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Forensic Science

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This applications review aims to present a concise survey of articles appearing in publications that primarily appeal to forensic practitioners. With this objective, we have focused our attention on the following journals: *Journal of Forensic Sciences*; *Forensic Science International*; *Forensic Science International: Genetics*; *International Journal of Legal Medicine*; *Legal Medicine*; *Forensic Science Communications*; *Analytical Chemistry*; *Electrophoresis; Science & Justice*; *Journal of the Canadian Society of Forensic Science*; *Journal of Analytical Toxicology*; *BioTechniques*; and *Forensic Science, Medicine, and Pathology*; as well as *Chemical Abstracts Selects: Forensic Chemistry*. Our literature survey encompasses the period from January 2007 through December 2008.

The format selected for this survey divides coverage into three distinct areas: forensic DNA analysis, trace evidence, and drugs and poisons. Within the scope of each of the areas, key articles have been selected to describe current forensic science practices in analytical chemistry and to outline relevant forensic science research interests. In accordance with the policy of the Managing Editor, we have strived to keep this review limited to important articles and to keep our discussions concise and meaningful.

FORENSIC DNA ANALYSIS

The literature for forensic DNA analysis has expanded rapidly in the past few years as various technologies and genetic markers have been adopted, validated, and examined in numerous populations around the world. During 2007 and 2008, more than 600 papers and a number of books were published regarding DNA markers that are applied to human identity testing. The new journal *Forensic Science International: Genetics*, which launched in March 2007 with a focus on forensic DNA analysis, published 148 articles in the eight issues released during 2007 and 2008. Unfortunately, due to space constraints, only a selection of these articles will be highlighted below. It is worth noting that conference proceedings are available online for important meetings in this field, including the International Symposium on Human Identification (aka the "Promega meeting") (http://www.promega.com/geneticidproc/) and the International Society of Forensic Genetics (ISFG) (http://www.isfg.org) meetings. Volume 12 of *Progress in Forensic Genetics*, which contains the proceedings of the ISFG meeting held in Copenhagen, Denmark, in August 2007 includes 258 brief articles covering current research on all aspects of forensic DNA typing (*1*).

Short tandem repeat (STR) typing of autosomal markers with fluorescence-based detection is now almost universally used in forensic DNA laboratories worldwide (*2*). Reduced-size STR, or miniSTR, assays are being developed for improved recovery of

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information from badly damaged DNA templates. Low-level DNA and samples containing mixtures continue to present challenges for forensic analysts. A large portion of the literature involves reporting STR allele frequencies from various populations. However, limited space in this review prevents a summary or description of the more than 250 population studies performed in 2007 and 2008.

Single nucleotide polymorphisms (SNPs) continue to be explored as potential supplements to STR markers already in use but will probably not replace STRs in the near future (*3*). Information on uniparental lineage markers from the Y-chromosome and mitochondrial DNA continues to accumulate in the literature. These lineage markers are also widely used for human evolutionary studies and genetic genealogy. The availability of commercial kits for Y-STR amplification has enabled more widespread usage of these important male-specific markers in forensic DNA laboratories. A number of X-chromosome STRs are also being investigated. Nonhuman DNA plays a useful role in many forensic investigations. Tests have been developed for plant and animal DNA testing to associate victims or suspects to crime scenes.

National DNA databases collectively house millions of STR profiles around the world. With the demonstrated success of linking previous offenders to unsolved crimes they have committed, new legislation is expanding the number of samples that will be going into DNA databases of the future. In December 2008, the United States exceeded 6.5 million DNA profiles in the National DNA Index System of the FBI Laboratory's Combined DNA Index System. The United Kingdom has over four million STR profiles in their national DNA database, which represents a significant portion of their active criminal population.

Automation of laboratory techniques and data interpretation with expert systems has become increasingly important with the large numbers of DNA samples that need to be examined. Forensic DNA testing also aids missing persons investigations and identification of mass disaster victims, albeit with some extra issues unique to kinship and parentage analysis. At the end of the forensic DNA analysis section, we also list relevant papers on interpretation and statistical weight of DNA typing results published in 2007 and 2008, along with several general reviews of forensic DNA typing.

Collection, Characterization, Preservation, Extraction, and Quantitation of Biological Material. New methods for detecting, preserving, extracting, and quantifying DNA are continually being developed and are aiding recovery of DNA from biological material found at crime scenes. The value of DNA evidence in detecting crime was reviewed (*4*), and an analysis of approximately 1500 samples of DNA material recovered from the property crime offenses during 2006 identified saliva and cigarette ends as the main sources of DNA recovered (*5*).

The Armed Forces DNA Identification Laboratory described a new DNA extraction procedure using demineralization that provides higher recovery from bone material (*6*). An improved DNA extraction method for STR typing of skeletal remains from mass graves was reported by the International Commission on Missing Persons DNA laboratory (*7*), and success rates were reviewed with this method (*8*). A method for recovery of DNA from old RFLP membranes to enable subsequent PCR amplification and STR typing was reported (*9*). Improved recovery of sperm cells from cotton swabs used in rape cases was addressed (*10*).

Recent progress in processing biological evidence was reviewed as part of the 15th International Interpol Forensic Science Symposium (*11*). Male cells have been isolated and identified in sexual assault mixture samples using fluorescence in situ hybridization and laser microdissection (*12*). A new method was developed for distinguishing skin, buccal, and vaginal epithelial cells (*13*). Developmental validation was completed for a lateral flow strip test to enable rapid identification of human blood (*14*). Six presumptive tests for blood were evaluated in terms of their specificity, sensitivity, and effect on high-molecular-weight DNA (*15*).

Successful DNA extraction from known reference samples was obtained using the Maxwell 16 and DNA IQ chemistry (*16*). Direct PCR amplification without DNA extraction was demonstrated from whole blood (*17*). Methods for preventing contamination when using nondisposable tips on robotic workstations were reported (*18*). DNA transfer on handled objects was explored (*19*). A double swab technique was evaluated for recovery of DNA from touched objects (*20*).

The developmental validation for Promega Corporation's Plexor HY quantitative PCR assay was published (*21*), as was Applied Biosystems' Quantifiler Duo assay (*22*). Quantitation of the amount of nuclear DNA in human telogen hairs was reported (*23*). Reduced volume Quantifiler assays were validated (*24*), and several observations relevant to forensic casework with Quantifiler were noted (*25*). Five different DNA quantitation methods were compared (*26*). A quadruplex qPCR assay was described for simultaneous assessment of total human DNA, human male DNA, DNA degradation, and the presence of PCR inhibitors (*27*).

Forensic applications of RNA analysis were reviewed (*28*). Whole genome expression analysis was conducted to find stable RNA markers for identification of blood and saliva stains (*29*). Body fluid identification using mRNA profiling has been performed with multiplex quantitative reverse-transcriptase PCR (*30*). Recovery and stability of RNA in vaginal swabs and blood, semen, and saliva stains were reported (*31*).

