its own photon to this group.

Stimulated emission is what enables us to build lasers. Here is the simplified version of how it works: First, get a lot of atoms together. Add some energy so that most of the atoms are excited. This is called "optical pumping." We need to have more excited atoms than unexcited ones – called a "population inversion" – since otherwise absorption will defeat us. Next, make sure that we have some photons around that are moving in a particular direction. This is usually done by bouncing the light we want back and forth with mirrors. Because photons are bosons, lots and lots of photons will be emitted in that same direction. ("laser" stands for "light amplification by stimulated emission of radiation"). The result will be a lightly directional beam of light having just 1 wavelength. This is called "coherent light."

The boson rule also explains some amazing low-temperature phenomena. Our first example is superfluid helium. Helium atoms are bosons. Helium gas liquefies at about 4° above absolute zero, and the resulting liquid is called Helium I. At about 2° above absolute zero, helium forms a superfluid (Helium II). A superfluid can flow without any friction, lead through tiny pores less than 1 millionth of a meter across, and literally "creep" out of an open container. The superfluid state represents trillions of helium atoms in a single quantum state – a macroscopic example of the quantum gregariousness of bosons.

Our second example of amazing low-temperature phenomena is superconductivity. In metals, electric current is carried by the flow of electrons. But there is some friction in the form of electrical resistance, which is why a current-carrying wire can heat up. Under some circumstances, the electrons can combine into "Cooper pairs." Cooper pairs can carry electric current, but they are bosons. Near absolute zero Cooper pairs flow as a superfluid in the metal. Electric current can be carried with zero resistance! This is called "superconductivity." If we set up an electric current in a superconducting circuit, it will continue to flow for millions of years without any addition of energy. This many technological applications, especially to make powerful electromagnets. A lot of research involves looking for superconductors that work at higher temperatures.

Our third example is a Bose-Einstein condensate. In this example, a supercold cloud of atoms can be created in which thousands or millions of atoms are in exactly the same quantum state. These atoms act like a single quantum system. This state of matter was first predicted in 1925 but was not created in the lab until 1995.

Questions to consider:

1. Three particles each have 4 basis states $|A\rangle$, $|B\rangle$, $|C\rangle$ and $|D\rangle$. If the particles are distinguishable, how many 3-particle basis states are there? If they are identical bosons, how many basis states are there?

2. Helium III is a rare isotope of helium that has 1 neutron in its nucleus, so that helium III atoms are fermions. Nevertheless,

at extremely low temperatures (only $^1/_{400}$ of a degree above absolute zero) it is observed that helium III can become a superfluid. How is this possible?

Anti-symmetric and Antisocial, Lecture 13

Last we talked about bosons and their curiously gregarious behaviour. It was a lecture full of laser physics and exotic states and super cold matter. Lots of particles were always doing the same thing.… This time we're going to discuss the other kind of quantum particle, the fermions. The fermions include electrons, protons and neutrons. They're anything but rare.… They are very different from bosons.

Because of the fermion rule, 2 identical fermions can never exist in the same state. Consider again 2 particles in 3 boxes: A, B, and C. For a pair of identical fermions, there are only 3 anti-symmetric basis states:

$s|AB\rangle - s|BA, s|AC\rangle - s|CA\rangle, s|BC\rangle - s|CB\rangle$

We cannot have states with the fermions in the same box, because those states cannot be anti-symmetric: $s|AA\rangle - s|AA\rangle = 0$, which is no state at all.

This is the basis of the "Pauli exclusion principle" discovered by Wolfgang Pauli in 1925 as he investigated atomic structure. Pauli said that no 2 electrons can be in exactly the same quantum state. The same principle holds for any sort of fermion (e.g., protons and neutrons). Fermions are antisocial simply because they are fermions-no actual "repelling forces" are involved.

The exclusion principle for electrons explains many of the properties of ordinary matter. The structure of atoms with many electrons depends on Pauli's principle. An atom has various energy levels corresponding to standing wave patterns. If electrons were bosons, they could all just collect in the bottom level. The Pauli exclusion principle means that the electrons can "fill up" in the lower rungs on the ladder. Note that, since electrons also have spin, there can be 2 electrons for each standing wave pattern. The chemical properties of the various elements depend on how the electrons (on the top rungs) are involved in chemical reactions.

