history prior to its recognition in the 19th century. But the major weakness of the book is that Kushner systematically cites and highlights infectious events in the case histories he discusses even though he notes that "researchers should remain skeptical about new claims and interventions, even when they appear to work." These events may lead the reader to hypothesize that the syndrome is a post-infectious (that is, possibly inflammatory or immune) disorder. The author fails to mention that although the incidence of post-infectious syndromes, such as Sydenham's chorea, has decreased in the last decades due to better treatment of infections, the incidence of Tourette's appears to be increasing. The human need to explain things is evident in Kushner's own narrative. The sad truth, however, is that all psychiatric disorders are still of unknown cause.

Of the five major pathological mechanisms of disease—neoplasia, infection, inflammation, degeneration, and ischemia—inflammation is the most compatible with the chronic waxing and waning course of disorders such as Tourette's. But inflammatory theories for psychiatric disorders are not new. The only Nobel Prize ever awarded to a psychiatrist was granted in 1927 to Julius Wagner-Jauregg for his work on the beneficial effects on psychiatric symptoms of the body's response to infection, work which led to the amelioration of the neurosyphilis symptoms after malaria inoculation.

More recently, the cloning of cytokines (the body's inflammatory mediators) and their receptors has led to an enormous growth of research on their possible relevance to neurological and psychiatric disorders. Current research has shown that cytokines and their receptors are expressed in the brain and exert their potent central effects through redundant but discrete pathways and mechanisms. Moreover, the central and peripheral cytokine compartments are integrated but differentially regulated. The pathways and mechanisms underlying the effects of inflammatory mediators on brain function can be activated in the context of stress, inflammation, ischemia, neurodegeneration, infection, and autoimmunity. Although considerable progress has been made in basic brain-immune research, it is not yet possible to conclude that inflammatory mediators cause Tourette's syndrome—or any psychiatric disorder.

I highly recommend *A Cursing Brain?* as a brilliant and readable narrative of how, over time, we change our minds when faced with a puzzling and hard-to-treat constellation of socially maladaptive physical, behavioral, and psychological symptoms. Despite the subtle but distinct bias towards currently fashionable theories whose history is not fully provided, Kushner presents superb and meticulously documented descriptions of Tourette's and of our understanding of the syndrome. Also emerging from Kushner's laborious endeavor is that we sometimes violate the Hippocratic oath (to "first do no harm") because of our persistent efforts to deny our ignorance; we attribute cause in the absence of a sophisticated understanding of how a multitude of biological, social, and cultural signals are processed and integrated to generate adaptive or maladaptive responses. This book might have suitably been subtitled "Pride and Prejudice in the Absence of Knowledge." Only the passage of time will reveal the distance between our current ideas of causation and the concrete reality of symptoms that exist as if they have weight.

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PERSPECTIVES: ATMOSPHERIC CHEMISTRY

Unraveling Aircraft Impacts

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As common as contrails are in the sky today, it is easy to imagine that the 10,000 or so jet aircraft operating every day alter the composition of the atmosphere substantially at aircraft cruise altitudes. But do they? And if so, by how much? Two recent campaigns in the North Atlantic region are now providing much-needed observational constraints on the chemical composition of the atmosphere at the relevant altitudes. Such studies are particularly timely as airline industry forecasts are predicting a doubling in the number of operational aircraft over the next 20 years (*1*).

Jet aircraft emit several chemical species that affect atmospheric chemistry and climate, including carbon dioxide (CO_2), water (H_2O), nitrogen oxides (NO_x), sulfur oxides (SO_x), and soot. Over the last decade, NO_x emissions have attracted the most attention because of their role in forming ozone, a potent greenhouse gas throughout the atmosphere and a common air pollutant in the lower troposphere. Considerable research has been focused on low NO_x combustor technologies, and the International Civil Aviation Organization (ICAO) has twice reduced the ceiling on aircraft NO_x emissions during landing and takeoff.

The NO_x emissions from present-day aircraft into the atmosphere are now relatively well quantified at about 0.5 teragrams of N per year. But their impact on ambient atmospheric chemistry is obscured by other NO_x sources such as lightning and surface emissions (see the figure). Surface emissions, in particular, are substantially larger than aircraft emissions. For example, NO_x emissions from fossil fuels and biomass burning amount to about 20 and 10 teragrams of N per year, respectively. However, most of these emissions are thought to be removed from the atmosphere by uptake on cloud drops followed by precipitation, before they can diffuse or be lifted to aircraft cruise altitudes. If this view holds, then the upper troposphere–lower stratosphere (UT-LS) region (at heights of 9 to 13 km), where most aircraft fly, represents a relatively pristine environment that is affected only episodically during weather events that rapidly lift surface air or bring down stratospheric air. Even the small fraction of surface emissions transported to high altitude is similar in magnitude to the aircraft source—although quantifying this fraction is a major challenge for atmospheric scientists. To complicate matters, the same weather events responsible for surface NO_x transport may also be associated with lightning that can produce and inject NO_x directly at the upper altitudes. But detailed understanding of NO_x generation and transport in lightning events is lacking.