Short Tandem Repeats. The impact of using additional DNA markers in forensic cases was explored (*32*). Assays containing additional autosomal STR loci to aid relationship testing were evaluated (*33*), as were the Humantype Chimera PCR Amplification Kit (*34*) and an assay labeled Paterniplex (*35*). New alleles and mutational events at 14 STR loci were described following analysis of 787 samples (*36*). A number of new variant alleles, triallelic patterns, and point mutations impacting STR typing were noted (*37*). Several discordant genotype calls between the SGM Plus and PowerPlex 16 kits were reported (*38*).

New methods for STR typing have been described, including ion-pair, reversed-phase liquid chromatography electrospray ionization time-of-flight mass spectrometry (LC−ESI-MS) (*39*), HyBeacon melting (*40*), and suspension bead array branch migration displacement assay (*41*). The mass spectrometry approach enables nucleotide variability within same sized STR alleles to be detected (*42*).

A portable microchip analyzer (*43*) was used to conduct "real-time" forensic DNA analysis and produce a DNA profile at a mock crime scene in approximately 6 hours (*44*). A microfabricated

capillary array electrophoresis device was successfully used by a forensic laboratory to produce STR profiles (*45*). Multiplex PCR amplification has been demonstrated in 35 min instead of 3 h using new DNA polymerases and fast temperature transitions (*46*). High-throughput DNA databasing capabilities of Promega's PowerPlex 16 STR typing kit were explored with reduced volumes and a 96-capillary 3730xl Genetic Analyzer (*47*). STR artifacts present due to reannealing of double-stranded DNA during capillary electrophoresis separation were eliminated with the addition of cDNA fragments (*48*). Fluorescent energy transfer-labeled primers were used to improve sensitivity of STR profiles (*49*).

Concordance with other PCR primer sets (*50*) and developmental validation studies (*51*) have been reported for a miniSTR kit called MiniFiler, which was released by Applied Biosystems in March 2007. To aid recovery of DNA results from degraded samples, 26 miniSTR loci were characterized (*52*). Improved STR typing from telogen hair roots and shafts was demonstrated with miniSTR typing (*53*). High-volume casework with miniSTRs was reported by the International Commission on Missing Persons (see http://www.ic-mp.org/) (ICMP) (*54*). A validation study was described with some in-house miniSTR assays (*55*).

To gain a better understanding of optimal conditions for low copy number DNA analysis, comparisons were made between 28 and 34 cycle PCR methods for analysis of trace DNA samples (*56*). Recovery of DNA from touched objects was explored (*57*). A software tool for the analysis of low copy number DNA profiles called LoComatioN was introduced (*58*). A comparison was made with two whole genome amplification methods on low-level DNA sample information recovery (*59*). Performing calculations on the limits of detection and quantitation for every STR profile was advocated (*60*).

Responses to the ISFG DNA Commission recommendations on mixture interpretation (*61*) included a European (*62*) and Australian and New Zealand (*63*) consensus on principles and UK national recommendations (*64*). The German Stain Commission has also presented a strategy for categorization of mixture types (*65*). Assessment in the uncertainty of the number of contributors was explored (*66*), as were the merits of two different approaches to statistical analysis of DNA mixture, random man not excluded and likelihood ratios (*67*). Empirical models were developed to aid interpretation of complex DNA profiles (*68*).

Single Nucleotide Polymorphisms. There continues to be interest in exploring the usefulness of SNPs to aid various aspects of forensic investigations and human identity testing, including inferring ancestral origin (*69*) and resolving some ambiguous STR results in relationship testing (*70*). SNPs used for forensic applications can be divided into four categories: identity-testing SNPs, lineage informative SNPs, ancestry informative SNPs, and phenotype informative SNPs (*71*, *72*). The SNPforID 52plex assay was validated for forensic casework (*73*) and used in paternity testing (*74*). A 49plex forensic marker panel was evaluated using the Genplex SNP assay (*75*). An interlaboratory evaluation was performed with a 29plex SNP assay (*76*). A SNPforID browser was developed to display frequency data for studied SNP markers (*77*). Candidate SNPs for a universal individual identification panel were identified (*78*). A book was published describing efforts to predict ancestry and physical characteristics of individuals using DNA (*79*). Genetic factors in hair, eye, and skin pigmentation in Europeans were reviewed (*80*).

Y-Chromosome and X-Chromosome Analysis. A number of online Y-STR databases are available as part of company Web sites that provide haplotypes for the loci present in their specific Y-STR kits (see http://www.cstl.nist.gov/biotech/strbase/y_strs.htm). The largest and most comprehensive Y-STR database for the minimal haplotype loci is the YHRD (*81*), which now contains over 70 000 haplotypes and is available at http://www.yhrd.org. Y-STR profiles have successfully been obtained from postcoital cervicovaginal samples more than 3 days after intercourse (*82*). A collaborative evaluation was reported involving Y-STR typing from DNA mixture samples (*83*). An internal validation of the Yfiler kit was reported (*84*). Performance characteristics of various commercial Y-STR kits were assessed (*85*). An evaluation of haplotype discrimination with 35 Y-STR markers was performed (*86*). A set of 14 Y-STRs were found to fully separate 572 male samples examined (*87*). Variation observed with 52 Y-STRs across a worldwide set of DNA samples was studied (*88*). Mutation rates in 17 Y-STRs were measured from 389 father−son pairs (*89*). Nomenclature rules for Y-STR loci have been spelled out to aid consistency in ancestry DNA testing (*90*). Y-STR interpretation guidelines have been released by the FBI's Scientific Working Group on DNA Analysis Methods (*91*).

Loss of a portion of the Y-chromosome can produce false negatives when using the amelogenin assay to perform sample sex-typing. Several articles examined the Y-STR haplotypes present and phylogenetic origins of these male amelogenin dropouts (*92*−*95*). Due to the potential of amelogenin Y-deficient results on true male samples, the addition of other Y-chromosome loci have been advocated for future autosomal STR kits (*96*). Null alleles at DYS448 were reported in seven out of 1005 unrelated Hispanic males (*97*).

The applications for X-chromosome markers were reviewed (*98*), and statistical issues were discussed (*99*). The value of X-STRs with complex paternity cases has been illustrated (*100*). A 12-plex X-STR assay has been described (*101*), as well as a number of population studies.

Mitochondrial DNA Typing. The European mtDNA control region database known as EMPOP, which is available at http://www.empop.org/, was described (*102*, *103*). Another web-based mtDNA database known as mtDNAmanager, which is available at http://mtmanager.yonsei.ac.kr, was also described (*104*). Extended guidelines for mtDNA nomenclature were published (*105*). A collaborative exercise between 36 laboratories evaluated causes of errors observed with mtDNA testing (*106*). Proficiency testing results during development of an Italian mtDNA database were noted (*107*). A real-time PCR system was developed for mtDNA quantity and quality assessment (*108*). The value of understanding forensic mtDNA variation in an evolutionary context was discussed (*109*). A comprehensive phylogenetic tree of global human mtDNA variation, which is available at http://www.phylotree.org/, was reported (*110*). To enable improved results from highly degraded forensic samples, modified mini-primer sets were described (*111*, *112*). Experiences with mtDNA analysis of 116 casework skeletal remains were described (*113*). LC−ESI-MS was used for length and sequence variation in mtDNA (*114*). Low-volume amplification and sequencing of

mtDNA was performed on a chemically structured chip (*115*). Length heteroplasmy was examined in siblings (*116*). The ability to separate mtDNA mixtures with denaturing HPLC was demonstrated (*117*). The discrimination potential for several mtDNA coding region assays was examined (*118*). The possibility of contamination from nuclear mtDNA insertions was studied (*119*). Theoretical studies were conducted regarding coverage of mtDNA and Y-chromosome information in databases in order to improve accuracy of haplotype frequency estimation (*120*).