The structure of atomic nuclei works in a similar way. There are 2 kinds of fermions involved: protons and neutrons. Both are called nucleons. The way that nucleons fill their nuclear shells determines nuclear properties. For instance, certain numbers of nucleons make unusually stable nuclei, while others make unstable nuclei.

The Pauli exclusion principle explains why matter occupies space. A gas is easily compressible. It is not very hard to push twice as much gas into the same volume. A liquid or a solid is much, much less compressible. It is almost impossible to push twice as much material into the same volume. Why is solid matter solid? Electric repulsion between electrons cannot be the whole story, since ordinary matter contains both positive and negative charges and thus attracts and repels the same amount. To push 2 solid objects into the same volume, we would have to add more electrons into the same region of space. To do this, we must give the electrons a very high energy, since all of the low-energy states in that volume are already occupied. Thus, it takes a lot of energy to get twice as many electrons into the same space. The Pauli exclusion principle affects almost everything we see around us.

Questions to consider:

1. Three particles each have 4 basis states $|A\rangle$, $|B\rangle$, $|C\rangle$ and $|D\rangle$. If the particles are distinguishable, how many 3-particle basis states are there? If they are identical bosons, how many basis states are there?

2. Look around the room and begin to make a list of the phenomena you can see that are directly affected by the Pauli exclusion principle. (You may stop your list after you reach a dozen items. That should not take long!)

The Most Important Minus Sign in the World, Lecture 14

I want to tell you the story of a mathematical idea and what [it] means for the quantum world. What mathematical idea? It's a minus sign. A minus sign seems like a pretty minor piece of mathematical paraphernalia.… In quantum mechanics, a minus sign can make the difference between constructive and destructive quantum interference and that's not a trivial matter.

What's the difference between bosons and fermions? At the fundamental level, bosoms and fermions differ only in a single minus sign. For a system of identical bosons, SWAP$|$state$\rangle$ = $|$state$\rangle$. For a system of identical fermions, SWAP$|$state$\rangle$ = $-|$state$\rangle$. Yet the difference between bosons and fermions is extremely important. Bosons are more likely to be found together, fermions less likely. Physicist sometimes say that bosons and fermions have different "statistics" – Bose-Einstein statistics versus Fermi-Dirac statistics. Boson properties are especially important for light and for matter at low temperatures, while fermion properties, especially the Pauli exclusion principle, determine atomic structure, chemical properties, nuclear structure, the solidity of matter, etc. This is undoubtedly the most important minus sign in the universe!

But where does it come from? Nature provides a clue: there is a link between a particle's spin and the swapping rule it obeys. Physicists call this the "spin-statistics connection." Bosons always have spin 0, spin 1, spin 2, etc. Fermions on the other hand always have spin ½, spin ½, etc.

Let's revisit spin and rotations, Richard Feynman created a useful "magic trick" based on an idea of Dirac's. In the trick, two pencils are connected by a flexible ribbon. Start with the ribbon untwisted. Rotate 1 pencil by 360°, which is 1 full turn. Now the ribbon is twisted, and it stays twisted even if we shift it around in space. Now start again with the ribbon untwisted. Rotate 1 pencil by 720°, 2 full turns. The ribbon appears twice as twisted-but this twist is not real, since we can remove it simply by shifting the ribbon around. The moral of this story is that a 360° rotation is not the same as no rotation-but a 720° rotation is!

What does this have to do with quantum mechanics? Recall the quantum physics of a spin–½ particle by 360° (4 x 90°), we wound up with an unexpected minus sign in the quantum state:

$|\uparrow\rangle \Rightarrow |\rightarrow\rangle \Rightarrow |\downarrow\rangle \Rightarrow |\leftarrow\rangle \Rightarrow -|\uparrow\rangle$

This is part of a general about 360° rotation. For spin 0, spin 1, spin 2, etc., ROTATE$|$state$\rangle$ = $|$state$\rangle z$. For spin ½, spin $^3/_2$, etc., ROTATE$|$state$\rangle$ = $-|$state$\rangle$.