The various source contributions to upper tropospheric NO_x concentrations must be quantified to reach an understanding of aircraft impacts on ozone. Atmospheric photochemical models incorporating the best available parameterizations of NO_x sources and atmospheric transport have hitherto provided the only quantitative guidance (*2–4*). These models have predict-

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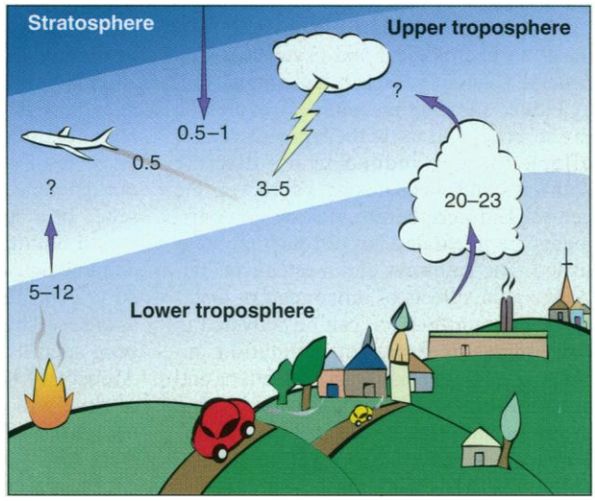
ed that current aircraft operations perturb NO_x concentrations at cruise altitudes in the northern mid-latitudes by about 20%, but possibly by up to 100%. The ozone response to this perturbation is moderated by the amount of hydrogen oxide (hydroxyl radical and its peroxy precursors) available for ozone-forming chemical reactions. Predicted ozone perturbation ranges between 2 and 14%. The wide range of predictions reflects the substantial uncertainties associated with model process parameterizations and source strength estimates.

Further model development is hindered by the lack of observational data. Satellite-based instruments have encountered substantial difficulties in probing the chemical composition of the upper troposphere and lower stratosphere, leaving sporadic aircraft- and balloon-based measurements as the primary data source. In addition to providing a basis for model improvement, observational data may enable an empirically based, model-independent assessment of aircraft impacts. This was one of the motivations for two recent aircraft-based field campaigns investigating cruise-level aviation impacts on NO_x and ozone photochemistry in and around the North Atlantic flight corridor between September and November 1997: the Subsonic Assessment Ozone and NO_x Experiment (SONEX) and the Pollution from Aircraft Emissions in the North Atlantic Flight Corridor (POLINAT) experiment (*5*–*7*). Investigations were carried out onboard the DLR Falcon and NASA DC-8 aircraft, which carried 10 and 14 chemical and radiation measuring instruments, respectively. The measurement efforts were complemented by advanced flight planning and data analysis modeling tools.

Empirical NO_x source deconvolution is possible only under favorable atmospheric conditions. The atmospheric NO_x impact of an individual source must have a geographically distinct pattern, preferably peaked close to its origin. Such patterns can develop if atmospheric mixing is slow relative to NO_x removal. For an aircraft source, maximum concentrations over the United States and Europe and in the North Atlantic flight corridor would be a likely part of the pattern. In addition, source separation is facilitated if the source emissions, atmospheric mixing processes, and chemical loss processes are steady, continuous processes that combine to produce smooth concentration patterns.

Neither of these conditions are expected to be met for NO_x in the UT-LS. Nevertheless, the SONEX and POLINAT findings have revealed more fully the extent of NO_x variability as a result of atmospheric dynamics and source fluctuations and the resultant difficulties with an empirical analysis. The picture that emerges from these studies is of a region with frequent, but irregular, injections of NO_x from the surface, from lightning, and from stratosphere-troposphere exchange. Ambient NO_x perturbations as a result of aircraft emissions are readily observed a few kilometers behind individual aircraft, but the signatures are quickly lost at greater spatial scales in a mostly incoherent NO_x landscape (*8*). Observed NO_x concentrations are unevenly distributed over a wide range, making it difficult to define average UT-LS background concentrations.



Sources of atmospheric NO_x. Biomass burning, automobile and industrial emissions, lightning, and aircraft emissions all contribute to the upper troposphere–lower stratosphere NO_x budget, but quantifying these sources remains difficult. Values are given in units of teragrams of N per year.

A degree of coherence is imposed on the NO_x observations through correlations with other tracers of emission sources and by air mass trajectory analysis. In particular, measurements of CO, O_3, and total particle density have been used to identify surface and stratospheric influences on sampled air masses. Combined with analysis of wind speed and direction over a 3- to 5-day period before an observation, these diagnostics provide insights into the latitudinal and altitudinal history of the air parcel. On the basis of these analyses, the derived magnitude of the aircraft contribution to the regional scale NO_x and ozone environment (*9*, *10*) is consistent with the low-end range of model estimates. At this impact level, the global climate forcing of aircraft-induced ozone change is predicted to be comparable to that of aircraft CO_2 emissions (*2*).

Even with the SONEX and POLINAT efforts, the UT-LS remains substantially undersampled. This scarcity of data is a considerable impediment to an improved assessment of aircraft impacts. Future satellite-based measurements of UT-LS chemical composition, such as those planned from the NASA Earth Observing System (EOS) platform, promise to improve this situation substantially. In the meantime, the SONEX and POLINAT findings argue strongly for the need to improve model treatment of tropospheric transport and chemistry through carefully designed modeling and data studies (*2*, *11*, *12*).

Although our understanding of aircraft effects on ozone remains incomplete, future studies of aircraft impacts are likely to focus increasingly on atmospheric cloudiness. The Intergovernmental Panel on Climate Change concludes that aircraft-induced cloudiness, either through direct contrail formation or through indirect effects on cirrus cloud formation, may increase global warming to a greater extent than aircraft CO_2 and NO_x emissions (*2*). SONEX and POLINAT measurements of condensation nuclei densities have provided initial constraints on the aircraft contribution to cloud precursors in the traffic corridors (*10*, *13*). However, the current level of scientific understanding of cloud-forming processes is considerably poorer than that of ozone chemical processes.

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