Nonhuman DNA Typing Systems. The uses of DNA testing for dogs, cats, insects, and wildlife investigations were reviewed in a book on nonhuman DNA testing (*121*). DNA typing systems were described for mule deer (*122*) and Eurasian badgers (*123*). Several approaches to species identification were described, including using the mtDNA COI gene (*124*), the12S rRNA gene (*125*), or a combination of 12S and 16S rRNA sequence comparisons (*126*). A STR typing system for cat DNA samples was validated (*127*). Dog mtDNA variation by breed and geographic information was studied (*128*, *129*). BK virus genotype distribution was used in an attempt to trace geographical origins of an unidentified cadaver (*130*). A multiplex assay involving 10 STR loci was developed for *Cannabis* (*131*). Spatial and temporal variation in bacterial DNA profiles from soil was examined (*132*).

DNA Databases, Missing Persons, and Disaster Victim Identification. The expansion of DNA databases has raised concerns over the impact on citizens' civil liberties and individuals' genetic privacy (*133*, *134*). The technical challenges of familial searching were explored (*135*, *136*). The ISFG DNA Commission published 12 recommendations for disaster victim identification efforts (*137*), which were supported by Australian and New Zealand scientists (*138*). Bioinformatic issues involved in the World Trade Center DNA identification effort were described (*139*). Lessons learned from Hurricane Katrina led to suggestions for improved data collection techniques in mass fatality kinship identifications (*140*).

Interpretation and Statistical Weight of DNA Typing Results. The rarity of DNA profiles and statistical calculations surrounding DNA database matches were examined (*141*). Confidence in sibship (*142*) and half-sibship (*143*) determinations were explored with 15 STRs. For immigration testing, recommendations have been made to use 25 STR loci to reduce the risk of erroneous conclusions (*144*). The ISFG has recommended approaches to biostatistics for paternity testing (*145*). Identification problems requiring linked markers were explored (*146*). Empirical support for the reliability of DNA interpretation in Croatia was discussed (*147*). An expert system entitled FaSTR DNA was described (*148*). An approach to combining the statistical results of Y-STR and autosomal STR profiles was reported (*149*). Concerns and caveats to this joint match probability were also noted (*150*).

General Reviews. The journal *Biotechniques* has published several mini review articles on topics of interest to forensic DNA scientists, including STR typing technologies (*2*) and DNA analysis by liquid chromatography−electrospray ionization mass spectrometry (*151*). Almost every issue of the new journal *Forensic Science Medicine and Pathology* contains a DNA review written by Eleanor Graham from the University of Leicester. These DNA reviews include coverage of low-level DNA profiling (*152*), efforts to predict phenotype (*153*), DNA identification following chemical−biological−radiological−nuclear incidents (*154*), analysis of hair samples (*155*), and a summary of the United Kingdom national DNA database (*156*). Potential problems when tumor tissue is submitted for STR analysis were also reviewed (*157*). Finally, several books on forensic DNA were published in 2007 and 2008 (*158*−*163*).

TRACE EVIDENCE

The term "trace evidence" refers to materials expected to transfer to a crime scene or to a suspect in very small quantities. Fiber, paint and glass evidence examination is included in this category, as is the examination of debris collected from fires and explosions to detect residues of ignitable liquids or explosives. Also covered in this section is the analysis of gunshot residue (GSR), inks and toners, techniques for the development of fingerprints, and other miscellaneous analyses considered trace analyses. During 2007 and 2008, one book (*164*), several reviews, and more than 250 journal publications were published reporting trace evidence analyses, only a selection of which is presented below. The reviews of most interest to trace evidence examiners include review of the new standard reference materials for environmental forensics (*165*); the use of X-ray diffraction (*166*) and X-ray fluorescence (*167*) in forensic science; the use of isotope signatures for bone analysis (*168*); a history of the use of nuclear forensic science (*169*), including a review focusing on the plutonium (*170*); the use of synchrotron radiation (*171*); and reviews on the use of capillary electrophoresis (CE) (*172*, *173*). Reviews on the use of palynology in forensic science (*174*), analysis of chemical warfare agents (*175*), and optics (*176*) were also published.

Petroleum Products and Explosives. A review of the European Network of Forensic Science Institutes ignitable liquid residue (ILR) testing program for the past 10 years was published (*177*). A review of the ILR analysis literature between 2001 and 2007 (*178*) and a review of the analysis of alternative fuels (*179*) were published, as was a survey of Canadian gasolines from 2004 (*180*). A comparison of the effectiveness of different sorbents for the extraction of ILRs (*181*), the application of a new carbon membrane (*182*), and the use of soild sorbents coupled to accelerant detection canines (*183*) for detection of ILRs were reported. The collection and persistence of gasoline on hands was also published (*184*), as was the comparison of motor oils using high temperature GC/MS (*185*). Covariance mapping was used in the analysis of ignitable liquids by gas chromatography/mass spectrometry (*186*), and GC coupled to differential mobility spectrometry was used for the analysis of ILR (*187*). Proton transfer reaction time-of-flight (TOF) mass spectrometry was also applied to the "fingerprinting" of accelerants (*188*). Matrix-assisted laser desorption ionization TOF-MS was used for the analysis of aliphatic petroleum resins (*189*), and the determination of sulfur in fuel using GC coupled to atomic emission was reported (*190*). Mass spectra data analysis was used for fire investigation (*191*), and chemometrics tools were used for oil spill "fingerprinting" (*192*). The statistical analysis of fire and explosion accidents in China's chemcal industry along with the key evidence found was also reported (*193*).