The effects of the minus sign can be observed in a clever experiment. We can make a Mach-Zehnder interferometer that works with neutrons instead of photos. The neutrons enter in the upper beam and undergo state changes at the beam splitters.

$|$upper$\rangle \Rightarrow s|$upper$\rangle + s|$lower$\rangle \Rightarrow |$upper$\rangle$

The neutrons are always detected by the upper neutron detector.

Neutrons have spin ½. We can rotate the spin of the neutron by using a magnetic field. Suppose we rotate the spin by 360°, but only on the lower beam. This introduces a sign change for the $|$lower$\rangle$ state but not the $|$upper$\rangle$ state. Now,

$|$upper$\rangle \Rightarrow s|$upper$\rangle + s|$lower$\rangle$
$\Rightarrow s|$upper$\rangle - s|$lower$\rangle \Rightarrow |$lower$\rangle$

In this case, the neutrons are always detected by the lower neutron detector.

We can make the table relating the amount of rotation and the fraction of neutrons that are detected by the upper detector.

Rotation	0°	180°	360°	540°	720°
Upper beam	100%	50%	0%	50%	100%

To restore the original situation, we must rotate the neutrons by 720°. Electrons, protons, and neutrons see a "720° world." This is very difficult to imagine!

The spin-statistics connection is as follows: Spin-½ fermions have 2 mysterious minus signs, with 1 for particle swapping and 1 for 360° rotation. In fact, these are the same minus sign!

We return to the Feynman magic trick with 2 pencils connected by a flexible ribbon. If we start with the ribbon untwisted and swap the positions of the pencils, the ribbon becomes twisted. To restore an untwisted ribbon, we have to rotate 1 pencil by 360°. The pencils represent 2 identical particles with spin. Swapping the particles involves an easy-to-miss relative rotation by 360°, which is revealed by the twist in the ribbon. This leads to the minus sign in the fermion rule!

We have not exactly "explained" the most important minus sign in the universe. However, we do understand much better what it means and why there is a connection between spin and statistics.

Questions to consider:

1. Use a ribbon or a belt to create your own version of the Feynman ribbon trick and try the following experiments. In each case, you should find out whether the belt ends up twisted or not. (Remember that a ribbon might appear to be twisted when in fact it can be straightened out by simply shifting it around.)

(a) Each end of the ribbon is individually rotated by 180° in the same direction.

(b) The ends are exchanged by rotating the whole setup by 180° around a central point, then unrotating each end individually to restore their original orientation. (In the lecture, we did not rotate the ends as we did the exchange.)

(c) Each end of the ribbon is individually rotated by 360° in the same direction.

2. In the neutron interferometer, suppose the neutrons enter with spin $|\uparrow\rangle$ and then the lower beam spin is rotated by 180°. The upper and lower beams now have distinct spins $|\uparrow\rangle$ and $|\downarrow\rangle$. The spin state thus amounts to a "measurement" of which beam the neutron is in, and thus there should be no interference effects. How does this analysis compare with the results we described?

To be continued.

Greed Coalition Outlines Plan to Renegotiate Loan Deal

By Niki Kitsantonis, The New York Times, June 24, 2012

Athens – Two days before Greece's international creditors return to Athens to begin talks on keeping the nearly bankrupt country solvent, the new coalition government on Saturday highlighted the main points it plans to renegotiate with lenders, aiming to revoke certain taxes, suspend planned layoffs in the bloated public sector and extend by two years the deadline for imposing additional austerity measures.

A joint policy statement issued by Prime Minister Antonis Samaras, a conservative, and his coalition partners – Evangelos Venizelos, chief of the socialist Pasok party and Fotis Kouvelis, leader of the moderate Democratic Left party – summarized the new government's chief aim as "tackling the crisis, opening the road to growth and revising the terms of the loan deal without putting at risk the country's European course or its continued presence in the euro zone."

The initiative is aimed at easing public opposition to two years of austerity, which led to big vote tallies in last Sunday's elections for parties opposed to the $170 billion bailout and obliged the more established parties to forge a tenuous coalition. But some of the goals set out in the document are unlikely to please Greece's creditors, the European Commission, the European Central Band and the International Monetary Fund, whose officials have repeatedly said in recent weeks that here was only marginal room for maneuvering, with an extension of the deadline for meeting fiscal deficit targets the only likely concession.

The chief priorities highlighted in the policy statement – the product of several days of tense negotiations between the coalition parties – include the extension of Greece's "fiscal adjustment period" by at least two years, to 2016, so that fiscal targets can be met without further cuts to salaries and pensions.

The blueprint also aims to revoke changes to collective-bargaining agreements in the private sector and to ease the burden on taxpayers by ensuring that they pay no more than 25 percent of their income in overdue obligations.

Party leaders also want to cancel planned layoffs in the public sector – the three lenders had called for 150,000 jobs to go by 2015 – and to reduce the value-added tax on food to 13 percent from 23 percent.

Higher taxes, lower wages and soaring unemployment, which has hit 22 percent, have crippled Greek households and raised public support for anti-bailout parties like the leftist Syriza, which came in second in last week's elections on a pledge to tear up a loan deal, and which dismissed the coalition's efforts to win over the public as a "publicity stunt," saying that it will ultimately honor the debt deal.

The development came amid health emergencies within the fragile government, Vassilis Rapanos, 65, the finance minister-designate and chairman of Greece's largest lender, National Bank, remained hospitalized on Saturday after being admitted on Friday with stomach pains and nausea. State television quoted doctors as saying on Saturday that Mr. Rapanos was stable, attributing his symptoms to extreme fatigue or a possible virus.

Meanwhile, Mr. Samaras, 61, underwent surgery on Saturday for a detached retina diagnosed on Friday, State television said he was recovering but would stay in the hospital through Sunday, It was not clear when Mr. Rapanos would be sworn in; he did not attend a swearing-in ceremony with the remaining cabinet on Thursday.

It was equally unclear whether Mr. Samaras would be fit to travel to a crucial European union leaders' summit meeting in Brussels on Thursday, where Greece's loan deal was expected to dominate the agenda.

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Our Comment. We are sorry to hear of the physical problems that have overtaken several leaders of the Greek government, but what concerns us most is that the team currently in charge of Greek affairs is still blind, deaf, and dumb to the teachings of classical Greece – that Greece and the rest of the world still stand so completely in need of – *the key importance of human capital.*

Without this heritage of classical Greece not only the government in Athens, but these in any part of the world will not be able to lift the governments throughout the world out of their current mess.

W.K.

Greek Health Care Feels the Hurt

After heavy dose of austerity, drugs are hard to find, patients are depressed and doctors want to leave.

By Daniel Dale, Toronto Star, June 28, 2012

Athens – Greece's government has made deep budget cuts. And now the country's doctors are cutting people open again.

Proud surgeons, some of them trained in the US, are doing large-incision gallbladder removal surgery for no good medical reason in 2012 – because their hospitals don't have the money to pay for the tools required for the keyhole laparoscopy that is the unquestioned standard in the developed world.

"It's not the rule – but even if it happens for one patient, it's too much, and it needs to be discussed," Dr. Georgios Papadoulos, a 39-year-old urologist at the large Gennimatas public hospital in Athens, said last Thursday. "If we were talking about something like this three years ago, it would be a joke. Now it's not.

"The problem is, sometimes you need to compromise the treatment. You may say, 'This is the best way, but I cannot do it, because we do not have what we need.'"

Drugs. Needles. Catheters. Gloves. Stents. Heart pumps. Surgical staples. All harder to obtain than at any point in recent history. None needed more urgently than today.

The country's budget crisis has triggered a health-care crisis at the same time as a crisis in mental and physical health. Doctors and nurses, working more hours for less pay with fewer supplies, are facing an influx of patients whose problems were caused or worsened by the same austerity program driving seen-it-all medical professionals to frustration, exhaustion and thoughts of emigration.

European Union leaders meet Thursday for a summit in which they will discuss their options for containing the continent's debt troubles. On the table is a proposal to give European institutions the power to change the budgets of member states. It will surely be noted by critics that the budget changes foisted on Greece by European institutions have massively intensified the country's social woes.

The rate of suicides and suicide attempts has soared. Hospitals report major spikes in the number of people walking in with ailments related to stress, depression, poor nutrition and drug use. And there is often little the doctors and nurses can do for them even when their cupboards are fully stocked.