A review devoted to explosives detection in air transportation facilities was published (*194*). Macroscopic observations of the

morphological characteristics of ammunition gunpowder was reported (*195*), and the evaluation of Nitron sulfate as a microchemical test for some common oxidizers was also reported (*196*). The identification of explosives and constituents of fuel oil in ammonium nitrate fuel oil (ANFO) using HPTLC and GC/MS was also reported (*197*). Several quality assurance reports were published, including the results from monitoring of an explosives trace analysis laboratory in the U.K (*198*). and another study on contamination prevention data (*199*). The results of an investigation of the "Independence Day Explosion on Lovers Key" in Florida, U.S., was also reported (*200*). A GC with a pulsed discharge detector was used for explosives detection when petroleum and tear gas are in the analytical matrix (*201*), molecularly imprinted polymers were used for explosives detection (*202*), and the use of porous graphitic carbon for the analysis of a number of explosives was reported when coupled to liquid chromatography−atmospheric pressure ionization-mass spectrometry (LC−API-MS) (*203*). Solid phase microextraction (SPME) sampling of explosives in the presence of radionuclides and radionuclide surrogate metals was reported (*204*). An investigation of the isotopic linkage between precursor and product in the synthesis of a high explosive was also reported (*205*). The on-site spectrophotometric determination of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) in explosive mixtures and residues was also reported (*206*). A strategy for the use of another on-site detection of explosives using laser induced breakdown spectroscopy (LIBS) was reported (*207*). A likelihood ratio approach was used to assess the links between Semtex samples using isotopic analysis of explosives (*208*) and the characterization and differentiation of high-energy amine peroxides by direct analysis in real time TOF-MS was reported (*209*). The detection of explosives on skin using ambient ionization mass spectrometry was also reported (*210*).

The extraction and detection of the volatile chemical markers of explosives using a novel, planar geometry SPME device coupled to ion mobility was reported (*211*), the analysis of a number of volatile components from explosives using SPME-IMS (ion mobility spectrometry) was reported (*212*), and the detection of explosives in hair using IMS was also reported (*213*). The forensic characterization of high-density polyethylene pipes using differental scanning calorimetry was reported (*214*).

Hairs, Fibers, Glass, and Paint. A systematic approach to hair color measurement and variation was reported (*215*). Air-segmented, low-volume injection into an inductively coupled plasma mass spectrometry (ICPMS) was used for elemental analysis in hair (*216*). Thermogravimetric analysis for human hair identification was also published (*217*). The effects of storage of samples on the stable isotopic analysis of human hair and nail was reported (*218*), and another study reported the use of (2)H isotope analysis of modern-day human hair and nail for forensic investigations (*219*).

A review of forensic fiber analysis was published (*220*). Descriptions for the forensic identification of luxury animal fibers or wool fibers (*221*), a new polylactic acid (*222*) fiber, and silk fibers (*223*) were reported. The evidentiary value of red and blue fibers was evaluated (*224*). The descrption of a mounting medium for use in forensic fiber examination was also reported (*225*). The discrimination of single fibers containing antimicrobial agents using SEM-EDX was also reported (*226*). The application of Raman spectroscopy to the analysis of forensic fiber case examination was reported (*227*), as was the use of microspectrophotometers using the first derivative of absorbance spectra in the UV/visible range (*228*).

An undergraduate forensic chemistry laboratory was described using visible relection spectroscopy for paint analysis (*229*). Several methods were used for the identification of trace amounts of paint evidence in traffic accidents occurring in China (*230*). The identification of organic pigments in automotive coatings using laser desorption mass spectrometry was reported (*231*), and the use of a combined μ-Raman and μ-XRF approach to the analysis of paint, fibers, and inks was also reported (*232*). The direct identification of various copper pigments in paints and paint smears using laser desorption ionization mass spectrometry was reported (*233*).

A review on the elemental forensic analysis of glass was reported (*234*), and tools for the classification of glass into end-use categories was used in conjunction with SEM-EDS data (*235*). Different X-ray microanalysis tools were used in the analysis of glass microfragments (*236*). The characterization of sheet glass trace elements using laser ablation-inductively coupled mass spectrometry (LA-ICPMS) was also reported (*237*), and the analysis of trace elements in ceramic prints on automotive glasses was achieved using high-energy synchrotron radiation X-ray fluorescence spectrometry (SR-XRF) (*238*). Additional reports using SR-XRF for the discrimination of glass fragments were reported (*239*, *240*). An investigation into the spatial elemental distribution within a pane of glass by TOF-SIMS was also reported (*241*). The effect of reannealing on the distribution of refractive index in a windshield and vehicle side windows was also reported (*242*). The discrimination of sheet glass exposed to high temperature by the determination of trace impurities using ICPMS was reported (*243*). The determination of iron in glass by laser ablation and solution sampling comparing dynamic reaction cell-ICPMS and high resolution (sector field) ICPMS was also reported (*244*). Several reports on the analysis of glass by LIBS, including a comparison of the results from LA-ICPMS, μXRF, and LIBS for the analysis of the same set of samples (*245*), the comparison of different irradiation wavelengths for the analysis of glass (*246*), and two other research studies on the application of LIBS to glass analysis (*247*, *248*) were published.

Gunshot Residue Analysis. Time-resolved fluorescence microscopy was used for the analysis of GSR (*249*), and XRF in combination with advanced light sources permitted the visualization of GSR (*250*), as did the use of infrared imaging (*251*). A comparison of cartridge case and airborne GSR was conducted using SEM-EDS and morphological evaluation (*252*). Methyl and ethyl centralite was detected on skin and other surfaces using desorption electrospray tandem MS (DESI-MS/MS) as evidence of the presence of GSR (*253*). LIBS was applied to determine the lifetime of detectable amounts of GSR on the hands of a shooter (*254*), and ICP-AES was used to determine the differences in the elemental composition between gunshot entry wounds with full-jacketed bullets and lead bullets (*255*). SPME was used to determine time since the last gunshot by targeting the concentrations of the PAHs naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, and acenaphthylene (*256*). LC−MS/MS was used to determine the amount of propellant powder stabilizers in GSR

(*257*), and SF-HR-ICPMS was used to detect GSR on the hands and discriminate between shooters and nonshooters (*258*). A visualization tool using X-ray emission spectra coupled to regularized discriminat analysis was used to detect GSR (*259*).

Fingerprints. A review devoted to the advances in the physical, optical, and chemical visualization of latent prints was published (*260*). Latent fingerprint development using a scanning Kelvin probe was reported (*261*, *262*). Chemical imaging of latent prints assisted by desorption electrospray ionization mass spectrometry was also reported (*263*). The application of IR chemical imaging to the enhancement of latent prints was reported (*264*, *265*), as was a study describing the use of imaging TOF-SIMS in the detection and analysis of fingerprints (*266*). An enhancement of ninhydrin or DFO-treated latent prints on thermal paper was also reported (*267*) in addition to fluorescence spectra and images of latent fingerprints excited with a tunable laser in the UV (*268*) range. Fluorescent TiO_2 powders prepared using a new perylene diimide dye were used for latent print detection (*269*). Attenuated total reflection FTIR imaging was used to visualize and analyze latent prints (*270*). The effects of formaldehyde gas on the recovery of latent prints was described (*271*). Water-soluble fluorescent CdSe quantum dots was applied to develop fingerprints (*272*), and the visualization of latent print corrosion of metallic surfaces was also reported (*273*). A study reporting the spectroscopic detection of exogenous material in fingerprints after development with powders and recovery with adhesive lifters was published (*274*), and metal-containing nanoparticles and nanostructure particles were used in fingerprint detection (*275*), as was the use of nanostructured zinc oxide (*276*), the use of novel SiO_2 nanocomposites (*277*), and the use of nanoparticles as molecular intermediates for the detection of fingerprints (*278*). The "dual fingerprint reagents" were used to produce color and fluorescence (*279*), and the steps leading up to the physical developer process for developing fingerprints was described (*280*), as was an explanation of the chemistry of the development of latent fingerprints using superglue fuming (*281*). The identification of oxidation products of squalene in solution and in latent fingerprints was reported using ESI-MS and atmospheric pressure chemical ionization (APCI) LC−APCI-MS analysis (*282*), and the thermal degradation analysis of amino acids in fingerprint residue by pyrolysis GC/MS was reported in an effort to develop new latent fingerprint-developing reagents (*283*).

Ink Analysis. The classification and individualization of black ballpoint pen inks was reported using UV−vis absorption spectra (*284*). The classification of pencil markings on paper using elemental analysis by ICPMS and TOF-SIMS was also reported (*285*). The identification of colorants in pigmented pen inks by laser desorption mass spectrometry was also reported (*286*), and the quantitation of europium in tagged blue ballpoint pen inks using ICP−AES was also reported. The separation of crystal violet dyes and its application to pen ink analysis using capillary zone electrophoresis (CZE) and micellar electrokinetic chromatography (MEKC) methods (*287*) and the use of TOF-SIMS for the analysis of red-sealing inks on paper was also reported (*288*). The potential of artificial aging for modeling of natural aging processes of ballpont ink (*289*) and trace element ink spiking for signature authentication were also reported (*290*). The analysis of extracts from black water-based pen ink by HPLC was published (*291*), and the application of IR imaging of document examinations was reported (*292*). The application of micro-Raman to the identification of ink marks was also reported (*293*), as was the quantitative analysis of ink solvents on paper after ballpoint pen ink deposition, using SPME (*294*). GC/MS was used to study the drying of ballpoint pen ink on paper (*295*), and the classification of blue gel inks was described by using pyrolysis GC (*296*). The differentiation of species of blue inks for roller-ball pens and the determination of relative age post-deposition was possible using CE methods (*297*). The analysis of writing inks on porous surfaces was described (*298*), as was the differentation of blue ballpoint pen ink by laser desorption ionization mass spectrometry and HPTLC (*299*). The forensic discrimination of trace fragments of photocopied materials was described using a number of analytical tools (*300*), and the detection of dyes was possible using MALDI-MS (*301*). The characterization of offset printing inks tagged with rare-earth taggants was possible using X-ray emission methods (*302*).

Miscellaneous Trace Evidence. Several reports on the detection and analysis of chemical and biological warfare agents (CBWAs) were published (*303*−*309*). Studies describing the analysis of human cremains were also reported (*310*−*312*), including the use of LIBS for the analysis of soils, plants, and cremains (*313*) and the analysis of teeth by using statistical analysis of 45 elements (*314*). LIBS was also used for the detection of chemical taggants placed on objects (*315*). Several reports were published on the analysis of soil samples for forensic purposes, including case studies (*316*), mineralogical analyses (*317*, *318*), the impact on particle size effects (*319*), and the use of several analytical tools (*320*−*324*). The analysis of adhesive tape for forensic discrimination was reported (*325*), and the analysis of condom lubricants using a variety of methods was also reported (*326*). The discrimination of rubber-based pressure-sensitive adhesives by size-exclusion chromatography was also reported (*327*), as was the forensic analysis of wooden safety matches (*328*). The elemental analysis of adhesive cloth tapes was reported (*329*), as was the chemical "fingerprinting" of adhesive tapes by GC/MS detection of the petroleum hydrocarbon products (*330*). The analysis of ambient surfaces for small and large molecules using nonproximate-DESI was also reported (*331*), and the analysis of tire rubber traces collected after braking incidents was possible using pyrolysis GC/MS (*332*). The forensic discrimination of steel wire was reported using ICP−AES (*333*), and the analysis of rosin in adhesives was possible using MALDI-TOF-MS (*334*). The identification of small bits of leather was reported using GC/MS (*335*), and trace element "fingerprinting" of Australian indigenous art was possible using LA-ICPMS (*336*).

DRUGS AND POISONS

During 2007 and 2008, more than 600 papers and a number of books were publishing regarding drug and poison analysis in the field of forensic drug and toxicological analysis. Unfortunately, due to space constraints, only a selection of these articles will be highlighted below. To keep our discussion concise and meaningful, we have limited our survey of drugs regulated under the United States Controlled Substance Act, ethanol, common poisons, and other drugs of importance to the forensic scientist. Further-

more, to eliminate unnecessary duplication of effort, citations of articles appearing in *Clinical Chemistry*, *The Journal of Pharmaceutical Sciences*, and other pharmaceutical journals have been avoided. We believe that ample coverage of these journals is provided within the Pharmaceuticals and Clinical Chemistry sections of this journal and recommend that interested readers consult these sections to obtain a complete survey of the drug-abuse subject.

Ethanol and Volatiles. Guidelines for determining the blood alcohol concentration (BAC) in blood for forensic purposes have been presented (*337*). BAC concentrations were measured to study the inter- and intrasubject variability in the ethanol pharmacokinetic parameters effects of testing interval and dose (*338*). The impact of storage conditions and collection tubes on plasma, serum, and whole blood ethanol concentrations have been studied (*339*). The change of antemortem BAC in inadequately processed samples was examined by gas chromatography (*340*). Blood and urine samples from drug-facilitated sexual assaults were analyzed for ethanol by HS−GC and for drugs by isotope dilution gas chromatography−mass spectrometry (*341*). A disposable biosensor to detect serum alcohol concentration has been proposed (*342*). An ethanol-positive fatal case initially reported as being from ingestion was ultimately determined to be from postmortem ethanol production using the ratio of two serotonin metabolites found in urine (*343*). The influence of sex hormones on the elimination kinetics of ethanol was studied by measuring BAC and sex hormones in serum concomitantly (*344*). The application of monitoring precision and accuracy of BAC measurement using control charts has been reported (*345*). A new enzyme immunoassay for the determination of the ethylglucuronide (EtG) in urine samples was reported (*346*). The concentrations of EtG were measured in blood samples under controlled conditions during putrefaction (*347*). EtG was measured in urine samples by microwave-assisted extraction and gas chromatography/mass spectrometry (GC/MS) (*348*). The first controlled experiment comparing the time-courses for ethanol, EtG, ethyl sulfare (EtS), and 5-hydroxytryptophol-glucuronide, and 5-hydroxyindole-3-acetic acid in urine has been reported (*349*). The effect of preservatives on the stability of EtG and EtS in urine was studied by LC−ESI-MS/MS (*350*). EtG concentrations were measured in head and pubic hair by solid-phase extraction (SPE) and liquid chromatography−mass spectrometry (LC−MS) (*351*). A rapid, simple method to detect the ethylglucuronide in hair has been developed using SPE, followed by derivatization with *N*,*O*-bis[trimethylsilyl]trifluoroacetamide, before confirmation by gas chromatography−mass spectrometry/mass spectrometry (GC/MS/MS) (*352*). A method for determination of EtG in hair samples was developed using ultraperformance liquid chromatography−electrospray tandem mass spectrometry (UPLC−ESI-MS/MS) and compared with the findings of phosphatidylethanol in femoral whole blood, as measured by high performance liquid chromatography with an evaporative light-scattering detector (*353*).