Dr. Maria Mela, head of gastroenterology at the cramped, century-old Polykliniki public hospital in Athens's poor Omonia neighbourhood, said she has seen a marked increase in patients whose issues – chest pain, irritable bowel, dyspepsia – are not being produced by anything that can be found on a gastroenterological test.

"We can help them up to a point," Mela, 42, said last Wednesday. "At least we exclude all the medical reasons. And then we have to refer. Because they need to sit down and do some sort of psych therapy. They're coming in with depression-like symptoms, they're coming in crying. It's like – hell." She grimaced.

Panagiotis Gourtzilidis, a burly 43-year-old plumber with a scruffy beard, sat in the Polykliniki waiting room last Wednesday with a vacant look on his face. He is unemployed. His wife is unemployed. His five children are unemployed. He has diabetes, but the hospital where he used to get his insulin says it can't fill his prescription. So he goes pharmacy-hopping – until he finds a store that promises to pay him back at some later date if he pays the full $65 up front.

"I'm facing so many problems, in the future I might have to jump off a building," Gourtzilidis said.

Greece's reported suicide rate was the lowest in Europe – 3 per 100,000 residents – in 2009, the year the crisis began. According to the Greek government, it rose about 40 percent by mid-2011. By all accounts, it has again surged significantly in the year since as the economy has deteriorated further, and as wages and pensions have been cut even more severely. So has the number of attempts.

The modern Gennimatas hospital, which vaguely resembles Toronto's Sunnybrook, is in the outskirts of the city. Before the crisis, said emergency department nurse Angela Frangouli-Papadaki, it would treat perhaps three people every month who had attempted suicide – jilted lovers, the seriously ill. Now, she said, the ER sometimes sees 20 in the span of a few days, most of them driven to despair by their financial circumstances.

The patchwork mental health system is unequipped to cope. Overwhelmed therapists affiliated with the public health system are turning away all but the most urgent of referrals. Private therapy, like the parallel private health system as a whole, is no longer affordable for most of the middle class. And many Greek therapists, says veteran psychologist Athena Androutsopoulou, have begun to feel that they are only pretending to assist their clients.

"In psychotherapy groups, for this whole year, the No. 1 topic is the crisis," Androutsopoulou, who holds a PhD from England, said in her sleek white-walled office on Sunday. "Not their symptoms, not their family problems. People are talking in their groups about the crisis. And this is very, very distressing for us. Because we can't do anything about that. We don't know how to help them.

"The truth of the matter is, we'd prefer people coming in with all sorts of psychological problems. Which we know how to deal with. What can we do with problems that are real? It's not in their heads."

She tells them to think of their parents' and grandparents' stories about the Nazi occupation – to remind them that people have survived worse. She urges them to summon positive thoughts. And she has them draw maps of their support networks to remind them that they are not alone.

But in truth, some of them are more alone than ever. Tight-knit Greek extended families, Androutsopoulou said, used to provide the aid that the state did not. "Now," she said, "when parents and grandparents are having their pensions cut, salaries are decreasing, they cannot play the social support and protection role that they used to." People who might have managed their mental health issues before the crisis are now attempting suicide, she said; people who might have made a half-hearted attempt are now finishing the job.

Crisis-related mental health issues are hurting even people who believe they are psychologically sound. Overwhelmed by new-found day-to-day challenges like paying the rent, urologist Papadoulos said, some patients now deny obvious warning signs, like blood in their urine, and allow problems to fester for months. When they do eventually come in, he said, they frequently show little interest in taking care of themselves.

"Yesterday, typical case. We had a lady with renal colic. She has four children: 28, 27, 24 and 17 years old. All of them unemployed. She was unemployed. Her husband as well. She came here, whatever we proposed, she quickly agreed with. Did not ask questions. Her attitude was, 'We are all unemployed, who cares, do whatever you want.' She had let herself go."

The president of the union representing Polykliniki's doctors and nurses, senior nurse Christos Papanastasis, works out of a bare office whose walls are adorned with images of Jesus, Mary and Greek Orthodox saints. One of them, of the patron saint for people with cancer, was a gift from a grateful patient.

Greeks with cancer and other serious illnesses now face a maddening new obstacle to survival. Because the government has been slow to reimburse pharmacies, many of them have shut down. The remaining stores, like the beleaguered hospitals, have little inventory – forcing outpatients like plumber Gourtzilidis to embark on scavenger hunts in search of the pills that keep them alive.

"The patient has to come here or go to another government hospital or to another one or to another one," said a sighing Polykliniki nurse, Helen Tomprou, 39. "So it's very difficult sometimes to find the medicines."

In the port area of Athens last week, dozens of residents lined up outside pharmacies. For the many Greeks suddenly as cash-strapped as Gourtzilidis, even the traditional 25 percent patient payment poses a dire challenge. One academic study publicized in April suggested that 90 percent of Greeks are buying less medicine than they did last year.

The "troika" that bailed out the debt-ridden Greek government on stringent conditions – the International Monetary Fund, European Union and European Central Bank – has nonetheless imposed a hike in patient fees. The troika also forced the government to approve $1.4 billion in health cuts in February – over and above cuts of more than $2 billion since 2010 – even though Greece's public health-care spending as a share of gross domestic product was among the lowest in the developed world in 2009.

"Major weaknesses still need to be addressed to increase the efficiency, cost-effectiveness and equity of the system," the European Commission said in a March report.

Critics, such as the commission and the IMF, say major reform is long overdue. Greeks have long been forced to pay bribes to doctors, colourfully known as "little envelopes," for expedited or improved care. Politicians have appointed ill-qualified cronies to top hospital posts. Administrative bureaucracy abounds. Cost-control policies have been nonexistent or ignored, and hospitals have regularly incurred large deficits the government has quietly covered. Over-prescription of medicines, and over-reliance on expensive name-brand drugs, has cost the government untold billions.

And yet, for its numerous obvious flaws, the available evidence suggests the pre-crisis version of the system was "relatively effective" by international standards, in the words of the Organization for Economic Co-operation and Development. Patient outcomes were good. Many Greeks wonder why the troika prescribed shock therapy rather than a new exercise regimen.

"Three years ago, we used to spend money without taking care," acknowledged Gennimatas interventional radiologist Nikolaos Ptohis, 38. "It was normal, OK. Now, it's the exact opposite. The hospital says to us, 'You have to choose between the cheapest things' – and we fight about this, and say, 'No, we cannot use the cheapest. Cheapest doesn't mean it's the best.' It's not good. There should be some criteria when doing something like this."

Ptohis and many of his highly educated colleagues are thinking about joining the country's growing brain drain. Their patients can't go anywhere.

Before Vasiliki Michalopoulou's husband died this year, his hospital had so few nurses on duty that she had to change him and get his pills herself.

"I did all the nursing," Michalopoulou, a 65-year-old retired hairdresser, said at Polykliniki last Wednesday. Now "broke," she attempts to manage a thyroid problem while battling with the government in court over the pension she says she is owed and dealing with a mind she says is betraying her.

She spoke calmly, with bursts of gallows humour, until she looked down at her pension documents. Then she broke into quiet sobs. "Now that I don't have any money," she said, dabbing at her eyes with a tissue, "I've started going mad."

Our Comment

Our greed-ridden society has long since dumped overboard the great heritage of classical Greece; we cannot simply read backward what we accepted read forward. Plato and the other great pupils of Socrates – who had written nothing but had been put to death for asking ever more disturbing questions. They recognized that instead of just turning around a proposition and taking that result to be valid, they emphasized the multiple ways in which the answers to our propositions bounce back at us from every possible direction and, indeed, are even influenced by the phase of the moon.

What we are being deprived of today is the concept of human capital – which is not a deposit in any bank – but those questions that the ancient Greeks learned to pursue as they came bouncing back to them from every conceivable direction. The reason that this has been kept secret even from modern Greeks is that is denied in the current accounting of all governments of the world today. Concede it to a single one, and no government in our contemporary world could continue to use speculative banking to displace serious accountancy.

Greece has been denied access to her great historical heritage – the crucial importance of human capital. What is being disallowed in contemporary Greece is what governments no longer tolerate in their own lands. Allowing Greece to return to her great heritage, would compel a return to serious accountancy throughout the world. Unless addressed in good time, this threatens the very survival of humanity.

W.K.