An experimental design comparing different instruments measuring replicate breath samples from several subjects has been presented (*354*). A controlled study of the time course of breath alcohol concentration (BrAC) after moderate ingestion of ethanol following a social drinking session as been reported (*355*). An amperometric electrochemical gas sensor with working electrode and counter electrode containing platinum as a catalyst has been developed for measuring BrAC (*356*). The usefulness of portable, hand-held breath analyzers equipped with an electrochemical sensor was assessed (*357*). Paired BAC and BrAC were determined for 11 837 drivers apprehended by the New Zealand Police (*358*). The effect of volatile interfering substances on the determination of BrAC using a five-filter infrared analyzer has been studied (*359*). The historical development of evidential breath alcohol analysis has been reviewed (*360*).

The feasibility of a Fourier-transformed IR (FT-IR) analyzer for out-of-lab use by screening the exhalations of inebriated individuals and to determine analysis quality using common breath components and solvents was evaluated (*361*). The possible contribution of the presence of volatiles in the interpretation of ethanol analysis results in postmortem cases has been discussed (*362*). Aroma compounds from alcoholic beverages in spiked blood samples were determined by dynamic headspace gas chromatography/mass spectrometry (HS-GC/MS) (*363*). Sevoflurane concentrations were measured by headspace gas chromatography (HS-GC) in the biofluids and organs of an individual dying from sevoflurane inhalation (*364*). Blood cyanide was determined by visible spectrophotometry and automated HS-GC with nitrogen−phosphorus detection (HS-GC-NPD) (*365*). An automated HS-GC method was developed for the determination of formate (formic acid) in postmortem specimens (*366*). Methanol and formic acid concentrations were determined using HS-GC (*367*). Antemortem and postmortem serum methanol concentrations were determined (*368*). The in vitro interaction between ethanol and imipramine at high concentrations was investigated by observing a mixed-function oxidation reaction using human liver microsomes (*369*). Trichloroethanol was detected in blood by GC using electron capture detection (ECD) and subsequently quantitated by HS-GC using flame-ionization detection (FID) (*370*). 1,3-Propanediol was determined in body fluids by GC-FID (*371*). A method for the quantitation of 1,1-difluoroethane using HS-GC-FID has been described (*372*). Helium was detected in an asphyxial suicide victim by GC/MS (*373*).

Cannabinoids. It has been shown that DELTA^9-THC (9-THC) isomerized to DELTA^8-THC (8-THC) during derivatization (*374*). Liquid−liquid or solid−liquid extraction was used to analyze for 9-THC commercial hemp products (*375*). Cannabinoid contents in cannabis products were determined by GC-FID (*376*). A new method to determine 9-carboxy-11-nor-DELTA^9-THC (9-THC-COOH) and 11-hydroxy-DELTA^9-THC (11-OH-THC) using two-dimensional (2D) GC/MS was developed to reduce interferences and carryover (*377*). An automated SPE method for 9-THC-COOH has been developed (*378*). 9-THC-COOH was determined in urine by GC/MS (*379*, *380*). Blood cannabinoid pharmacokinetic properties were investigated in cannabis users (*381*). A direct LC−MS/MS method for measurement of urinary 9-THC-COOH was developed (*382*). A comprehensive SPE technique based on the formation of an inclusion complex between β-cyclodextrin and cannabinoids was developed using GC/MS (*383*). An ID-GC/MS reference measurement procedure for 9-THC in serum was developed and

validated (*384*). The analysis for 9-THC in blood and 9-THC-COOH in urine using disposable pipet extraction with confirmation and quantification by GC/MS has been reported (*385*). LC−MS/MS was used for the determination of cannabinoids in blood (*386*−*388*), plasma, and urine (*389*), and oral fluid, urine and blood (*390*). GC/MS was used to determine cannabinoids in blood (*391*).

GC/MS has been used to determine cannabinoids in hair (*392*), oral fluid (*393*), and serum and oral fluid (*394*). Cannabinoid concentrations in hair were determined by ELISA and GC/MS/MS (*395*). 9-THC excretion in sweat from cannabis users was evaluated by analysis of sweat patches by GC/MS (*396*). Vitreous humor specimens were screened by immunoassay and then assayed for phencyclidine (PCP) by GC-FID, and cannabinoids, by GC/MS (*397*). The prevalence of driving under the influence of cannabis has been surveyed (*398*).

Morphine and Related Narcotics. Opium samples were assayed using micellar capillary electrophoresis incorporating a sweeping technique (*399*). The applicability of UPLC−MS/MS for heroin profiling has been described (*400*). An automated method for profiling heroin samples has been reported using GC (*401*). Heroin in seized street illicit drugs was determined using partial least-squares regression analysis of diffuse reflectance near-IR (NIR) spectra (*402*). Opiates were determined in blood (*403*) using ELISA and SPE, followed by GC/MS in the selected ion monitoring (SIM) mode (*404*). Hydromorphone and other opiates were determined in urine by GC/MS as their respective trimethylsilyl (TMS) derivatives following SPE (*405*). Thebaine, morphine, and codeine were detected in urine as their TMS derivatives using GC/MS (*406*). A stationary phase combining zwitterionic ion chromatography and hydrophilic interaction chromatography (ZIC-HILIC) was evaluated for opiates and their polar metabolites (*407*). Opiates have been detected in vitreous humor by enzyme immunoassay (*408*). Heroin was determined in bile (*409*). Liquid chromatography−atmospheric pressure chemical ionization (APCI)−MS/MS was used to determine opiates in human hair (*410*) and other biological fluids (*411*). A comparison of methadone-, oxycodone-, and hydrocodone-related deaths has been reported (*412*).

Fentanyl was determined in hair by immunoassay and two-dimensional GC/MS (*413*). Fentanyl was determined in postmortem blood (*414*). Clenbuterol was detected in postmortem specimens using ELISA, SPE, derivatization with trimethylboroxine, and GC/MS (*415*).

Cocaine. Tropane ethyl esters were detected in illicit cocaine by GC/MS and quantified by ion-pair chromatography isolation, followed by GC-FID (*416*). Four new illicit cocaine impurities from the oxidation of crude cocaine base have been characterized by GC/MS, LC/MS, and NMR (*417*). Analysis and statistical methodologies were applied to chromatography data from two laboratories for cocaine profiling (*418*). Cocaine samples were analyzed by HS-GC/MS for the purpose of profiling (*419*). GC/MS combined with SPME, pyrolysis technique, Fourier transform IR spectrometry (FTIR), and SEM with energy-dispersive X-ray detector (SEM-EDX) were used to analyze samples from a cocaine clandestine laboratory (*420*). Cocaine and its major metabolite, benzoylecgonine (BZE), were determined in blood by GC/MS (*421*). LC−MS/MS has been used to quantify cocaine and metabolites in blood and urine (*422*). Automated SPE and LC−MS/MS has been used to detect cocaine and its metabolites in urine (*423*), BZE in urine (*424*), and cocaine and metabolites in blood (*425*). Cocaine has been detected in hair by SPME and compared with supercritical fluid extraction (*426*). Analyses of cocaine and metabolites in hair were done by LC−MS/MS (*427*), GC/MS (*428*), and HPLC with fluorescence detection (*429*). Discriminant analysis was used to differentiate between incorporation of cocaine and its congeners into hair and contamination (*430*). Raman spectroscopy was used to detect cocaine in human nails (*431*). Cocaine and heroin with their respective metabolites have been determined in meconium by GC/MS (*432*). A method for determing cocaine and BZE in human bile using HPLC with UV detection has been described (*433*).

Amphetamines. A review of recent advances in impurity profiling of illicit 3,4-methylenedioxymethamphetamine (MDMA) samples has been published (*434*). Impurity-profiling for MDMA has been accomplished by comparing physical properties of the tablets (*435*) using SPE and HPLC (*436*) and GC/MS (*437*) and for methamphetamine using GC/MS (*438*−*440*) and GC-FID and GC/MS (*441*, *442*). A method was developed for the isolation of MDMA and other active ingredients from illicit ecstasy tablets using SPE and GC/MS (*443*) and headspace solid-phase microextraction (HS-SPME) and liquid−liquid extraction (LLE) (*444*). A rapid and simple method for the simultaneous detection and quantitation of amphetamine, methamphetamine, methylenedioxyamphetamine (MDA), MDMA and methylenedioxyethylamphetamine (MDEA) in human serum was developed and fully validated using derivatization with perfluorooctanoyl chloride and GC/MS in the selected ion monitoring mode (SIM) (*445*). Differentiation of MDMA from some of the methoxy methyl methamphetamines was possible after formation of derivatives and GC/MS (*446*−*448*). An on-site screening system for amphetamine-type stimulant tablets with a portable attenuated total reflection Fourier transform infrared spectrometer has been developed (*449*). Isomers of 2,4-dimethyl-3,5-bis(3,4-methylenedioxyphenyl)tetrahydrofuran (11) have been presented as chemical markers formed during the peracid oxidation of isosafrole (*450*). A LC−MS method for quantification of trimethoxyamphetamines in human urine after SPE with C_{18} was developed and validated (*451*). A comparison and classification of methamphetamine seized in Japan and Thailand using GC/MS with LLE and SPE has been reported (*452*). The influence of hair bleaching on the enantiomeric ratios of amphetamine-type stimulants by GC/MS-negative chemical ionization (GC/MS-NCI) has been studied (*453*). Characteristic deuterium distributions of ephedrines and methamphetamines by NMR spectroscopy have been evaluated for drug profiling (*454*). MDMA samples were analyzed for ^{13}C, ^{15}N, and ^{2}H isotope abundance using IRMS (*455*). A simple, rapid, and highly sensitive method for simultaneous analysis of methamphetamine and MDMA in human serum was developed using SPME combined with ion mobility spectrometry (IMS) (*456*). A two-step autoinjector has been developed for the automated on-column derivatization using trifluoroacetylation and subsequent GC/MS of amine-type drugs and metabolites (*457*). Para-methoxyethylamphetamine was detected in postmortem specimens by GC/MS with trifluoroacetylation (*458*). A GC/MS method was developed and validated for the determination of psychotropic phenyla-

lkylamine derivatives in human hair (*459*). A reference material using authentic hair samples for the determination of methamphetamine and amphetamine in human hair has been developed (*460*, *461*). A new method has been reported for the simultaneous extraction and derivatization of amphetamine and MDA using headspace hollow fiber protected liquid-phase microextraction (HS-HF-LPME) (*462*). A method for analyzing amphetamine-type stimulants and their metabolites in plasma, urine, and bile by LC−MS/MS with a strong cation-exchange column has been developed (*463*). The acetyl, propionyl, and trifluoroacetyl derivatives of the primary and secondary regioisomeric amines were prepared and evaluated by GC/MS (*464*). A method for the determination of methamphetamine and dimethylsulfone by fast GC/FID has been presented (*465*). Data from the simultaneous analysis of six phenethylamine-type designer drugs have been presented from the following techniques: proton NMR, IR, HPLC, GC, and TLC (*466*). A LC−APCI-MS/MS method for quantification of 10 amphetamine-related analytes in meconium has been developed (*467*). A stereospecific GC/MS method for amphetamine-type stimulants in human urine was recently developed (*468*). A device which comprises a spin column packed with octadecyl silane-bonded monolithic silica for extracting amphetamines and methylenedioxyamphetamines from urine has been developed (*469*). The structural elucidation of a compound produced during the synthesis of MDMA via the reductive amination of 3,4-methylenedioxyphenyl-2-propanone (3,4-MDP-2-P) with methylamine and sodium cyanoborohydride has been reported (*470*). GC/MS analysis of urine samples resulted in the detection of trans-phenylpropene as a marker of smoked methamphetamine and anhydroecgonine methyl ester as a marker of smoked cocaine (*471*). Microwave-assisted derivatization following SPE combined with GC/MS was developed to detect amphetamines in urine (*472*). A rapid and sensitive method for the detection of MDMA and related compounds by TLC with fluorescence detection has been proposed (*473*). A method to screen for and quantify 4-alkyl-2,5-dimethoxyamphetamine derivatives in urine samples using capillary electrophoresis coupled to electrospray ionization-mass spectrometry (CE−ESI-MS) has been described (*474*). Using ^{1}H NMR, carbon NMR spectroscopy (^{13}C NMR), GC/MS, IR spectroscopy, and total synthesis, methyl 3-[3′,4′(methylenedioxy)phenyl]-2-Me glycidate was identified as a MDMA precursor (*475*). A rapid and sensitive method using LC−MS/MS for the determination of six amphetamines and analogues in hair, blood, and urine has been developed and validated (*476*). A simple method for simultaneous identification and quantification of 13 amphetamine-related drugs in human whole blood by GC/MS has been described (*477*).

Benzodiazepines. A comparison of molecularly imprinted solid-phase extraction with classical SPE for the detection of benzodiazepines in postmortem hair samples by LC−MS/MS has been reported (*478*). A column-switching LC−MS method allowing high-speed determination of benzodiazepines in whole blood has been presented (*479*). A method for the separation and determination of 10 benzodiazepines in urine using capillary electrochromatography−time-of-flight mass spectrometry (CEC−TOF-MS) has been detailed (*480*). The Drugwipe benzodiazepines oral fluid on-site tests for roadside drug screening were evaluated on oral fluid and whole blood samples collected from drivers and tested for amphetamine-type stimulant drugs, cannabis, opiates, cocaine, and benzodiazepines by immunological methods, GC, and GC/MS (*481*). False-negative results for bromazepam in urine samples have been observed by the EMIT II plus benzodiazepine assays (*482*). A rapid and sensitive method for the determination of benzodiazepines in oral fluid using LC−ESI-MS/MS has been reported (*483*). Four immunoassay screening kits for the detection of benzodiazepines in urine have been evaluated (*484*). SPE and LC−MS/MS have been used to study the stability of benzodiazepines and cocaine in blood spots stored on filter paper (*485*). LC−MS/MS was used for the determination of benzodiazepine in human plasma (*486*); urine, hair and preserved oral fluid samples (*487*); and urine, serum/plasma, and meconium (*488*). GC/MS was used to quantify benzodiazepines in whole blood (*489*). LC−MS/MS-time-of-flight has been used for the simultaneous analysis of benzodiazepines in urine specimens (*490*). Concomitant heart and peripheral blood determinations were performed on fatal cases involving nordiazepam and bromazepam (*491*). A simultaneous analysis method for etizolam and its main metabolites in whole blood was developed using SPE, TMS derivatization, and ion trap GC/MS/MS (*492*). A rapid fluorometric screening method for the 1,4-benzodiazepines has been described (*493*). A HPLC method using SPE was developed and validated for the determination of four frequently prescribed 1,4-benzodiazepines (*494*). Detection of nitrated benzodiazepines by indirect laser-induced fluorescence detection on a microfluidic device has been described (*495*).

γ-Hydroxybutyrate. The ability of commercially available date-rape drug test kits to detect γ-hydroxybutyrate (GHB) in popular drinks has been evaluated (*496*). The detection of exogenous GHB in urine specimens was investigated by means of gas chromatography/combustion-isotope ratio mass spectrometry (GC/C-IRMS) (*497*). An enhancement of the microcrystalline test for the detection of GHB has been described (*498*). A method for the identification and quantification of GHB in saliva has been developed using GC/MS-SIM (*499*). Further evidence of in vitro production of GHB in urine samples using GC/MS has been demonstrated (*500*). An assay using GC/MS and GC/FID has been described for GHB, γ-butyrolactone, and 1,4-butanediol in blood or urine samples (*501*).

Miscellaneous Drugs. A method has been presented for the detection and quantitation of the major urinary metabolite of zolpidem by GC/MS-SIM (*502*). Ketamine and its major metabolite were determined in urine by positive ion chemical ionization gas chromatography−mass spectrometry (PCI-GC/MS) with automatic SPE (*503*). Methadone and its metabolites have been identified and quantified in human breast milk by LC−APCI-MS/MS (*504*) and GC/EI-MS (*505*). A chiral LC−MS/MS method was used for measurement of the *R* and *S* enantiomers of methadone and its main metabolite (*506*). GC/MS was used to identify methadone and its metabolites in plasma of umbilical cord blood (*507*). Methadone and metabolites have been quantified in postmortem specimens by LC−MS/MS (*508*). Cyanide was determined in blood by a visible spectrophotometric method and by an automated HS-GC/NPD (*509*). LC−MS-MS was used for the screening and confirmation of mescaline in human urine samples (*510*). Selective serotonin reuptake inhibitors in human serum (*511*); methylphenidate in hair (*512*); and low-dosage

antipsychotic drugs buspirone, fluphenazine, flupenthixol, perphenazine, risperidone, ziprasidone, and zuclopenthixol in human postmortem blood (*513*). Rapid screening of clenbuterol in urine was performed by combining desorption electrospray ionization (DESI) and MS/MS (*514*). SPE and LC−MS/MS have been used to detect PCP in human oral fluid (*515*) and for quantification of buprenorphine, norbuprenorphine, and glucuronidated conjugates in human meconium (*516*). Unique marker compounds from the Tasmanian poppy *Papaver somniferum N.* have been isolated and identified (*517*). Scopolamine was identified by quantitative one-dimensional and two-dimensional NMR (*518*). The separation of nine tryptamines was compared by GC, HPLC, and CE (*519*). LC−MS-MS was used to identify thiodicarb and its methomyl metabolite in postmortem fluids and tissues (*520*) and aconitine in blood and urine (*521*). A microwave-assisted extraction method, followed by HPLC (*522*), has been developed and optimized for the extraction of tricyclic antidepressants. Halogenated solvent interactions with *N*,*N*-dimethyltryptamine has been reported when performing GC/MS (*523*). The detection and quantitation of piperazines has been accomplished using UV and GC/MS (*524*) and GC/MS and LC−ESI-SIM (*535*). A method for the detection and quantitation of salvinorin A in human biological fluids was developed utilizing SPE and LC−ESI-SIM (*526*). A reversed-phase HPLC method for the separation and quantification of mescaline in peyote was developed (*527*). A chiral LC−MS/MS method was developed for the measurement of methadone and its major metabolite enantiomers in postmortem blood (*528*). A method, using internal standard, was developed for the determination of dichlorvos in biological specimens by GC/MS (*529*). Bromadiolone was quantified in whole blood using LC−MS (*530*). A method for the direct determination of buprenorphine and metabolites in urine was developed using SPE and LC−ESI-MS/MS (*531*). UPLC−MS/MS was used to detect ketamine and its metabolites in urine (*532*). LLE and LC−ESI-MS in the positive ionization mode was applied for the quantitation of fentanyl and norfentanyl in postmortem samples (*533*).

Other Techniques. A comprehensive screening method for the qualitative detection of narcotics and stimulants using a single-step derivatization and GC/MS has been described (*534*). Illicit drugs and medicinal drugs and their metabolites have been detected in oral fluid using LC−MS/MS (*535*). A generic CE-ESI/MS method was developed for the enantioselective determination of basic drugs in plasma (*536*). The applications of capillary electrophoresis in forensic science have been reviewed covering the period from 2005 until the first part of 2007 (*537*). SPME-IMS has been used to detect volatile components in drugs (*538*). The differentiation between systemic exposure and external contamination for certain drug groups in the drug testing of hair has been reported (*539*). The feasibility of desorption atmospheric pressure photoionization in the direct analysis of illicit drugs was demonstrated (*540*). Electrochemiluminescence detection of narcotic drugs on a microchip after separation by MEKC has been presented (*541*). A qualitative IMS procedure for the detection of trace amounts of heroin and cocaine on incriminated material using a vacuum cleaner for sampling has been reported (*542*). The application of confocal Raman microscopy to the detection and identification of drugs of abuse in situ on undyed, natural synthetic fibers and colored textile specimens has been described (*543*). Methods for screening of drugs in hair have been developed using LC−MS/MS (*544*, *545*), GC/MS (*546*), and GC/EI-MS and GC/NCI-MS (*547*). A new method was developed for the analysis of illicit drugs in human urine by coupling carrier-mediated LPME to HPLC (*548*). The concentration of drugs and metabolites in cerebrospinal fluid and blood were determined in autopsied cases using LLE and GC after confirmation by GC/MS (*549*). Methadone, heroin, cocaine, and metabolites have been detected in sweat by SPE and GC/MS (*550*). A headspace sampling and detection method for cocaine, MDMA, and marijuana via volatile markers in the presence of potential interferences by SPME-IMS has been described (*551*). GC × GC/TOF-MS and GC × GC-FID have been combined with pixel-based chemometric processing for the chemical profiling of illicit drug samples (*552*).

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